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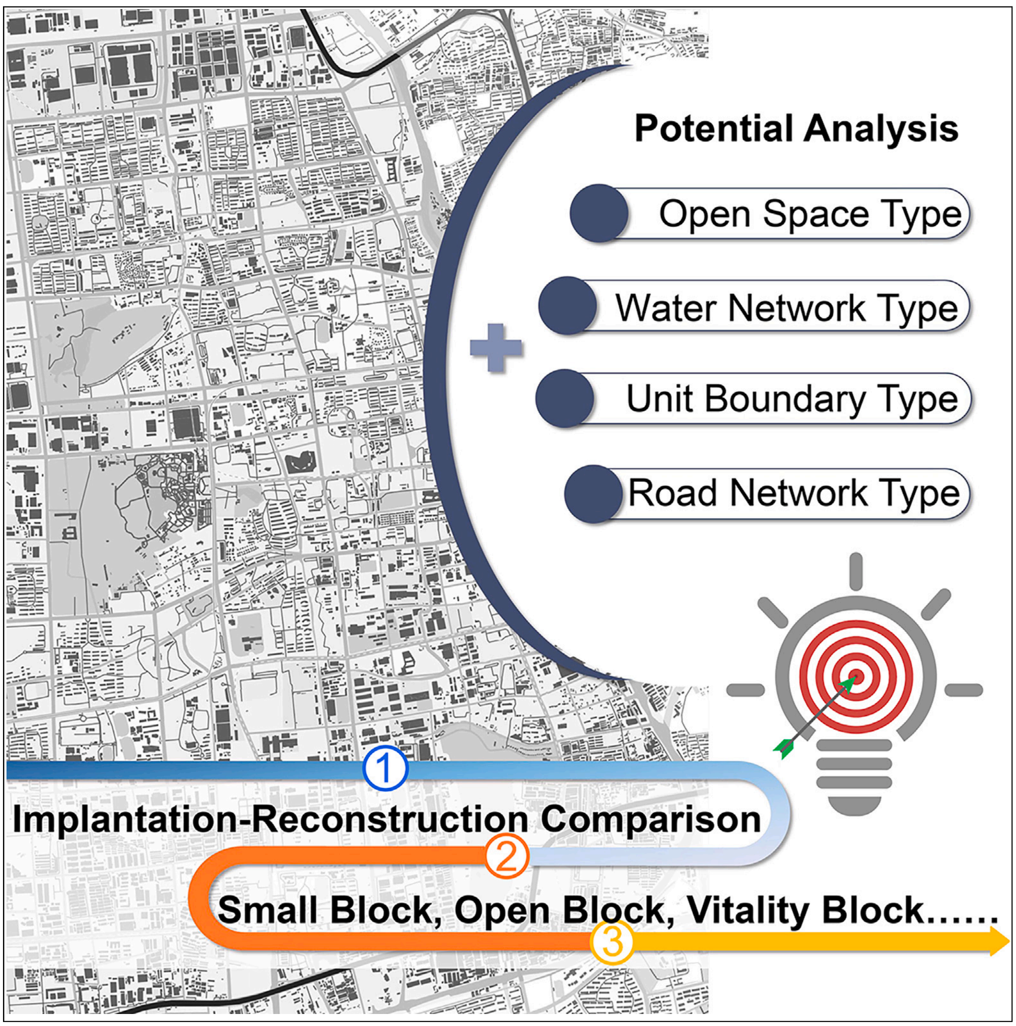

Fang Zhang, Xi Zhou

2140@usts.edu.cn (F.Z.)
zhouxi@usts.edu.cn (X.Z.)

Highlights

Blocks, like cells in creatures, are integral to the city

The structural renovation of blocks in the build-up area is facing complex factors

External space elements play an important role in structural reconstruction of blocks

The Implant-Reconstruction model portrays the potential impact and paths

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Structural renovation of blocks in build-up area of Jiangnan cities, taking Suzhou new district as an example

Fang Zhang[1,*] and Xi Zhou[1,2,*]

SUMMARY

The rationality of block scale and structure is the guarantee of vitality and humanization quality, facing complex and diverse problems, and the structure reconstruction of urban built-up areas is one of the most difficult challenges in the process of promoting the block system. The traditional planning-construction strategy, as practice in recent years has demonstrated, faces challenges in terms of construction costs, demolition costs, property rights, and jurisprudence. Based on the interaction of the block structure and external space, the study presents a "implant-reconstruction" model. It investigates possibilities of implanting elements and graphically depicts the potential impact of implant-reconstruction using Space Syntax. The findings indicate that the external space implantation mode may actively encourage the construction of small-scale blocks and has benefits in terms of texture respect, low impact, and ease of operation. The simulation and pre-judgment dynamically illustrate the viable path and gives a scientific reference for block alteration.

INTRODUCTION

The rationality of block scale and structure, as the basic unit of urban structure and residents' lives, is the guarantee of urban space vitality and humanization quality. However, in the new stage, the urban renewal of built-up areas is confronted with complex and diverse problems.[1,2] For a long time after the rapid urbanization process, the main body of urban space in China has been dominated by closed blocks and large-scale blocks,[3] causing problems such as decreased traffic efficiency and loss of neighborhood relations.[4] The traditional texture of water and land in Jiangnan cities has been greatly challenged, resulting in traffic congestion and a loss of water town image. To realize the reconstruction of small blocks, it is necessary to combine scientific design methods with flexible policy guidance.

On February 22, 2016, the Chinese Council proposed that "the block system will be promoted for new residential districts" and "the existing residential quarters and closed units for staffs of offices and enterprises should be gradually opened" indicating the direction for urban renewal.[5] In contrast to China's traditional closed residential areas, the block system advocates for the reconstruction of open residential areas, the opening of closed residential areas, and the inclusion of internal roads into the urban road traffic system.[6,7] Many cities have promoted small-scale open blocks in urban new district, whereas construction activities focused on demolition and redefining blocks face opposition in built-up areas, potentially endangering traditional urban texture, spatial form and street vitality.[8] Given the characteristics of internal urban renewal in the Jiangnan region, where the urbanization rate has exceeded 80%,[9,10] the goal of this study is to propose a flexible path to urban renewal from the external space, and to guide accurate urban renewal operations with scientific analysis.[11]

This study proposes an "implant-reconstruction" model based on the block as the basic unit, and empirical research is conducted in typical urban areas. In terms of construction difficulty, demolition cost, property rights, jurisprudence, and so on, the operation of urban external space has more practical advantages.[12] In order to accurately carry out urban renewal, it investigates implantable external spatial elements based on regional characteristics, uses GIS (Geographic Information System) to conduct data integration and analysis of the implantation potential of various types of elements, and performs quantitative calculations to show the structural changes after implantation by using Space Syntax. The potential analysis and implant-reconstruction comparison show that external spatial elements have practical advantages in the process of small-block reconstruction.

Literature review and relevant research

Measuring urban design and relevant research

With the advancement of technical methods for analyzing urban problems and related theories of urban design, quantitative analysis at the urban design level has become the mainstream method for studying urban problems and has been widely popularized and applied,[13] as

[1]School of Architecture and Urban Planning, Suzhou University of Science and Technology, Suzhou 215000, China
[2]Lead contact
*Correspondence: 2140@usts.edu.cn (F.Z.), zhouxi@usts.edu.cn (X.Z.)
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evidenced by network structure analysis, perceptual analysis, feasibility evaluation, urban vitality evaluation, and so on. Reid Ewing developed the measurement index of urban streets in *Measuring Urban Design*.[14] Matthew Carmona proposed a six-dimensional system for urban design.[15,16] Scholars express concern about not just the scale of urban blocks, but also the quality associated with them.[17] Many scholars' efforts have resulted in the development of more than 60 quantitative indexes and more than 40 common methods in the visual dimension,[18] cognitive dimension, social dimension, functional dimension, morphological dimension, time dimension, and so on.

