Mapping the Past with Present Digital Tools: Historic Urban Landscape Research in Chinese City, Xi'an Walled City Area*

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ABSTRACT In 2015, the Study of Xi'an Historic Walled City Regeneration Strategy applied the Historic Urban Landscape (HUL) Approach through experimenting and testing digital technologies following recommended action steps of HUL Approach. Within the context of urbanisation and heritage deterioration happened past decades in Chinese cities, this paper proposes an innovative HUL Information System that can be used to integrate the approach and technical support measures. This enables comprehensive identification of spatial–temporal relativity of urban landscape morphology, linking between the past and present. The use of spatial digital tools such as aerial photo modeling, geographic information system analysis, and space syntax is explored to trace the continuity of the historical landscape in the built environment. The research team uncovered the context of Xi'an's cultural and historical landscape through historical literature and related studies over past decades, and summarised and obtained a spatial data set for the dominant historical landscape pattern of the walled city area. Compared with the existing spatial pattern identified by digital tools, the findings showed similarity with historical landscape patterns, including part of a *fengshui* landform, the 17th to 19th century water system, and an evolving community habitat. This could be explained by the literature and academic research, which demonstrates the influence of historic landscape system in urban evolution. This research aims to show the potential of the HUL Information System as a technical support for urban conservation in Chinese cities, particularly with regard to mapping resources, which is fundamental toward other relevant steps in the HUL approach.

KEYWORDS cultural landscape, urban heritage, HUL approach, information system, digital mapping, relativity

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Introduction

The study proposes a framework of Historic Urban Landscape (HUL) Information System to serve as a technical tool to support HUL implementation in Chinese cities. Considering the global capacity of virtual spatial information network technologies' innovation and communication, the system is built on the relationship of layers of historic landscape value of a city and the relative real-time spatio–temporal urban data in the built environment. This is aimed at reconnecting the city's past and present with the HUL approach (Bandarin and van Oers 2012, 2014), amid deteriorating urban heritage deterioration in Chinese cities. The study area of the Xi'an historic walled city has been an urban centre for over 1,000 years, and still faces the great pressure of urban renewal. Within this context, the research implements spatial digital tools and resources, such as Unarmed Aerial Vehicle (UAV) device aerial photography, Location Based Service (LBS) data and space syntax depth map software, to analyse and explore relativity between the past and present. The relativity concept here refers to the value of inner relationships shared by the historical and current urban landscape, in accordance with natural, cultural, social, and economic dynamics in the urban evolution. With the inevitable changes from urbanisation in the modern age, historical landscapes may survive where there is deliberate conservation, but those that disappear physically may change their form of existence. Thus, tracing the historical landscape continuity in a built environment

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with less built heritage remains as the initial challenge for Chinese cities, but may also contribute to the thinking on urban development in another way: discovering the value of implementing the HUL approach in China.

This paper comprises four sections. First, it introduces the research design of the HUL Information System. The second part uncovers the cultural and historical landscape context of Xi'an in spatial terms, integrating the dominant historical landscape components and features into the system. In the third part, the existing condition of the spatial pattern is assessed with Geographic Information System (GIS) analysis, Point of Interest (POI) kernel density, and road axial space syntax analysis, and three sectors of findings unveil the spatial synchronicity with the historical landscape pattern with *fengshui* landform, water system, and evolving traditional community habitat. The experiment of digital mapping in the research generally provides another way of thinking about authenticity of the historical landscape, which embrace the reality of urban landscape morphology change in the urban evolution (Ken Taylor 2018), and at the same time finds out how the historical landscape influenced the evolution process.

Research Contents

Background and Research Question

Xi'an is one of the most significant historic cities both in China and globally (Li 2009). The present study was undertaken in the context of Xi'an promoting a cultural strategy for urban regeneration and development. In 2015, the Xi'an Rural and Urban Construction Committee organised a workshop on the Study of Xi'an Historic Walled City Area Regeneration Strategy, and the joint team of the Historic Urban Landscape Creative Research Platform, China (HULC)[1] and East China Architectural Design & Research Institute Co., Ltd. (ECADI)[2] took part in and accomplished the study in 10 months. This area regeneration strategy was considered important in balancing historical conservation and urban renewal, and finding more integrated solutions for sustainable urban development in the future, bearing responsibility for the city's deeply established culture and history (Erkan 2018). This was especially important considering the significance of Xi'an as a World Heritage City and the complexity of its historic walled area that has been evolving for almost 1,500 years as the city centre. The HUL approach was applied in the study, as it provides relevant tools and concepts, as well as concrete steps for more balanced and integrated urban management (UNESCO 2011).

Four of the six steps the HUL approach suggested were applied:

a. Undertake comprehensive surveys and mapping of the city's natural, cultural and human resources;
b. Reach consensus using participatory planning and stakeholder consultations on what values to protect for transmission to future generations and to determine the attributes that carry these values;
c. Assess the vulnerability of these attributes to socio-economic pressures and impacts of climate change;
d. Integrate urban heritage values and their vulnerability status into a wider framework of city development, which shall provide indications of areas of heritage sensitivity that require careful attention to planning, design and implementation of development projects;

The other two steps were considered in the proposal for the future based on the research outcome of the above steps:

e. Prioritise actions for conservation and development;
f. Establish the appropriate partnerships and local management frameworks for each of the identified projects for conservation and development, as well as to develop mechanisms for the coordination of the various activities between different actors, both public and private.

To better understand how people perceive the site, we began the research process by distributing an online questionnaire survey[3]. In three weeks, we collected 709 valid questionnaires via mobile-based social network distribution using the WeChat app[4].The questionnaire had 14 questions: three were about the respondent's personal details, while the other 11 were designed to cover the key topics of the four steps of the HUL approach above. Respondents were asked about how they identify cultural life and historic places within the walled area, the value of the historic walled city, weaknesses in its development, and their vision for the future. They indicated they found it difficult to access a majority of cultural heritage units[5] and to perceive the historical context and sense of the place other than the widely known City Wall and Bell and Drum Towers. About 51% of the respondents had noticed the deterioration of cultural heritage was one of the main obstacles for the walled city area's future, and considered strengthening historical conservation and upgrading the overall quality of public spaces to be the strategies that should take priority. Respondents were highly concerned with issues about conservation of cultural heritage, as shown in comments by 59 residents and visitors in the final question.

Based on the questionnaire results and on-site investigation, the most critical research questions were identified: (1) Facing the present dominant condition of

deterioration of existing heritage, do historical landscapes still exist or influence the present urban environment? and (2) How can the historical context actually be traced in the modern urban built environment with relatively fewer heritage resources remaining?

Fortunately, abundant academic achievements exist in archeology and the history of the city's evolution. Traditional historical landscape layers can be illustrated based on these. To explore the relativity between the past and present, the team proposed attempting digital techniques for examining the built environment, as this would allow tracing of the historical landscape pattern's continuity.

Research Design of an HUL Information System

In previous comprehensive HUL implementation research in China, the HUL China Road Map (WHITRAP 2012, 2016) and Shanghai Agenda (WHITRAP 2014) both pointed out: 'Urban cultural heritage in China has been greatly undermined by its rapid urbanisation and the unsustainable use of the natural and human-made resources of cities.' The most critical reality leaves challenge for future urban conservation in China, both on the methodology and value guidance for practice indication. The landscape-based HUL approach extends the perspective of seeing the city as a continually evolving cultural landscape (Mitchell 2008; Han 2012; O'Donnell and Turner 2012; Taylor, Clair and Mitchell 2014). Amid this is inevitable debate on the dynamics characteristic of the HUL approach and the notion of cultural heritage authenticity (Jokilehto 2006, 2013; Gustavo 2008; Bandarin and van Oers 2014; Ken Taylor, 2018).

At the same time, the global information communication paradigm has been rapidly changing the interactive relationship between people and urban culture on the spatio–temporal level. The year 2014 was notable, with the announcement of Nara+20 and the Florence Declaration on Heritage and Landscape as Human Values, both emphasising the evolution of the cultural heritage concept, and acclaiming that progress in cultural value and social engagement were bringing new and diverse perspectives on understanding authenticity and sustainable development (Japan ICOMOS 2014; ICOMOS 2014). Additionally, as a milestone, the Florence Declaration suggested promoting innovative digital technologies for sharing value, democratisation, and fostering cultural growth. These points are a reminder there is not only a physical world of cultural landscapes inhabited by human value, but that there has also been an era of the virtual landscape of information shifting how human value is inherited.