In terms of theoretical research, the three main schools of urban morphology—Conzen, Versailles, and Muratori Caniggia—believe that it is possible to abstract and analyze urban spatial characteristics and historical evolution through architecture and its open space, streets, land use units, and other fundamental spaces.[19,20] Scholars have proposed using GIS technology, digital overlay, and other digital design as auxiliary means to establish a scientific and effective external space design evaluation system and interactive feedback design system of urban external space. The digital overlay method and GIS platform are used to establish an "evaluation-design" linkage research mechanism, and quantitative techniques are applied to the entire design process to improve the scientificity and measurability of urban design.[21,22] A typical representative of two-dimensional plane analysis is the method of quantitatively measuring the vitality and quality of urban streets with data in the new data environment.[18,23,24]

In terms of quantitative analysis tools, after Space Syntax theory was introduced by Bill Hillier in the 1970s, the digital model is constructed using the mathematical relationship of topological structure.[25,26] He pointed that people rely more on spatial topological linkages and spatial angle relationships when navigating in metropolitan areas than they do when using local settings or local spaces, and drawn connections between spatial logic and social efficiency, pointing out that local spatial compactness and general geographic accessibility enhance the life of the urban center.[27] For more than 30 years, the computational method of Space Syntax has been constantly improved. More than 400 universities in 75 nations and regions have embraced the Space Syntax over the past ten years.

With the help of digital platforms in understanding the significance and mechanisms of spatial gene theory in urban research, quantitative analysis methods such as Space Syntax, Spacematrix, MXI, Place Syntax, Urban Network Analysis, Morpho, Form Syntax, and other quantitative analysis methods have increased the depth of morphology research and aided urban design practice.[28,29] Ye Yu led the development of the Form Syntax tool, which integrated several morphological ideas, and his work provided a quantitative method for urban design to stimulate urban vitality.[30] Space Syntax helps to investigate urban morphology in both the visual approaches of urban morphology and the attributes of street space.[31] Song Yacheng investigated the expression method of urban block morphology complexity with Space Syntax.[32] In the new data environment, Space Syntax can be applied to a variety of datasets based on Baidu POI data, user comments, street view maps, and other open data platforms, examining the relationships between urban morphology and public space, pedestrian streets, and water systems and providing rationale for urban internal renewal.[33] Academics have also consistently demonstrated the close relationship between urban accessibility and the economy, highlighting how improving accessibility can aid in the macrourban economy's revival.[34–36] In practice, the combination of Space Syntax and big data have been shown to produce considerable spatial and social benefits for the renovation of historical districts, especially those with complex features. Quantitative analysis based on Space Syntax was used to guide design in the renovation of the Qinhuai Historic District and Xiaoxihu District, establishing a relationship between evaluation and design and accomplishing a "small-scale, gradual" renewal process.[37] The difficulty in using Space Syntax software tools has been shown through extensive research and practice to be related to the choice of objects, the definition of the proper scope, and the interpretation of each parameter diagram.[38,39] In summary, Space Syntax has been increasingly popular in quantitative urban planning during the last decade. On the one hand, research on Space Syntax has demonstrated a varied feature, and its research area has also evolved from a single to a multi-directional direction. The application of Space Syntax technology approaches is versatile and broad; it is frequently combined with big data technology and applied to urban renewal. On the other hand, it reflects the subjective shortcomings of the syntax model based on urban data, the lack of a unified standardized system for model evaluation, and the need to expand the "analysis-design" linkage through the simplification of the Space Syntax computing system and the improvement of the analysis model.

In the past 6 years, small scaled block research and practice in China have focused on returning to the pedestrian environment and improving the economic and social value of land,[40] but they lack a thorough understanding of regional applicability and land use conditions. One of the main challenges to promoting the block system is the rehabilitation and renovation of blocks, particularly in metropolitan built-up areas. The public generally has a wait-and-see and skeptic attitude toward the neighborhood system, with conflicting public opinion foundations. The transformation involves property rights of land nature, which have legal contradictions before and after.[41] The block structure in the built-up areas is essentially formed, with densely distributed buildings and high demolition costs. In the built-up area in Jiangnan region, urban design focus on block structure in recent years frequently flows into the appearance of new urbanism, ignoring national conditions, and regional connotations. Block structure integration attempts frequently result in urban texture fragmentation, the block constructing conflicts with the natural waterway network system, and the urban texture is disturbed.[42] It is essential to rely on rigorous quantitative analysis to determine the region's entry point in addition to taking traffic, space, indicators, and other elements into account while considering the small-scale reconstruction and renewal of urban built-up areas in Jiangnan cities. This study approaches block renewal from the standpoint of external space elements, and it explores the feasible path of renewal using a mix of qualitative and quantitative methodologies.

Evolution trends of block

Throughout the history of urban development, the scale of the block has evolved in a regression trend of small-large-small.[43] Small-scale blocks of 80–120 m (262–394 feet) in Europe and the small grid of urban rules in the United States outlined the typical urban texture image of small-scale blocks in early urban construction. The introduction of automobiles at the beginning of the twentieth century resulted in urban

Table 1. Block scale in representative cities worldwide

Time	City		Shape/Pattern	Scale (M)
7th century B.C.	New Babylon		Close to square	(385–600) × (635–850)
	Mohenjo ~ Daro		Irregular rectangle	80 × 150
	Kahun/Lahun		Rectangle	18 × 75
8th century B.C. to 4th century A.D	Ancient Greek	Milet	Rectangle	30 × 52
		Priene	Rectangle	35 × 47
		Olynth	Rectangle	35 × 90
		Agrigento	Rectangle	35 × 300
	Ancient Roman	Pompeii	Rectangle	40 × 100
		Herculaneum	Rectangle	45 × 100
		Timgad	Square	25 × 25
4th century A.D to mid 15th century A.D (The Middle Ages)	Major cities in Switzerland		Rectangle	(20–60) × (50–180)
	Major cities in Germany and Poland		Rectangle	Grid pattern: (45–80) × (60–125)
				Linear pattern: (50–100) × (70–200)
			Square	(50–100) × (50–100)
	Major cities in Czechoslovakia		Rectangle	(35–90) × (60–160)
			Square	(40–80) × (40–80)
	Major cities in France		Rectangle	Grid pattern: (35–60) × (40–60)
				Linear pattern: (20–60) × (30–130)
	Major cities in Italy		Rectangle	(25–50) × (45–125)
17th to 19th century A.D	Major cities in Pennsylvania,USA		Rectangle	(85–128) × (110–220)
	Major cities in Texas,USA		Square	(60–90) × (60–90)
	Vienna		Rectangle	(37–50) × (200–300)
	Florence		Rectangle	(37–50) × (200–300)
20th century A.D to the present	Brasilia, Brazil		Rectangle	200 × 280
	New York, USA		Irregular Rectangle	(60–80) × (240–270)
	Savannah, Georgia, USA		Square	200 × 200
	L'Eixample Barcelona, Spain		Square	113 × 113
	Paris, France		Irregular rectangle	(50–80) × (100–120)
	Berlin, Germany		Irregular Rectangle	(150–200) × (150–200)
	Tokyo, Japan		Irregular rectangle	(50–100) × (50–100)
	Singapore		Irregular Rectangle	(80–150) × (150–200)

development centered on vehicular traffic and an efficient road network, with large-scale block development.[44] In the 1920s, for example, Le Corbusier suggested a bold concept for urban design, and in the *Plan Voisin* for the reconstruction of Paris's center city, the block size was divided into 400 m, approximately 16 ha. Clarence Perry produced the notion of Neighborhood Unit, which divide a city's neighborhood units into squares of 800 m (an area of around 65 ha). After World War II, large-scale blocks began to be questioned, which gave rise to ideas like *Smart Growth*, *New Urbanism*, and *Compact City*, as well as concepts like *BLOCK*, *Urban Growth Boundary*, *Sustainable Block*, and *Complete Streets*.[45,46] Small-scale structural recovery is observed in urban planning and renewal subsequently.[11,43] For example, the smallest residential block in the Brasilia Plan (1956) was 200 m × 280 m, and several of them were combined to make a 960 m × 720 m neighborhood unit. It may be noticed that although the block scale of contemporary cities is expanding, small-scale neighborhoods are returning (Table1).