In fact, the science of information has already been pervasive in the field of heritage study and conservation, from remote sensing to digital modeling. Technical efficiency has greatly improved in recent decades. (Warden 2009; Roumpani, Hudson and Hudson-Smith 2018) With spatial technology progressing in China, it is now feasible to apply big data, smart cities, and social networks toward heritage management as tools for sharing and public participation. More importantly, the information-based way of thinking may fundamentally change ways of understanding urban social and spatial activity. This is changing the paradigm for physical formation of urban areas. (Shapiroa and Varian 1998; Hudson-Smith et al. 2009)

A technical framework was developed based on the combined understanding of landscape value orientation and the trend of progressing digital heritage, involving digital technologies categorised into three types that support the six steps of implementing the HUL approach (Table 1). Each category consists of multiple information types generated through integration techniques. Virtual network innovation enables imagining of an information platform in which people can access and participate in the HUL implementation process, and the HUL information system can continually evolve with the influence of real-time urban data. For studying the Xi'an walled city area, online open source data of social media apps, online communities, and location-based service apps were selected to identify the existing condition of the historical landscape morphology within the built environment (Table 1).

Historic and Cultural Landscape Context and Features of Xi'an

Identifying Historic Landscape Formation of the City

Xi'an was one of the most significant ancient cities in China's history, and has been seen as representing the greatest Chinese city in terms of power of culture influence and politics. Most historic Chinese cities share the traditional paradigm of *fengshui* and *shanshui* landscape ideology over thousands of years of history. These serve as the basis for understanding the city as a cultural landscape continually integrating both natural and cultural resources and context into its developing process. The natural environment of traditional Chinese cities contains strong cultural properties, including pictographic information and divination-based meanings, combining ecological wisdom to build a relationship with human settlements (Han 2012). As listed in Table 2, a framework combining both

Table 1 Historic Urban Landscape Information System platform design (Source: the author).

HUL approach 6 steps	Action goals	Information category			Digital tools selected in Xi'an research case	
		HUL data category	Integration technic	Information types	Tool	Data source
a) Resource mapping b) Value consensus c) Vulnerability assessment	Identify value system	I. Historic landscape data	GIS Modeling Web/Mobile technology Visualisation VR/AR MR	Geographic information 2-D historic image 3-D model	Remote sensing; UAV monitor	Historic archive & literatures; Satellite image; Drone aerial panorama photograph (by research team); 720-yun online community; 360-degree panorama photographs
					ArcGIS; Space syntax; Spatial and network analysis	Topographic Map; Baidu Street View Photo; LBS Data: POIs of Baidu Map/Dianping/Weibo Inter Data: Douban Data/Online Questionnaire distributed through Weibo & WeChat
d) Development indication e) Action priority	Value and carrier assessment	II. Real-time impact data		GPS data; LBS POIs; Street view photo	Social network and data flow analysis	
f) Coordination establishment	Decision making	III. Scenario data		Evaluation scores; Votes; Comments; Suggestion text; Designs and plans	Interactive design; 3D mapping	Consultation result; Assessment result; Research findings Design proposal

Table 2 Identification of historic landscape system in Chinese cities (Source: the author).

Landscape Layers	Traditional Chinese urban cultural landscape paradigm			Listed heritage in Chinese management system
	Ideology	Morphology	Historic place	
Natural and cultural–natural	I-A. *Fengshui*/*Shanshui*	I-B. Natural environment; geological and topographic landscape pattern	I-C. Scenic landscape, mountain, hill, peak, slope land, lower land, valley …	National park; Scenic area; Historic city, Historic street and block, Historic town and village; Historic building; Cultural heritage unit
Ecological economic	II-A. Water Daoism, traditional ecologic-wisdom	II-A. Waterways system, conservancy system, drainage System	II-C. River, canal, lake, stream; ports and piers, markets	
City, civic life	III-A. Hierarchy, position, symbol, axis	III-B. Urban spatial pattern, planning and layout, road system	III-C. Wall and moat, functional zones, street and block, related villages	
Religious, aesthetic, political, public	IV-A. Genius loci, spirit of the place, sense of place	IV-B. Spatial relation of religious and imperial tomb and cultural places with landscape	IV-C. Administration area, cultural places as temple, Confucian College, schools and library, gardens …	

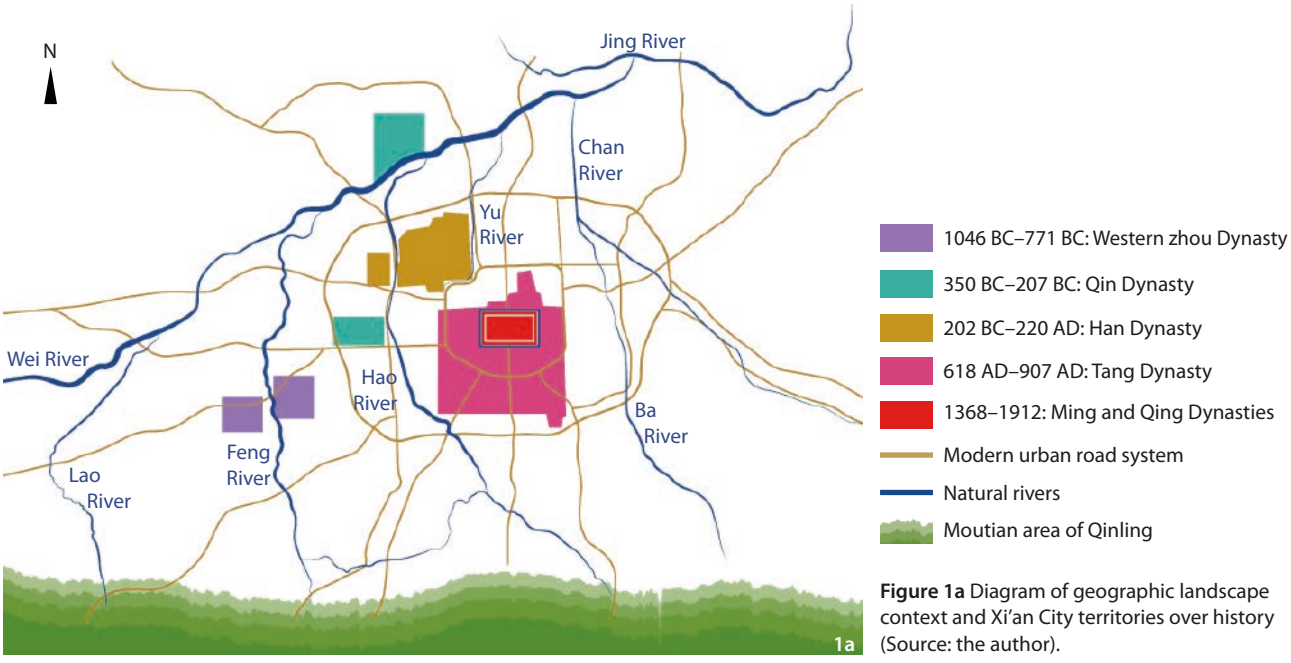


Figure 1a Diagram of geographic landscape context and Xi'an City territories over history (Source: the author).