In China, policymakers paid attention to the dual significance of space and people early in the urban construction process, leading to the evolution of the block scale. The scale of the block started to converge with western development with the relaxation of the identity system attached to the land after experiencing the Li-fang system (a complex of the basic unit of urban and rural planning and the residential management system in ancient China), the Street system (Song Dynasty, before 1279), the Hutong system (modern times of China, 1840–1949), and the Lilong system (Republic of China, 1912–1949). The term "Li-fang" refers to a community that is one mile square (about 415 m per square meter in the Tang Dynasty), with a typical Li-fang being roughly the same size as the present-day neighborhood. Hutong, the term

Table 2. Block scale in representative cities in China

Time	City	Shape	Scale (M)
7th century B.C. (The Xia Dynasty to the early years of Spring and Autumn Period)	Royal city of West Zhou	Square	240 × 240
6th century B.C. to 1th century A.D (The Spring and Autumn Period to the Han Dynasty)	Royal city of West Chu	Rectangle	1500 × 1500
	Chang'an (West Han)	Square	300 × 300
			900 × 900
	Luoyang (East Han)	Irregular Rectangle	(400–500) × (500–1200)
	Yecheng (Eastern Han Dynasty)	Square	250 × 250
	Luoyang (Northern Wei Dynasty)	Square	440 × 440
1th century A.D. to 19th century A.D (The East Han Dynasty to the Qing Dynasty)	Chang'an (Sui and Tang Dynasties)	Rectangle	(515–797) × (515–955)
	Luoyang (Sui and Tang Dynasties)	Square	440 × 440
	Yangzhou (Tang Dynasty)	Rectangle	300 × (450–600)
	Kaifeng (Song Dynasty)	Irregular Square	(120–240) × 240
	Suzhou (Song Dynasty)	Irregular Rectangle	(70–100) × (70–100)
	Beijing (Yuan Dynasty)	Rectangle	500 × 900
	Beijing (Ming Dynasty)	Rectangle	500 × (500–700)
	Shenyang (Qing Dynasty)	Square/Rectangle	(350–700) × (350–700)
20th century A.D to the present	Wangjing district, Beijing	Rectangle/Free-form	400 × (400–600)
	Suzhou new district, Suzhou	Square/Rectangle	(70–100) × (200–500)
	Ancient area of Suzhou, Suzhou	Irregular Rectangle	(70–100) × (70–120)
	Dacisi, Chengdu	Irregular Rectangle	(100–150) × (100–150)
	Qinhuai District, Nanjing	Rectangle/Free-form	(70–120) × (70–200)
	Hexi Distiect, Nanjing	Rectangle/Free-form	(50–120) × (100–500)

used by the Mongolian people to describe streets and alleyways, later came to be used to refer to all streets and alleys in the north. By 1944, there were approximately 3300 hutongs in Beijing. These hutong systems played a pivotal role in dividing urban blocks and attaining a pleasant scale within Beijing's historic urban region.[47–49] However, due to the influence of the Soviet Union and European-American models, a large number of large scaled blocks were built for office and enterprise staffs, and closed communities were formed in many cities from the beginning of the People's Republic of China to the 1990s.[12] With the implementation of the block system in China after 2016,[5] it is emphasized that the open layout mode shall be adopted within the appropriate and reasonable geographical range enclosed by urban roads to share and integrate the public resources and functions within the geographical range with the city, and create a dynamic block[50,51] (Table 2).

The scale of urban block

It has been observed that a variety of factors, including politics, the economics, technology, and others, have an impact on the blocks with the development of the city. At the block scale, certain factors can be further divided into numerous sub-factors, each of which performs independent or collaborative actions. Numerous academics have discussed the block scale from different perspectives, contributing concepts as well as data for this study.

From the perspective of Sociology, contemporary urban planning promotes zoning policies that diminish the significance of mixed-use, small-scale blocks, and open spaces, resulting in the degradation of the city's diversity (Jacobs, 1961). Urban development affects both block size and layout.[52] To address the complexity of urban built-up areas and the construction of small-scale blocks, Jacobs proposed four strategies: preserving old homes as locations for conventional small and medium-sized businesses; maintaining a high residential density to create complex needs; increasing the number of small businesses along the street to increase street activities; and reducing the size of street blocks to foster greater resident interaction. The minimal scale of a block is 40–50 m, and if traffic is taken into account, it is 60 m.[53,54] From the perspective of external space, the optimal size for external space is 50–100 m, while block should be within 500 m.[55] The study of New Urbanism advocates for the construction of communities on a pedestrian scale, aiming to establish interconnected street networks that foster the growth of complete and well-rounded pedestrian neighborhoods, providing a platform for various urban activities.[56] The Traditional

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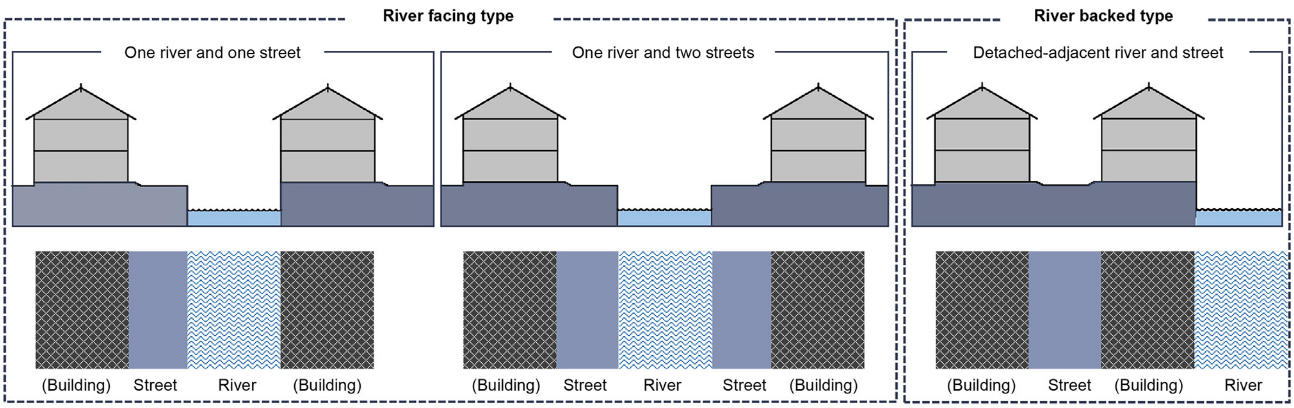

Figure 1. Typical river-street pattern in the Jiangnan area

Neighborhood Development (TND) model, for example, emphasizes the construction of residential communities based on walking distance, with a community size restricted within a radius of around 400 m, or a 5-min walking distance, implying that a road network ranging from 70 to 100 m is considered reasonable and appropriate.[57] From the perspective of Open Blocks, a block with good neighbors should have a spatial range of 150 m, or a land use area of 4 ha.[58] From the perspective of practical exploration in Europe, it is noted that the most important criterion in deciding the scale of a block area in a sustainable city is perimeter, and big ones can be cut into numerous smaller ones.[59] They argued that the block scale in conventional European cities, which is 70–100 m in length, is the proper scale for urban blocks. From the perspective of urban efficiency, 90 significant cities, in both China and outside, were statistically investigated to determine the appropriate block scale. When combined with the tendency of growing block scales in urban construction in China, the ideal block scale in China is 150–200 m. It can be seen that the scale of ideal block is constantly changing due to the influence of conditions and regions, but it is generally concentrated within a range of 60–500 m. This quantitative indicator can be used as a general criterion for determining the suitability of block scales and as a guide for designing the right block scale in urban design.