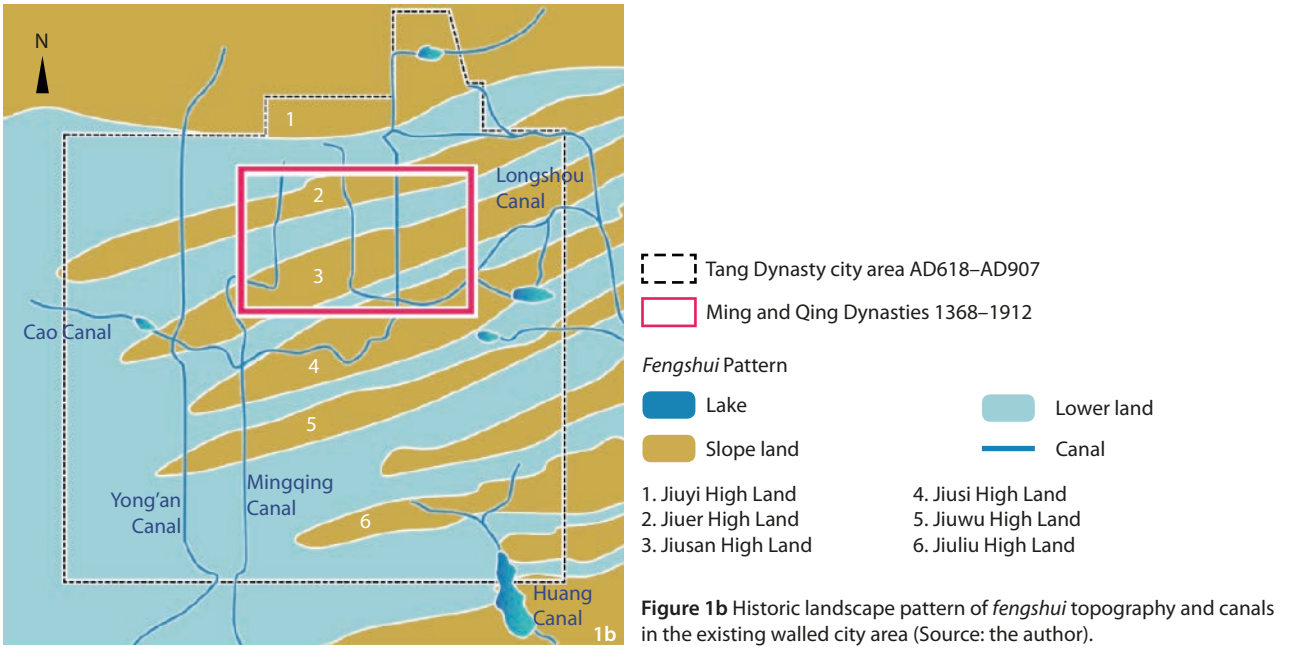


Figure 1b Historic landscape pattern of *fengshui* topography and canals in the existing walled city area (Source: the author).

landscape layering (landscape approach) and the paradigm of traditional Chinese landscapes was designed for identifying the formation of the city's historic and cultural landscape. This method was developed based on previous research of HUL in Chinese cities such as Yangzhou, Hangzhou, Ji'nan, and Nanjing (Han and Wang 2018).

From the perspective of another aspect, the current heritage conservation management system, tangible heritage entities are listed, providing reliable material evidence for the historical landscape system. Critically, owing to the circumstance of deteriorating heritage in Chinese cities, there are considerable limitations on identifying the full picture of historical landscapes only by relying on existing heritage. However, this existing heritage can be seen as a key to the past, anchoring the accumulated landscape layers.

Landscape Context and Component of Xi'an

The historic *fengshui* and *shanshui* systems of the Xi'an walled city area were generated in the Sui and Tang dynasties spanning 581–907 AD. In the past decades, scholars have been identifying the greater geographical landscape pattern of Xi'an based on historical maps and literature, which detail the topographic landforms and water system. As seen in the diagrams in Figure 1a and Figure 1b, the

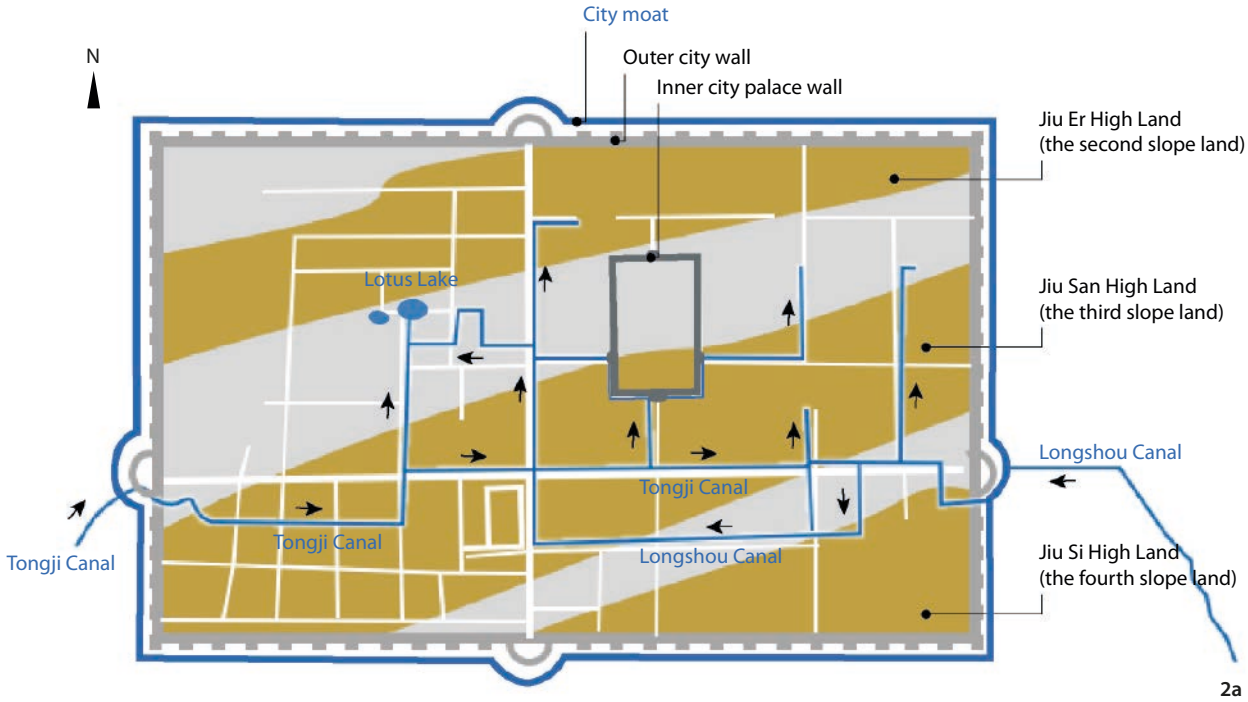


Figure 2a Dominant landscape structure of the walled area (Source: the author).

locations of historical urban settlements since the 11th century BC evolved and closely bonded with the river waterways. In urban construction and evolution since the Sui and Tang dynasties, the most influential landscape components seen are Six Parallel Slope Lands, also called *Liu-yao* (六爻, word of *fengshui* trigram) and five man-made canals linked to eight natural waterways, known as *Bashui-wuqu* (Eight Rivers[6] and Five Canals) (八水五渠), which spanned the entire plain (Shi Nianhai 1998; Shi 2000; Wen 2005; Li 2010).

Historic Landscape Structure of the Walled City Area

The walled city area of Xi'an encompasses about 12 km^2 within the wall and moat boundary. The walled territory structure was maintained for nearly six centuries, from the 1370s to 1950s; however, the history of urbanisation of this territory dates back about 1,500 years ago, initiated in the city in the Sui and Tang dynasties (581 AD–907 AD), with the vitally important Tang Dynasty Imperial City Palace within it. From the Later Liang Dynasty (907 AD–923 AD) to the Yuan Dynasty (1279–1368), Xi'an had lost its capital position in China, and the city contracted to the scale of the former Tang Dynasty Imperial City Palace area. In the Ming Dynasty (1368–1644), the city again expanded, to the scale of the modern-day walled area, with the city wall rebuilt and strengthened, and the foundation of the walled city achieved. It continued evolving through the Qing dynasty (1644–1911) and the time of the Republic of China (1912–1949) (Shi 2000; Yan Xijuan 2002; Zhu 2002; Li 2009).

The walled area is within the greater *fengshui* landscape context and occupied the centre of the *fengshui* topography's Six Parallel Slope Lands. In this, the second, third, and fourth slope lands traversed the territory as the dominant topographic feature (Figure 2a). The Longshou Canal water system was constructed from the Tang Dynasty, connecting to natural river waterways, and its structure evolved with reconstructions throughout the various regimes. In the Ming Dynasty, the water system transformed into a fully developed network from two main canals: the Longshou Canal from the east and the Tongji Canal from the west. The spatial function and formation pattern were resultantly influenced in multiple ways (Wang and Zhou 1999; Shi 2000).