As one of fundamental function of city, traffic occupies pivotal position in development of city, and arterial roads are frequently used as block borders. The density of planned road networks impacts how urban land resources are used objectively. In recent urban development of China, the relationship between urban road network density and urban scale has been widely acknowledged, with varied construction criteria proposed in *Code for Transport Planning on Urban Road* (GB50220-95).[60] Overall, small and medium-sized cities have a higher benchmark setting for road network density than major ones. The density of the road network in southern cities (6.9 km/km^2) is generally higher than in northern cities (5.3 km/km^2), and the density of the road network in cities with cluster-shaped spatial structures is higher than in cities with agglomerate-shaped and belt-shaped spatial structures(T/CECS 377–2018).[60] According to the recent three-year *Annual report on road network density and traffic operation in major cities in China* (CAUPD),[61] the average density of 6.4 km/km^2 is slightly increased compared to the average density of 6.2 km/km^2 in 2020, but there is still a significant gap from the goal of achieving a city road network density of 8 km/km^2 set in the 2016.[5] Nevertheless, given the highly collaged condition of the urban built-up area, the scale and structure of the block update path require more precise scientific analysis to advise, therefore this study will refer to the common road network scale for group debate, and seek the best scheme via comparison.

Urban renewal backgrounds and the study area

Connotation and backgrounds of Jiangnan

In Chinese, the word "Jiangnan" conjures up images of a city with bridges, waters, rivers, and streets. The unique spatial features of "land and water" and "river and street" in Jiangnan cities reflect the response trend of urban blocks to the development of the times and functional changes in the process of long-term growth and expansion, which can help understand and define the space-society order of blocks.[1,40] Until now, developed cities such as Suzhou have retained a characteristic spatial pattern of "river and street" isomorphism, emphasizing the regional characteristics and cultural charm of cities to the southern reaches of the Yangtze River.[2,8] In the Ancient City Area of Suzhou, water network, streets, and buildings form the repetition and combination of three spatial elements, "river", "street", and "building", along the direction of the water system, and evolve into representative spatial patterns (Figure 1).

(1) One river and one street pattern (River facing type): It refers to the street on one side of the river and the buildings on the other side of the river. This spatial mode mostly appears on the secondary river channel. In the Jiangnan area, the public wharves are often set on the roadside of the river channel, while the private wharves are usually set on the building side.
(2) One river and two streets pattern (River facing type): It denotes a spatial layout of "street-river -street" where buildings are located outside the streets and streets are on both sides of the river. The major river channel is where this spatial pattern is most prominent, making it simple to switch between water and ground transit. On each side of the river channel are public wharves, and the majority of

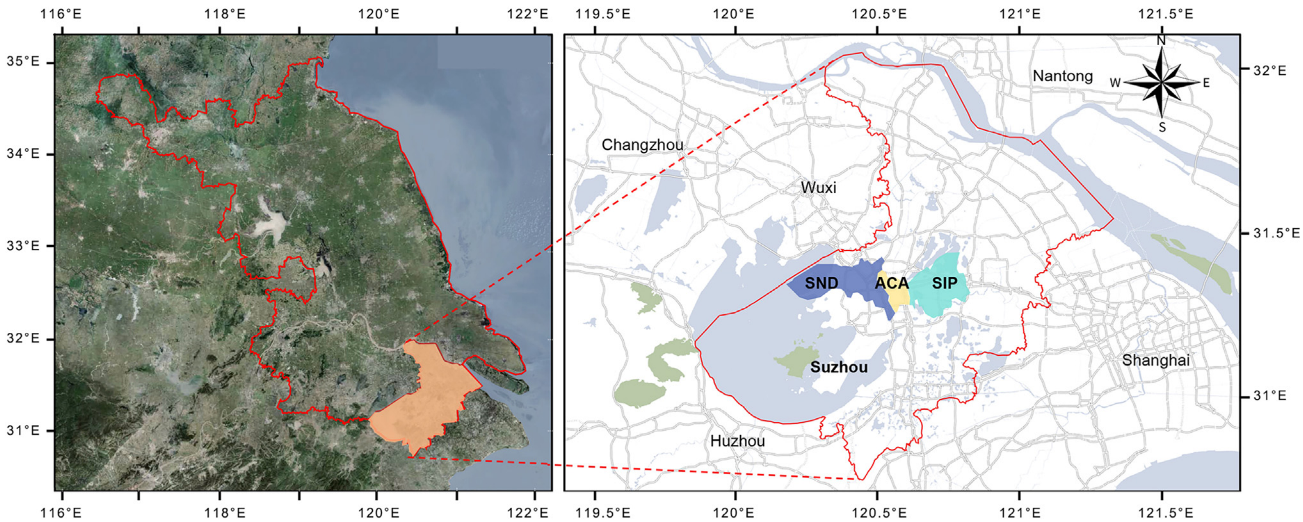

Figure 2. Location of Suzhou and SND, ACA, and SIP

the structures along the roadway are businesses. The structures that line the street are often front stores, back factories, front shops, and back dwellings. On one side of the roadway, there are arcades or corridors that make it easier to stroll.

(3) Detached-adjacent river and street pattern (River backed type): It means that the buildings are arranged in the form of a "building-river- building", with streets or other roadways placed outside the structures. The building's proximity to the river on one side in this spatial model makes it easier to carry goods by water. It can also be used for commerce on the other side of the street, creating a spatial shape of the front street and rear rivers.

Status of Suzhou and study area

Similar to the majority of cities in Jiangnan area, Suzhou's growth and development is primarily centered on the water, showcasing the geographical evolution of block growth in relation to the expansion of the waterway network. As a result of the diverse development time series of each urban region in the Suzhou metropolitan area, three unique urban forms have arisen (Figure 2): the central Ancient City Area (ACA, Gusu District), the eastern Suzhou Industrial Park Area (SIP, Gusu District), and the western Suzhou New District (SND, Huqiu District).

The Ancient City Area (ACA, Gusu District) of Suzhou formed a water network system of "three horizontal, four vertical and one ring", which profoundly influenced and guided the growth of blocks (Figure 3). It has formed 54 neighborhoods in the Song Dynasty, and "water-land chessboard" block pattern of "small scale, dense road network" has a high vitality up to now.[41] The organic organization mode of the block, external space and the waterway network can provide a reference for the reconstruction of small blocks, and also is an internal requirement for its structural form maintenance.[62] As a prime example of modern urban planning, the Suzhou Industrial Park Area (SIP, Gusu District) takes full advantage of Singapore's New Town's planning experience, particularly the Town-Neighbourhood-Precinct-Block-Apartment hierarchical structure. It also integrates the residential planning characteristics of China with the specific conditions of the area to create a distinct and comprehensive urban framework.[41,63]

In comparison to the "land-water double checkerboard" spatial structure in ACA, most area of SND has experienced fast urbanization, resulting in complex and diverse functions and forms of urban blocks. The road network of SND is discovered to be unevenly distributed, and the core shape of the spatial organization is restricted. This is closely related to the lack of systematic branch roads in the road network and the excessive size of local blocks, according to structuralism's view of urban block scale and road network.[64,65] In addition to some large-scale open commercial land, there are a large number of closed residential areas (including a large number of large-scale and well-located resettlement communities built during the city's rapid expansion), closed factories, schools, administrative units, and so on. This collage texture is created by intertwining and functionally interlacing large closed clusters or blocks. To realize the reconstruction of small blocks, it is required to combine scientific design methodologies with flexible policy guidance.

The study area encompasses the Taihu Avenue Viaduct in the north, the Sufu Highway in the south, the Central West Line in the west, and the Beijing Hangzhou Grand Canal in the east (Figure 4). It contains the traditional geographical characteristics of a crisscrossing river network, with a significant proportion of green space, waterfront space, and so on. However, following the rapid urbanization process, the early industrial plants in the study area were surrounded by residential blocks, and the large-scale closed blocks disrupted the water network and caused the texture to fracture. Therefore, to reshape the block scale and enhance the openness of each block, the internal renewal of the study area and the implementation of the block system require scientific guidance. It also implies the internal demand for repairing the waterway network system, restoring the urban fabric, and enhancing the quality of life in accordance with the regional characteristics.

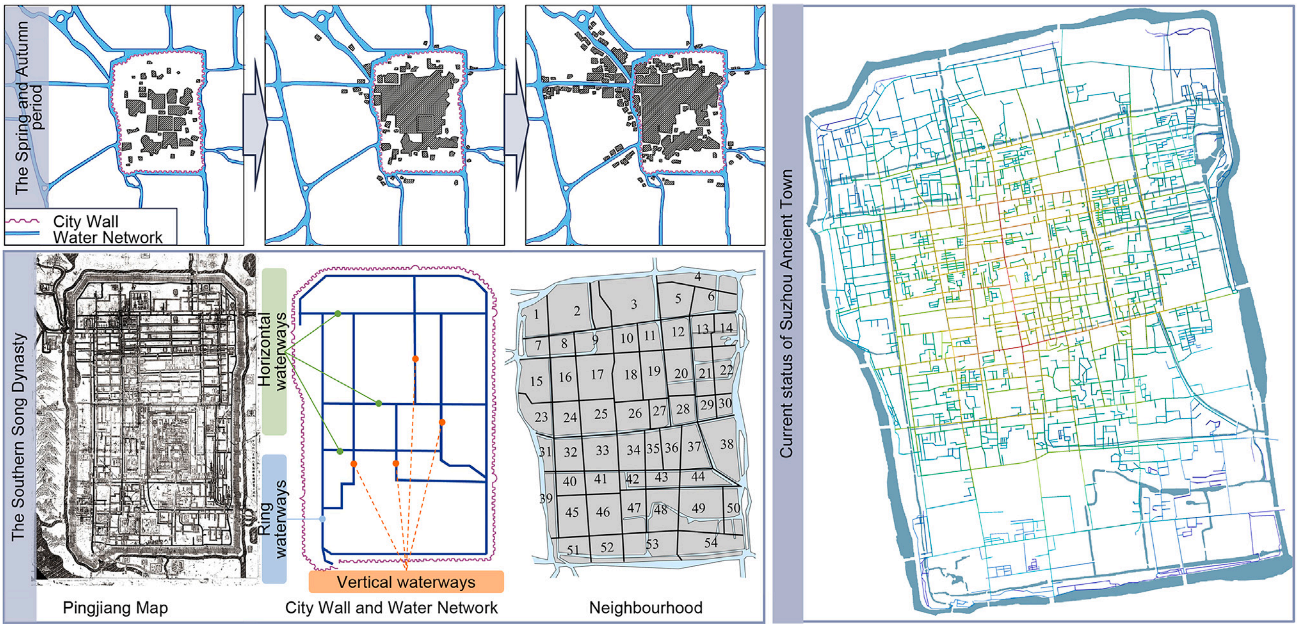

Figure 3. Urban development trace of the of Suzhou ACA (Ancient City Area)

Block scale reference system of the study area

To explore the possibility of block scale reconstruction further, the research must abstract the road network within the research scope—the main dividing medium of block scale—establish a reference road network system, and combine research and unplanned requirements to set a target road network, providing scientific reference for subsequent quantitative research.

The study team conducted statistical comparisons on the main road networks and block scales in the typical areas of ACA, SIP, and SND, abstracted and summarized the current street scales, and discussed the appropriate street scales (target scales) in urban renewal in accordance with the planning requirements. Preliminary research findings indicate that the ACA is primarily comprised a road network ranging from 100 to 200 m in length, with local small-scale blocks measuring 50 m and a few closed blocks.[62] The planning and layout of SIP adheres to a distinct hierarchical framework, consisting of four levels: regional, zoning, neighborhood, and cluster. The blocks are highly open, except for a few companies and research facilities. Despite the significant scale variation between the blocks within the main region of the SIP, ranging from 60 to 600 m, the majority of them are 100–200 m scale blocks.[41] In terms of scale, functionality, openness, and other core regional elements, the study area of SND exhibits a typical collage tendency. The block scale ranges from 50 to 600 m, with several closed blocks located in the central region, but blocks with a scale of 400–500 m predominate.[42] As a result, this study built a reference system based on the general state of the block scale in the study area, which mostly consisted of a 500 m road network. Based on the small scale of the ACA and SIP and taking into account relevant study data of small-scale blocks, a preliminary target scale system of 100 m, 200 m, 300 m, and 400 m was constructed.

However, it is crucial to take into account specific planning requirements and the block scale of representative cities when choosing the target scale (T/CECS377-2018).[66] According to the *Standard for Green Urban Area Planning and Construction*,[67] the average block scale of a commercial office should be within 150 m; the size of a residential block is determined by the density of the branch road network and the appropriate overall development scale, and the average block size should be within 250 m; the size of an industrial block is determined by the production needs of relevant industrial sectors, and the general block size should be within 250 m. As a result, the average urban road network density should be larger than 10 km/km^2, and the road area ratio will greater than 15%. Therefore, it is suggested that the 500 m road network be used as a reference for the existing block scale in the quantitative calculation process of this study, taking into account the current situation of small-scale blocks such as the ACA as well as the complexity of the functional composition of the research samples within the core area of the high-tech zone. 100 m road network and 200 m road network have been selected as reference target scales in reference to the size of the major open small blocks in contemporary cities.

RESULTS

Potential analysis of implantation

Framework and of block unit

This study provided a block-framework based on the interconnection of blocks, road networks, and water networks (Figure 5). The spatial pattern of the water and road network is highly coincident with the block unit, while the land use function within the sample range is complex. The industrial land is concentrated in the northwest, the residential distribution presents two obvious centers, representing an unequal

Figure 4. Status of the study area in Suzhou New District (SND)