The present research undertook a comprehensive historical layering, uncovering each chronological era, and accumulating landscape information from historical literature and maps, as well as archeological, geological, and urban history research and survey reports. That information was then categorised and integrated as per Table 2, overlapping in a geospatial map. From 581 AD to 1949, each of the seven dynasties left its unique urban spatial morphological pattern (Shi 1996; Ren 2005; Wang 2007; Su 2006); literature and historical maps document a total of 827 historic sites[7]. Figure 2b visually depicts the

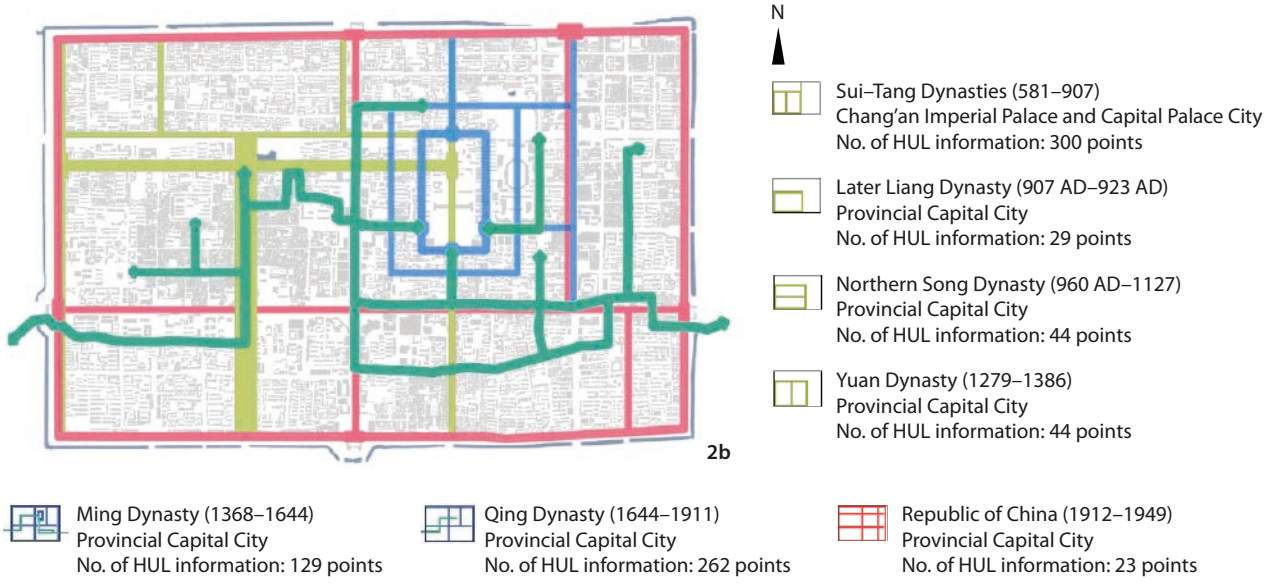


Figure 2b Urban spatial structures layers of seven dynasties (Source: the author).

dominant axis and grid of the overlapping layers of the urban spatial structure; this represents the accumulated morphological patterns of the walled area. Conversely, cultural heritage conservation management information published by the city government in 2014 states there are only 34 listed heritage historic buildings and archeological sites remaining within the walled city area, apart from the famous Ming Dynasty Bell and Drum Towers and City Wall, and most of these are 20th-century historic buildings (Xi'an Government 2014).

Digital Mapping, Findings on Relativity of Past and Present

Discovery of Existing Urban Landscape Condition Using Aerial Photo

The existing built environment of the walled city area contains a considerably dense and diverse pattern over 12 km^2, with a cadastral block scale mostly under 5 acres, and building elevation of about 9–24 m. Since the 1980s, Xi'an has been involved in the National Historic City conservation system in China, and implements zoning height restrictions inside and around this historical area. Until 2015, including the city wall itself, there were nominations of National (10) and Local (15 provincial-level and nine city-level) Cultural Heritage units within the historic walled area and occupying a total of 23.4 acres. To acquire a comprehensive landscape evaluation of the research area, the team used a UAV device to take aerial panoramic photos from 20 locations on-site, and added 10 more 360-degree aerial panoramic photos from an online community[8] and consisting of image data sources covering the entire walled area. As shown in the aerial panoramic photos in Figure 3, a grid axis and square blocks are dominant in the built spatial orders. The overall height control of the area can be clearly observed (photos C and D), with the city wall shown as a red line, and the plot ratio raising up immediately outside the wall boundary. Most of the street blocks were reformed in the 1970s–1990s with basic modernised characteristics. The scale of public buildings expanded in the central area around the Bell and Drum Towers. Such buildings were built in the 1990s and used traditional Chinese architectural features in their designs. Nearly half of the existing built heritage units are amassed in the central-west area around the Bell and Drum Towers and Muslim Quarter; this is also the most commonly recognised tourism destination in Xi'an. Other listed heritage units are located separately. This situation is reflected in the questionnaire question on visited heritage sites. Over 88.58% of respondents had been to the Bell and Drum Towers, which were the most commonly selected among areas visited. Selection rates of the other 32 of 34 heritage units were under 40%. This rate was under 20% for over half of the heritage units. Furthermore, in the questionnaire's comments section, strong disappointment was expressed about the conservation work, noting that old buildings and street patterns had long been disappearing.

GIS and Space Syntax Analysis: Findings on Invisible Power of Historic Landscapes

To address the controversial situation of deteriorating historic heritage, the research involved technical support

Figure 3 Map of existing heritage and aerial photos in 2016 (Source: the author).

for interpreting the value of historical landscapes that physically seem invisible. GIS and the space syntax method were selected because of their logical approach toward the geographic–social–spatial relationship and their capacity for easuring geometric information and configurational modelling of space. To include social and economic perspectives, online open resource data, such as map POIs and social network LBS data, were collectively applied with the location-based questionnaire results. A built environment data mapping series was implemented, including building density, height and plot ratio analysis, function display analysis, block scale and openness analysis, road axial depth and integration, cultural and consuming facility kernel, heritage unit network, and service area.

As shown in Figure 4, further research of relativity included procedures including tracing the built heritage in both the historic landscape and existing built environment, and mapping with new digital techniques to evaluate the overall status. The most critical parts are in the integration process, which refers to comparison of past and present patterns in a shared landscape context.

Interesting findings emerged after examination of the relativity between built heritage and historical landscapes. First, the six *fengshui* parallel slope lands' topography, well known in the Tang Dynasty, has continued to influence the built density for more than 1,000 years. Second, the Longshou Canal system disappeared hundreds of years ago, but still intangibly serves as a living facility flowing across the walled area. Third, the historical street

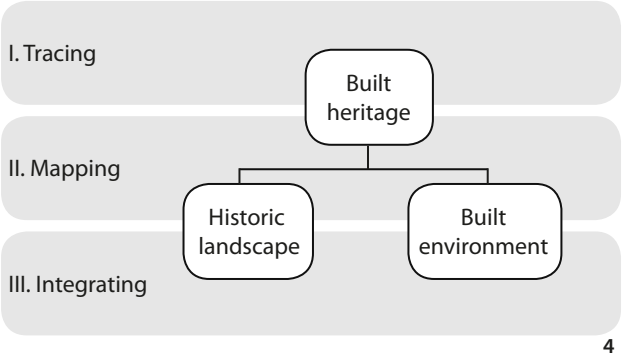


Figure 4 Process of examine the relativity (Source: the author).

community and grid was shown in chronologic sequence with the trend in degree of choice measured by space syntax.

Mapping *Liu-yao Fengshui* Topography with Building Density

As mentioned, the walled area was built on *fengshui* topography for the second, third, and fourth of the six parallel slope lands. According to historical speculative figure research by Li (2010), the geographic alignment of these slope lands is from northeast to southwest. The third slope land, called the Jiusan High Land (九三高地), is a dominant feature within the walled territory (Figure 2a). Historical literature indicates the Jiusan High Land had importance related to its *fengshui* value in that urban construction in the Sui and Tang dynasties was strongly related to this approach with its site plans for important administrative public buildings and cultural facilities[9]. The urban functional layout seems to have been inherited in the latter Five Dynasties to Song dynasties, and Ming and Qing dynasties, as seen in locations uncovered in historical documents (Zhu 2002; Shi 2000). However, no direct evidence shows the latter dynasties also followed the rule of ideological *fengshui* topography as with the Jiusan High Land.