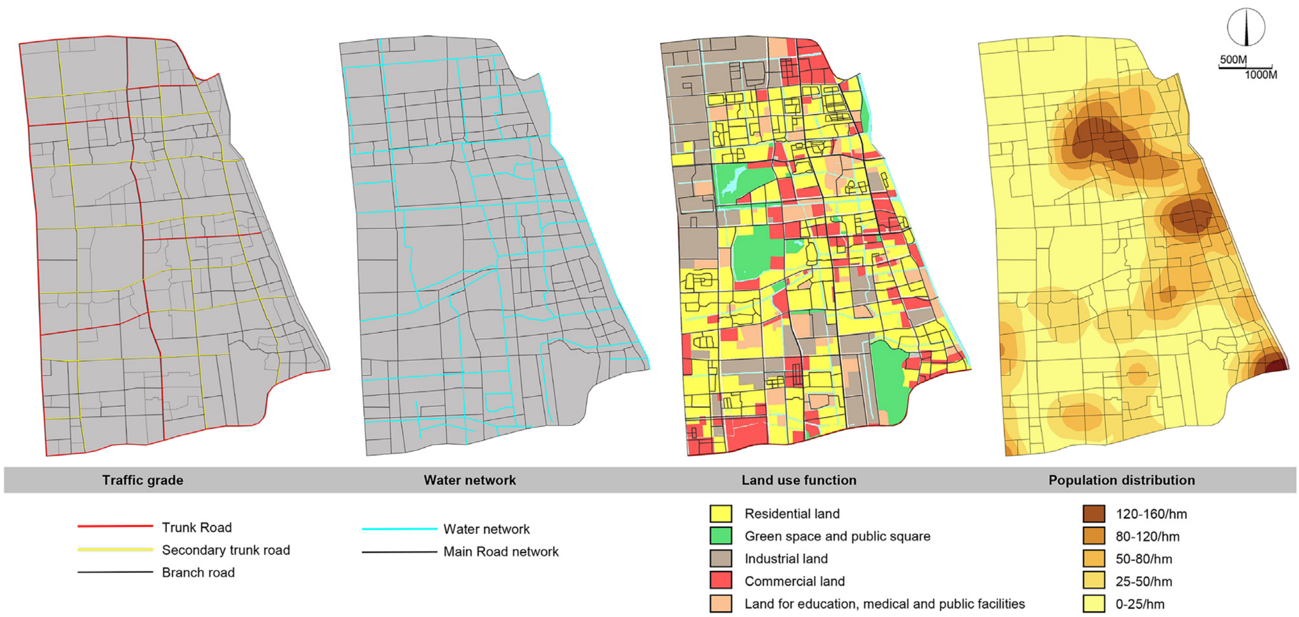

Figure 5. Basic data in the study area

distribution of blocks, excessive scale, fracture of the river-road link. There is also less coupling between the road system and water network. To prepare for further analysis and evaluation, this approach must be combined with data integration to generate a highly connected framework of the present block boundary. Moreover, the open property of the block needs to be evaluated in connection with the field survey.

The degree of openness of a block varies according to its land use, the functional character of its buildings, management approaches, and so on.[58] The land use of the study area is divided into three types based on the land use nature and the principal building function (Table 3). For example, the industrial land are mostly under closed management, marked as closed block, the residential district with closed management is also marked as closed block, and the block mainly for direct external office, business and apartment is marked as open block. Given that many blocks typically contain different types of land, if the open area in the block hits 50%, the block's overall characteristic will be classed as open. Due to the fact that the land use of the undetermined type only involves residential land (R) within the study area, its openness can be determined by investigating its management methods. Therefore, the study area are divided into 145 block units taking into account urban management division, community organization, overlay analysis of the water network, land use function, and population distribution. And the 145 block units are divided into open and closed blocks based on its functional attributes and management (Figure 6).

Certain block units with widths more than 500 m are designated as large-scale closed in addiction according to the *Standard for Green Urban Area Planning and Construction*.[67] Although the land use function within the sample range is diverse, it is discovered that many residential areas and industrial land are under closed management, resulting in a large number of closed blocks. In particular, of the 145 block units in the sample range, 43 are open blocks, accounting for 29.7%; 102 are closed blocks, accounting for 70.3%. Particularly, there are 21 large-scale closed blocks among the closed units, accounting for 14.5%.

Potential analysis of implantation

To analyze the implantation potential of each type of external elements, the factors of the four types are load into the block-framework. Examine whether these elements can be turned into an implantable element and implanted into the target road network via connection (connection with the road network), expansion (expanding based on the existing form and coupling with the road network), and activation (participating in street activities through form, function transformation, etc.). A database of implantable external elements in the study area can be established.

Then, the degree of impact following implantation of four types can be examined in the model of "Potential analysis of implantation". In general, the water network element, 200 m road network element, and boundary element have significant potential, followed by the open space element. Conversely, the 500 m road network element has the smallest potential. However, despite the significant potential of the 100 m road network element, it could potentially cause severe fragmentation of the block structure (Table 4).

(1) Potential analysis of implantation (Open space type)

Figure 7 illustrates the potential analysis of open space element. There are a considerable number of open space components in the study area, and the distribution is relatively even. The abundance of existing access points makes it easy to connect to the urban road network. However, the distribution of large-scale open space among them is imbalanced, and the number of existing entrances and exits is limited. To ensure

Table 3. Classification of urban land use and its characteristic

Category of land use		Open/Closed	Characteristic
R Residential Land		Undetermined	Mainly closed, depend on the management.
A Land for public administration and public service	A1	Undetermined	Administrative office land: Carrying public service but may not open, depend on the management.
	A2	Open	Cultural facilities land: public-open.
	A3	Undetermined	Land for educational and scientific research, mainly closed
	A4	Open	Sports land
	A5	Undetermined	Land for medical and health Depend on the management.
	A6	Closed	Land for social welfare facilities.
	A7	Open	Heritage sites
	A8	Undetermined	Land for foreign affairs
	A9	Undetermined	Religious facilities land: open to specific population
B Commercial and business facilities		Open	Commercial
M Industrial Land		Closed	Closed land use
W Logistics and warehouse land		Closed	Closed land use
S Street and transportation land	S1	Open	Urban street land: Public-open
	S2	Undetermined	Land for rail transit: depending on the specific project
	S3	Open	Integrated transport hub: public-open
	S4	Closed	Transport station land
	S9	Undetermined	Other transportation facilities
U Municipal utilities land	U1	Closed	Supply facility land
	U2	Closed	Land for environmental facilities
	U3	Closed	Land for safety facilities
	U9	Closed	Other utility sites: Carrying public service but not open
G Green space		Open	Green space

connectivity with the urban traffic network and minimize any undue interference with the park's green space, it is essential to establish appropriate entrances and exits for large-scale open space elements. For example, in the A12 block, the Park of SND, and Heshan Park each have 2 entrances in use under independent administration (2 access between the two parks and 2 entrances of Park of SND are currently closed). In such cases, the rise in entrances and exits can be combined with management to enhance the interaction between the internal roadways according to *Code for classification of urban land use and planning standards of development land* (GB50137-2011) and *Standard for Green Urban Area Planning and Construction.*[67,68] The entrances and exits of parks along the main road and secondary road should be consistent with urban traffic as well as tourist orientation and flow. A20, formerly known as Theme Park of Suzhou, is now fully operational in tandem with the revitalization of surrounding communities, and positive social evaluation and spatial benefits have been attained. In general, it is discovered that the implantation operation can cover 38 block units, with 42% of large-scale closed blocks covered. The implantation of these elements has a significant effect on closed residential blocks, but has little impact on large-scale industrial land which lacking such space element.

(2) Potential analysis of implantation (Water network type)

Figure 8 illustrates the potential analysis of water network element. There are numerous water network elements in the study region with balanced distribution, and the block pattern is closely related to the water network system. There are 107 block units that are adjacent to water bodies or are crossed by water networks, accounting for 73.8% of the total. It is evident that the pertinent water network elements possess certain quantitative advantages. However, the water network cannot be linked directly to the road network. It must be connected to the existing road