To some extent, the results of the existing built density assessment showed relativity with the historical phenomena. As shown in Figure 5a, the building density was calculated in units of 50×50 m grid squares, and a clear low-density spatial sequence layout exists from the northeast to southwest, which is consistent with the area of the third slope land (Figure 2a). The blocks of this sequence now hold a series of less-concentrated public buildings with more open space on each site. Most importantly, they share similar functions as historical public and cultural sites. These existing buildings include: (1) the current Shaanxi Province Government and Xi'an City Government Administration Building, which is atop the highest elevation point of the walled territory, and is where the Ming and Qing Qinwangfu (provincial administration palace) (秦王府) of the inner-walled territory also stood; (2) the heritage buildings of the Bell and Drum Towers of the Ming and Qing dynasties at the central-south, and surrounding historic places of previous dynasties, and which is also now the largest public space inside the walled territory; and (3) the current provincial library with a 20th-century heritage building, and which was once also the location of the most widely recognised official school in the Song Dynasty, the Zhengxue Official School and Academy. Additionally, in the Tang, Ming, and Qing dynasties, this area was the location of provincial government office assembles (总督府 , 巡抚衙门). As illustrated in Figure 5b, cultural and administrative sites in the first half of the 20th century continued the pattern of spatial sequence similar to in the Ming Dynasty official site layout in the walled territory (Wu 2013). Most of the buildings at this site were renewed in the early 20th century and are now registered as heritage units.

While having evolved over thousands of years and been covered with urban reconstructions through the various dynasties, the landform terrace of the slope land is barely noticeable today. However, via a comparison with the geomorphic survey elevation map (Figure 5c), ground fissure distribution, and geological sedimentation (Bo 2014), we verified the geographic existence of the *Liu-yao* historical *fengshui* landform trend, which is not only an ideological form. The mapping of building density also revealed the influence of the *fengshui* pattern applied since the Tang Dynasty on urban public and cultural construction, and which has lasted up to the present. The historical landscape has, thus, layered and accumulated in ways that act as physical imprints of the walled city.

Mapping Longshou Canal with Living Facility Display

Regarding the water system greatly appreciated in traditional Chinese cities (Wu 2009), historical water canals inside and outside the walled territory of Xi'an were gradually filled from the 1940s to 1970s (Wang and Zhou 1999), except for the moat system. While there have been natural rivers and canal systems since the beginning of city construction in the early Han Dynasty (200s BC), the greatly revered Eight Rivers and Five Canals were finally realised and constructed in the Tang Dynasty (Wu 1990; Wen 2005). Within the wall, two canals were developed to an adequate extent in the Ming and Qing dynasties: Longshou Creek entering from the east gate and the Tongji

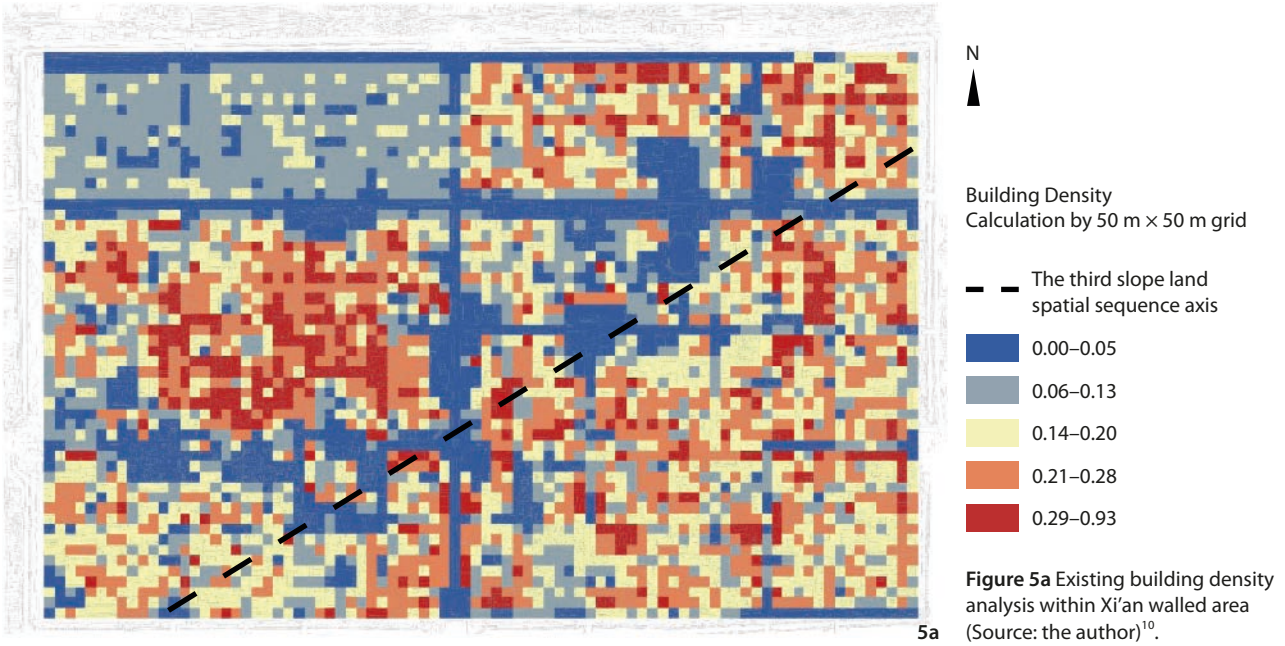


Figure 5a Existing building density analysis within Xi'an walled area (Source: the author)[10].

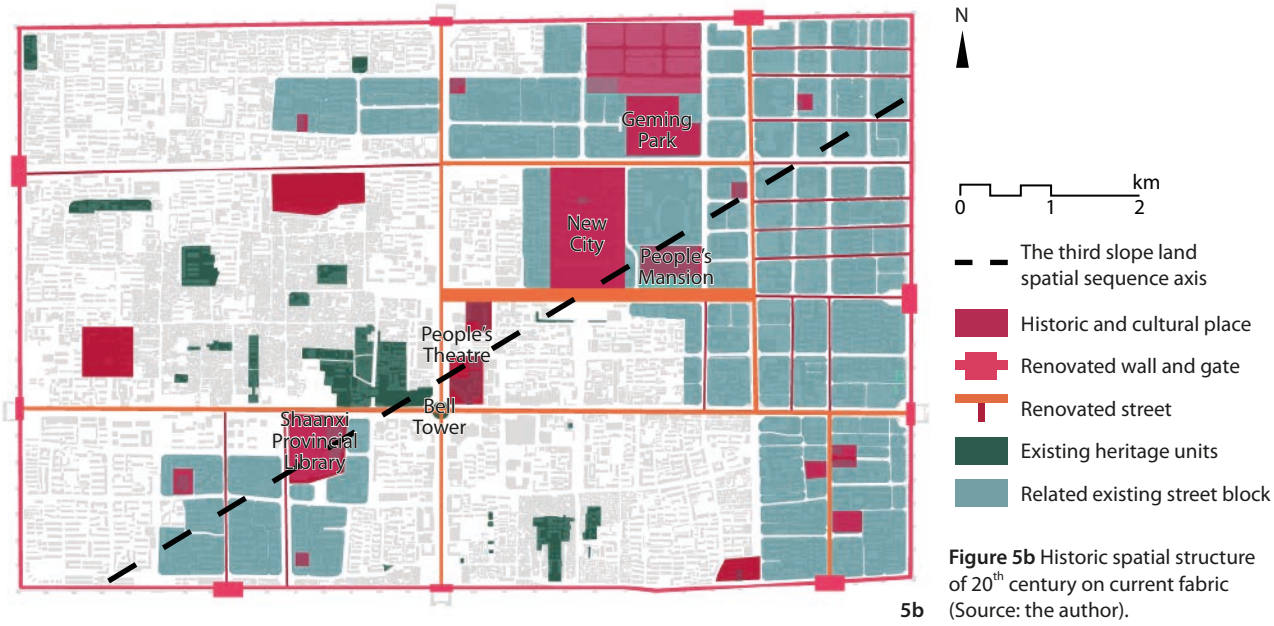


Figure 5b Historic spatial structure of 20th century on current fabric (Source: the author).