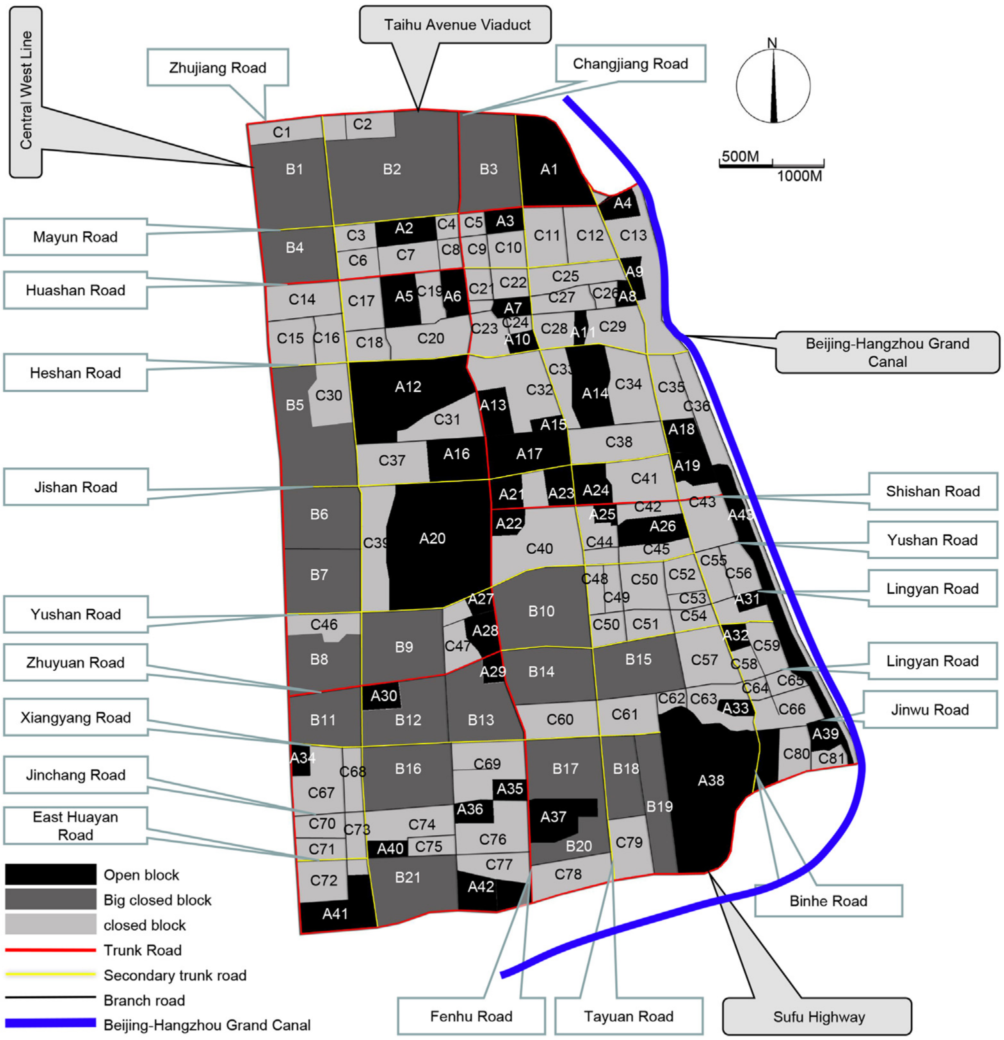

Figure 6. Basic data in the study area (Block units and traffic grade)

network via roads parallel to the water body or bridges perpendicular to the water body, in conjunction with waterfront space. The potential analysis provides association paths based on the river-street pattern, which are then loaded into ArcGIS for superposition. It has been discovered that the implantation of water network elements can be adaptable to all types of closed blocks, covering 86% of large-scale closed block units.

(3) Potential analysis of implantation (Unit boundary type)

Figure 9 illustrates the potential analysis of unit boundary element. Under the current management conditions, boundary elements refer to the boundary corridors and secondary roads of each unit in the block that are not connected to urban roads. Within the study range, there are

Table 4. Potential analysis of implantation

Element type		Distribution of implantable element	Block quantity with implantable element	Operable units in total blocks	Operable units in Large closed blocks
Open Space type		Relatively balanced	38	26%	42%
Water Network type		Relatively balanced	107	74%	86%
Unit Boundary type		Relatively balanced	61	42%	81%
Road Network type	500 m scale	Discrete	42	30%	29%
	200 m scale	Relatively balanced	100	69%	95%
	100 m scale	Dense	129	89%	95%

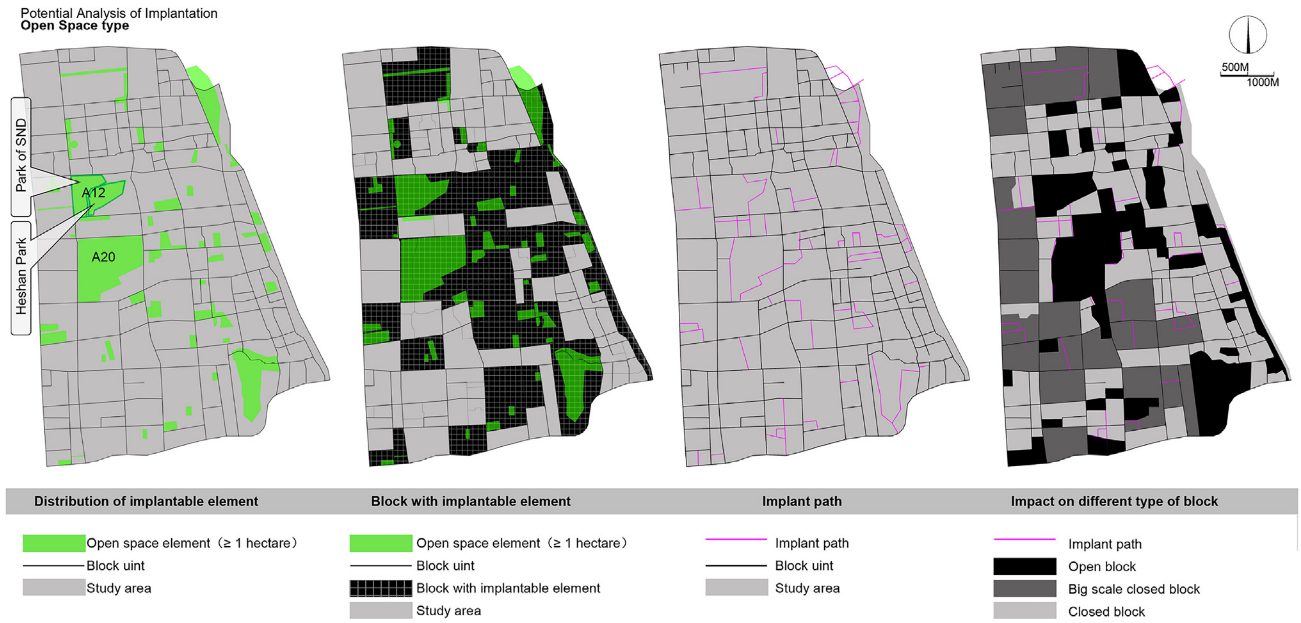

Figure 7. Potential analysis of open space element

a large number of boundary elements of the internal cluster, which are significant and evenly distributed in the large-scale blocks and closed blocks. Through simple management and adjustment, these elements can be connected to the urban road network. In accordance with the *Code for classification of urban land use and planning standards of development land* (GB50137-2011),[68] certain units unsuitable for implant operation have been eliminated, including B7 and C46, which are unable to be opened due to their functional characteristics and closed management mode. Therefore, there are 61 block units that can implant unit boundary elements, accounting for 42% of the total. The implantation approach is proved to be effective in the reconstruction of 81% of large-scale closed blocks, particularly in industrial land and closed residential blocks, by simulating the implantation path in ArcGIS.

Figure 8. Potential analysis of water network element

Figure 9. Potential analysis of unit boundary element

(4) Potential analysis of implantation (Road network type)

Figure 10 illustrates the potential analysis of road network element. The road network comprises numerous and uniformly distributed elements, which necessitate a combination of grading and screening in accordance with the target scale. It is necessary to analyze its reasonable scale in the simulation and calculation. On the 500 m road network scale (corresponding to the larger scale of the block), there are 42 units available for implant operations, accounting for 30% of the total block units, and cover 29% of large-scale closed block units. On the 200 m road network scale (corresponding to the common scale of the small block), there are 100 units capable of performing implant operations, accounting for 69% of the total block units, and cover 95% of large-scale closed block units. There are 129 units capable of performing implant operations on a road network scale of 100 m (equivalent to the smaller scale of the small block), accounting for 89% of the total block units, and covering 95% of large-scale closed block units. It should be pointed out that, the scale of the road network is inversely proportional to the density, and high road network density means that the number of intersections in the region increases. The scale of the road network must be discussed in light of the current situation and should be further examined in conjunction with the comparative quantitative reconstruction study.