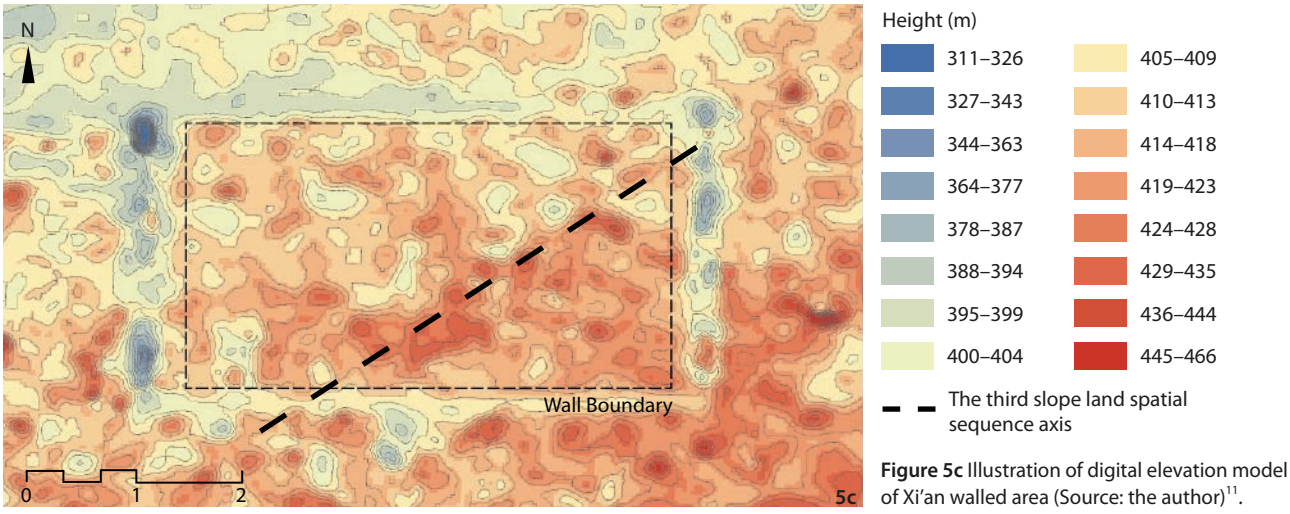
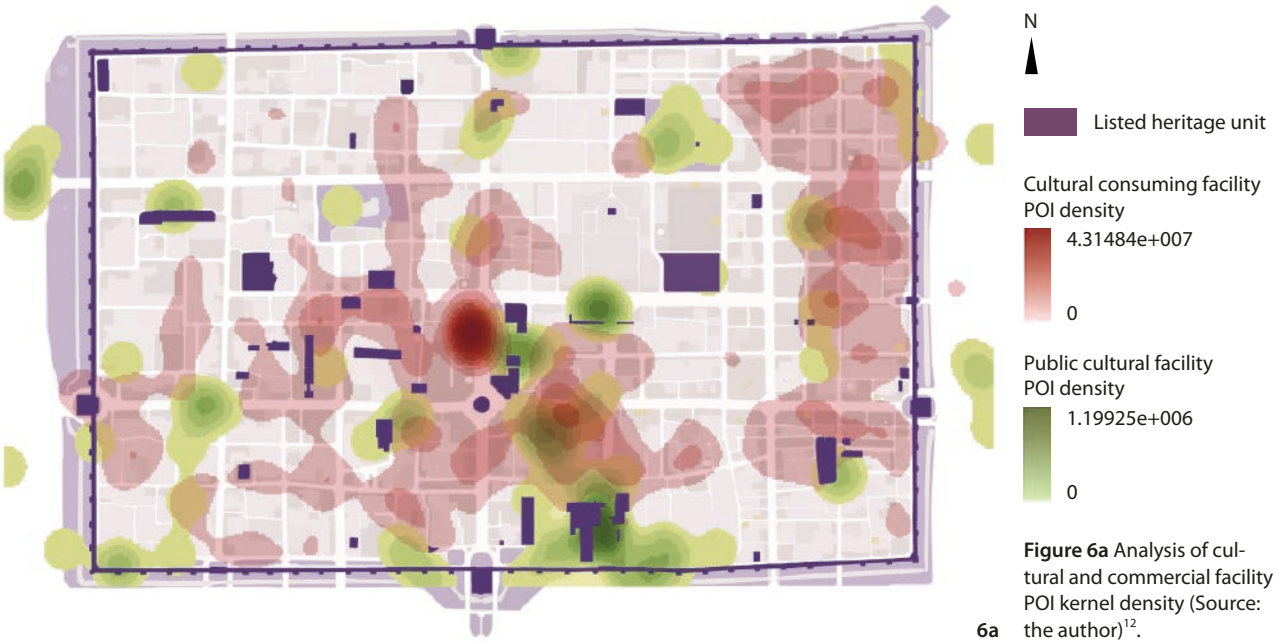
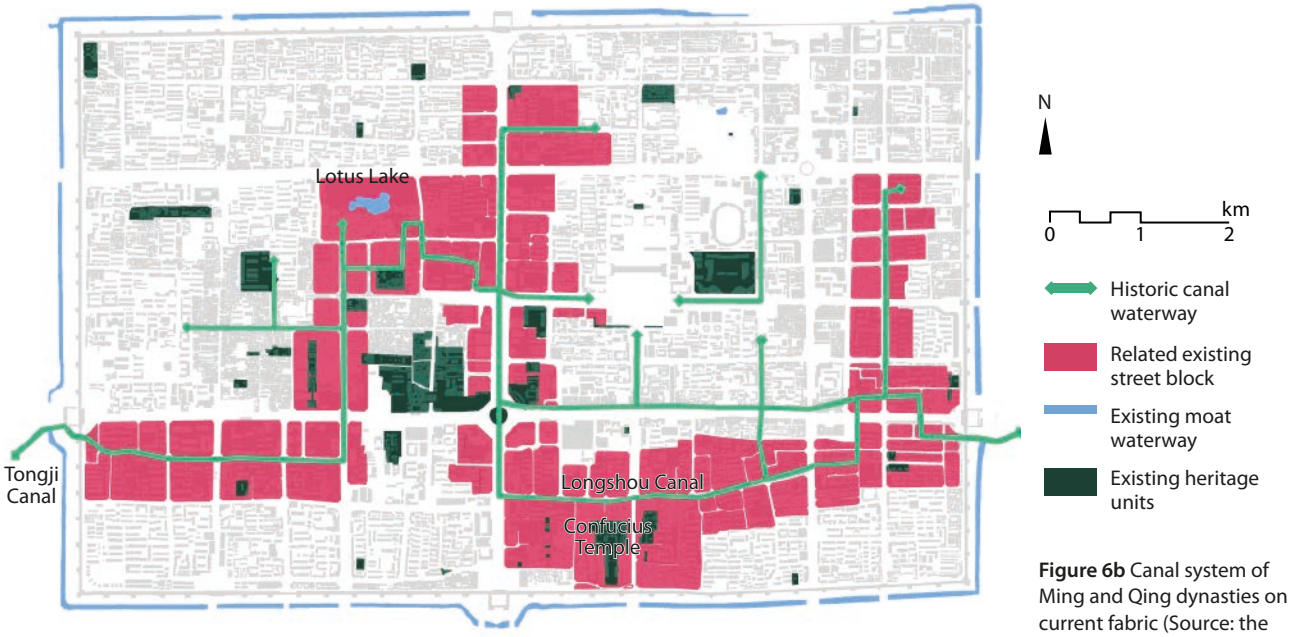


Figure 5c Illustration of digital elevation model of Xi'an walled area (Source: the author)[11].



6a **Figure 6a** Analysis of cultural and commercial facility POI kernel density (Source: the author)[12].



6b **Figure 6b** Canal system of Ming and Qing dynasties on current fabric (Source: the author).

Canal from the west gate (Wu 2013). These were built on the foundation of previous canal ways and were basically reconstructed together with roads. The chief function of these canals was to convey drinking water from rivers outside the walled area, because the underground water resource inside the wall was not fit for drinking. Thus, the residential living spatial pattern including service facilities for living was closely related to the water canals' distribution pattern.

Without physical evidence, the canal waterway only appeared traceable in historical maps, but surprisingly, the digital analysis results showed existence of the canal influence on the site of present-day distributed urban facility locations. This research used online open-source POI data from LBS Map Apps to examine the social and economic space pattern. The POI data were filtered into two categories: commercial facility points, including restaurants, hotels, cafes, and stores, and public cultural place points, including theaters, cinemas, museums, galleries, libraries, cultural centres, and parks. Measured with kernel density, continuing neighbourhood areas of POIs were visualised as the spatial pattern shown in Figure 6a. The more POI accumulated intersections of radius distance on total, the colour got darker as long. POI showing

accumulation of business premises is shown as a linear shape segment in the east of the walled area, and another larger network shape occupying the centre area. The coherence and spread of POI kernel density in the spatial sequence shows the similarity with the canal waterway network uncovered by researchers with reference to historical records and maps. This is illustrated in Figure 6b. The current street blocks beside the historical waterway and coloured red occupied 22% of the area of the walled territory, containing 3,051 POIs, which is 60% of the total POI number.

The historical literature indicates most of the streets with water canals were also traditionally residential and commercial streets (Shi 2000). The existing land use map shows the locational distribution of service facilities closely relates to residential neighbourhoods, and the density of facilities represents the scale of space competence oriented by the historical placement of water resources. In the western part of the area influenced by the canal network, there are still small cadastral land units of space fabric. At the same time as limited conditions of water resources, there were also restrictions on and planning of the spatial arrangement, so that some parts of the canal were not permitted to have excessive aggregation of residents and facilities. For example, the POI kernel density is rather low on Grand East Avenue, which contradicts the general impression of this as a traditional commercial street. In fact, in the Ming and Qing dynasties, the main segment of the Longshou Canal was on this street, but served as a moat of the walled provincial government palace (秦王府). In this way, the water resource was an exclusive supply. This area was only transformed into a commercial street after the 1910s and residences began to be allocated in the surroundings. Thus, in a sense, the quantity of accumulated spatial information can be measured to identify the age of a space.

Mapping Ancient Street Community with Road Axial Syntax

A comprehensive historical urban spatial structure revealing each chronological era was pursued in this research. The road system as the dominant component was chosen to represent the spatial structure. In 581 AD–1949, each of the seven dynastical periods had its own road system that evolved and was overlapped in later generations. Wall and gate systems were of substantial importance in ancient city morphology.

A segment of the archeological site of the Palace City wall in the northwest, from the Tang Dynasty, provides an anchor location for tracing the primary Sui–Tang dynasty palace city layout. This is the only remaining aboveground feature of the Tang Dynasty (Wang 2007), and is an area that was once the entrance of the Qingming Canal and ran into the palace all the way through to the north and out of the wall. It has now been transformed into a road. The Xi Wutai Temple from the Song Dynasty is built on the terrace of the ruin, located in an isolated area with other heritage units that, as indicated in the questionnaire, only 23.7% of respondents had visited. The road beside the ruin, named Sajinqiao, with street blocks known as 'Muslim Street' received the highest index in syntax choice evaluation[13]. Another interpretation of this is the street most people pass through in the walled area was scarcely known by its historical heritage value (Figure 7a).

The distance of 300 m was chosen as the shortest route length in the syntax measurement because is the general street block scale of the Tang Imperial Palace (Guan 2012) and it is the length of the wall remains and temple site (west–east: 300 m), which likely survived because of fitting into a block scale and being protected by surrounding it later with buildings. Additionally, 500 m was chosen as the measurement for heritage units overlapping the network area because the average street block has grown to the scale (400–600 m side length) in the existing built environment. A GIS network service analysis was applied to evaluate the spatial relation of the heritage units and the surrounding street area. Figure 7a shows the aggregation of existing heritage units, consisting mainly of three areas; the largest occupies the central-west area, influenced by 18 heritage units (53% of all those within the walled area), including the Bell and Drum Towers, three mosques, and the Chenghuang Temple, and mainly constructed in the Ming and Qing dynasties.

The Muslim community is the most popular tourist destination, and was also the most commonly cited in questionnaire responses regarding conservation. This community began settling during the Song Dynasty and continued evolving to a scale occupying half of the previous Tang Dynasty Imperial City (Huang 2010) for 800 years until the Qing Dynasty. Today, historical information on the Tang Dynasty is almost invisible apart from the road axis (Figure 7b), The result in the degree layout of road segment choice shows a clear coloured gradient moving from west to east (Figure 7a); this represents the walking time scales of the street community, from short to long, and is also the historical sequence of the walled area's development process from the Tang Dynasty to the 20th century and up to the present. But eventually it is the basic landscape layers underneath that foster the living

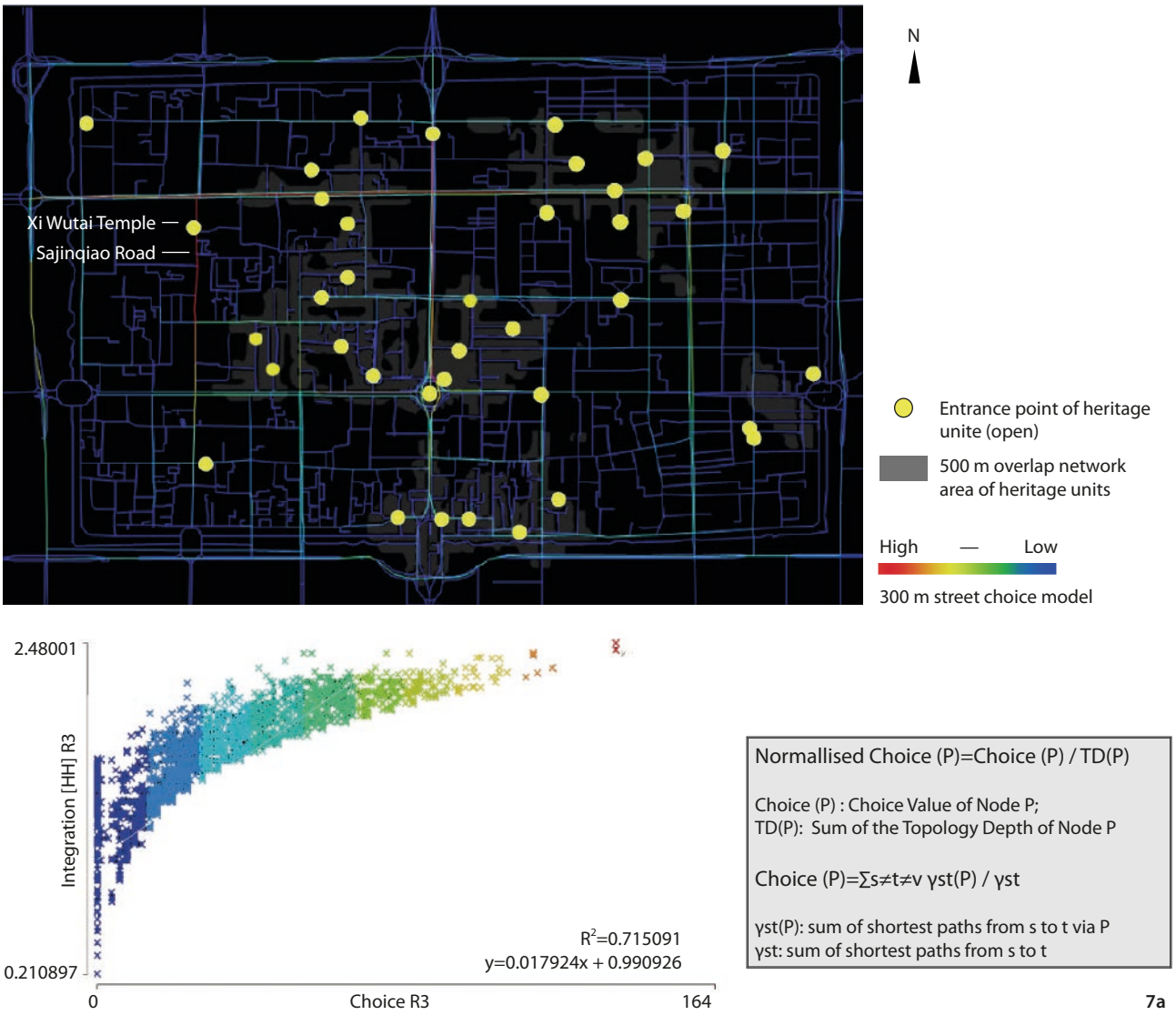


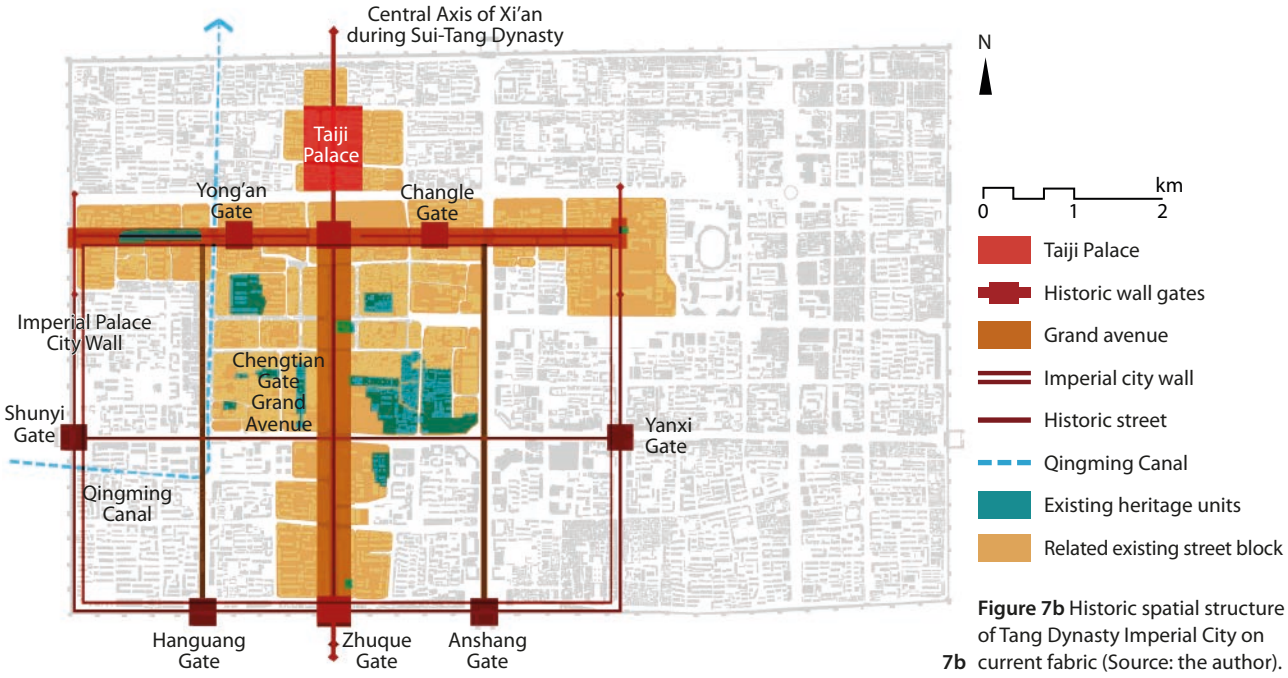
Figure 7a Road axial choice and heritage unit network (Source: the author).

habitat of the community, consisting of the Qingming Canal in the Tang Dynasty, Tongji Canal drainage system in the Ming and Qing dynasties, and lower land between the second and third slope land. The story has long since been written in the cultural–natural relationship.

Conclusion: Imagining a Smart HUL Information Platform

The findings via mapping have revived the relationship between past and present, extending the value boundary not only temporally, but also spatially. A HUL information system as technical media is an attempt to bring information-based thinking into the field. In integrating the social–spatial and cultural–natural logic in the system, it is efficient for helping to: (1) identify the invisible continuity of historical landscapes in the existing built environment, (2) improve the integrity of the urban heritage system, and (3) provide knowledge on urban heritage, urban evolution, and sustainable conservation and development.

It is critical to introduce time as a consideration, as real-time urban data flow serves as a resource for smart cities and already influences urban development and daily urban life. With innovation in spatial information technology progressing rapidly in China, a HUL information system is also proposed for sharing and social cooperation via the HUL approach. Implementation on a virtual reality platform is expected in the future. With interaction through social media, an information-based HUL online platform could be an efficient tool for public engagement on decision making regarding urban conservation, regeneration, and development. The dynamic pattern of the



7b **Figure 7b** Historic spatial structure of Tang Dynasty Imperial City on current fabric (Source: the author).

evolution of cities is changing with the global network of information flow, only to recognise the mechanism of sharing, communicate, and exchange from the mindset, would help to stop the deterioration of human value.

The Xi'an walled city epitomises the most historic cities in China. It is a key representative of ways for Chinese cities to recreate their cultural and natural relationships to solve the problems of environmental crises and deteriorating cultural heritage after the massive urbanisation of the past decades. The HUL approach could be applied as a practical route for uncovering the traditional Chinese philosophical wisdom steeped in the value of the environment, and at the same time strengthening the capacity for conservation of urban heritage conservation in future evolution of urban areas.

Notes

1. A research platform for young professionals that promotes creative thinking and innovative technologies in the HUL approach, founded in 2015 at Tongji University in Shanghai.
2. Team: AISA Urban Design Research Centre, Urban Cultural Architecture Research & Design Centre from Arcplus Group PLC Institute of Shanghai Architectural Design & Research Co., Ltd.
3. This was done via an online professional questionnaire, survey, and voting web platform provided by www.wjx.cn; see the questionnaire at https://www.wjx.cn/jq/7249628.aspx
4. WeChat is a Chinese multi-purpose messaging, social media and mobile payment app developed by Tencent. By 2018, it was one of the world's largest standalone mobile apps, with over 1 billion monthly active users (902 million daily active users). https://en.wikipedia.org/wiki/WeChat , http://wechat.com
5. Cultural Heritage Unit: Listed cultural heritage management site in administrative cultural heritage management system in charged by the State Administration of Cultural Heritage.

Refer to Xiangru Sima (179 BC–118 BC), *Shanglinfu* [Shang Lin Ode] (上 林 赋), which describes the Eight Rivers.

6. Historic Places List from: "Appendix 3–8, Xi'an Historic City Conservation Plan Session", *The Overall Plan of the City of Xi'an (2004–2020)*, Xi'an Bureau of Cultural Heritage, Xi'an University of Architecture and Technology, Xi'an Urban and Rural Planning and Design Institute. Source: Xi'an Rural and Urban Construction Committee
7. 720yun is a professional panoramic platform online community https://720yun.com/
8. Refer to Jifu Li (758 AD–814 AD) *Yuanhe junxian tuzhi* [Ancient Chinese Historical Geography Book] (元 和 郡 县 图 志); *Zhouyi* [I Ching or the Book of Change] (周易).
9. Data source: Topographic Survey Map 2013, provided by Xi'an Rural and Urban Construction Committee

10. ASTER GDEM 30M 2009, The data set is provided by the Geospatial Data Cloud site, Computer Network Information Centre, Chinese Academy of Sciences. (http://www.gscloud.cn)
11. Data source from: AMap POI Data Source, https://lbs.amap.com/api/webservice/guide/api/search
12. Choice measures how likely an axial line or a street segment it is to be passed through on all shortest routes from all spaces to all other spaces in the entire system or within a predetermined distance (radius) from each segment. See Betweenness and Segment Angular Choice. Sources: Hillier, B., Burdett, R., Peponis, and J., Penn, A. 1987. "Creating Life: Or, Does Architecture Determine Anything?" *Architecture et Comportement/Architecture and Behaviour* 3(3): 233–250. pp.237 http://otp.spacesyntax.net/term/choice/

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