Implant-reconstruction comparison

The topological structure and mathematical relationship model of Space Syntax are employed in the quantitative analysis, revealing the spatial relationship in block and vitality characteristics. The calculation radius under each parameter is: r1 = 400 m (referring walking range for 5 min), r2 = 800 m (referring walking range for 10 min), r3 = 1200 m (referring walking range for 15 min or cycling range for 5 min), r4 = 2500 m (referring cycling range for 10 min), r5 = 3750 m (referring cycling range for 15 min). Due to the significant variations in motor vehicle travel, reference values of r6 = 5000 m and r7 = 10000 m are employed. To minimize interference, the computation is not stretched to the scale of cars as this study focuses on the implantation influence of everyday activities and the block structure. There are many parameters for Space Syntax calculation, but the integration, choice, and total segment length (TSL) are representative in terms of block structural change, traffic efficiency, and road network density. The results and interpretations of these three calculations are as follows. Along with comparing the numerical values of various types of parameters and two-dimensional images, the rate of change is added for further feasibility comparison in order to more clearly compare the potential effects of changes in various parameters after implantation and reconstruction. The rate of change following the implantation of external spatial elements demonstrates the susceptibility of urban blocks to various external spatial elements during the operation process (different calculation radii can reflect the features under varied travel conditions).

$$\text{Vi-x} = \frac{i - x}{i - 0} \times 100\%$$

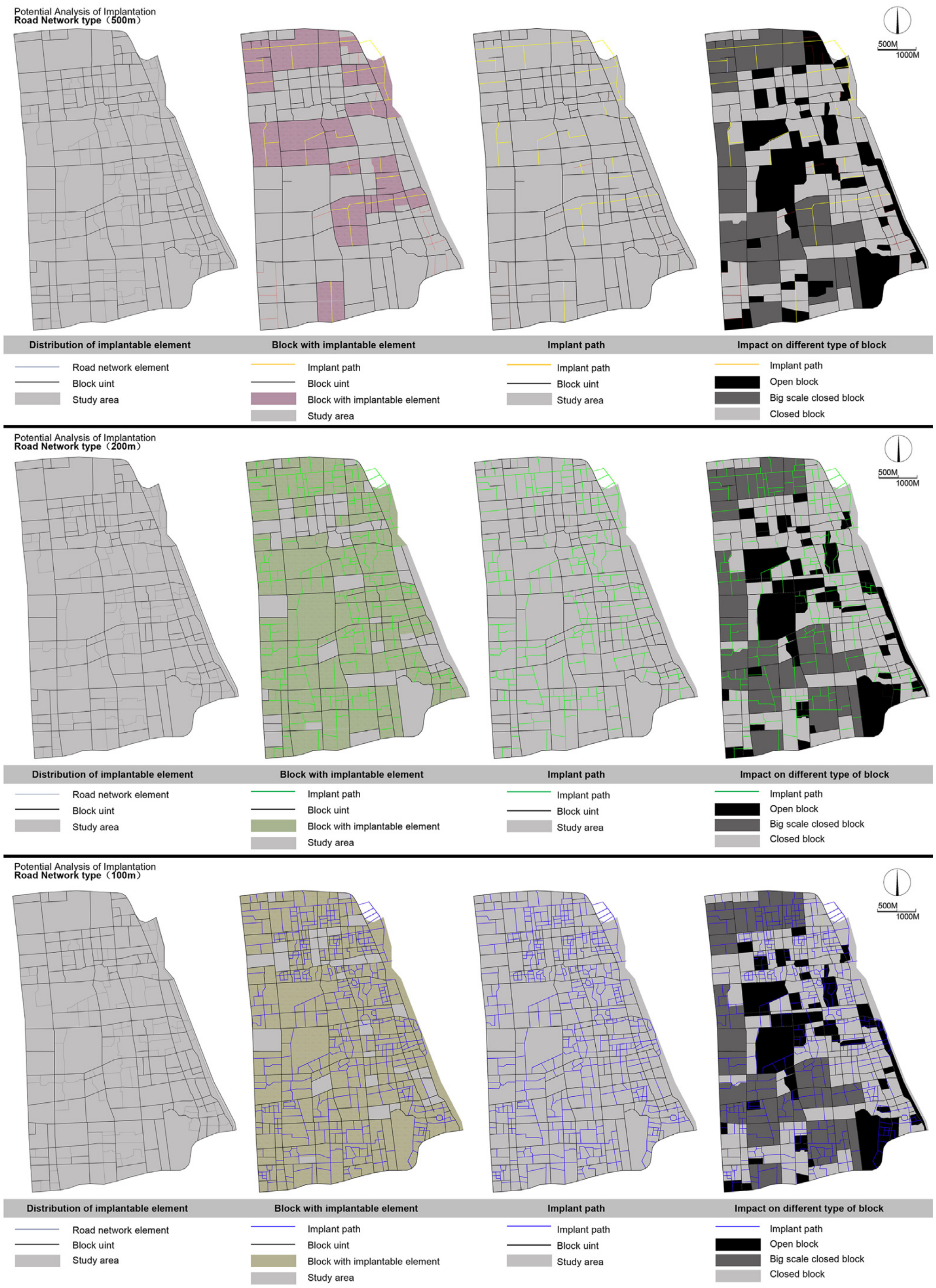

Figure 10. Potential analysis of road network element

$$\text{Vc-x} = \frac{c - x}{c - 0} \times 100\%$$

$$\text{Vtsl-x} = \frac{\text{tsl} - x}{\text{tsl} - 0} \times 100\%$$

Table 5. Integration variation

Items		Implantation elements	Value/Change rate under different calculation radius						
			r = 400m	r = 800m	r = 1200m	r = 2500m	r = 3750m	r = 5000m	r = 10000m
Integration value (Status quo)	i-0	–	11.5923	17.53	26.7306	66.332	104.706	138.514	194.785
Integration value after Implantation	i-1	Open space	12.4275	20.3956	32.5478	85.2701	140.161	188.7	258.293
	i-2	Water network	12.9601	24.1454	40.8229	113.115	187.353	247.217	328.53
	i-3	Unit boundary	12.9949	24.2984	40.501	109.226	178.905	239.161	342.576
	i-4	500 m road network	11.4926	16.8984	25.6477	66.9482	109.981	145.504	199.957
	i-5	200 m road network	14.3053	28.8036	49.2228	137.825	229.569	309.313	431.632
	i-6	100 m road network	19.0084	42.9923	76.4181	218.956	358.797	483.513	682.266
Integration Variation (Vi-x)	Vi-1	Open space	107.20%	116.35%	121.76%	128.55%	133.86%	136.23%	132.60%
	Vi-2	Water network	111.80%	137.74%	152.72%	170.53%	178.93%	178.48%	168.66%
	Vi-3	Unit boundary	112.10%	138.61%	151.52%	164.67%	170.86%	172.66%	175.87%
	Vi-4	500 m road network	99.14%	96.40%	95.95%	100.93%	105.04%	105.05%	102.66%
	Vi-5	200 m road network	123.40%	164.31%	184.14%	207.78%	219.25%	223.31%	221.59%
	Vi-6	100 m road network	163.97%	245.25%	285.88%	330.09%	342.67%	349.07%	350.27%

Integration variation (Vi-x) and interpretation

The value of integration represents the level of aggregation and dispersion of the elements within the spatial system. The larger the integration value, the more accessible and central the region becomes. To some extent, the integration value can, reflect the distribution of the core range in the spatial structure of the study area. Comparing with the variation of choice value (Vc-x) and the variation of TSL value (Vtsl-x) with varying radius parameters, the variation of the integration value (Vi-x) is found to be smaller and spatial balanced. The gradient of the variation of integration is:

Vi-6 (100 m road network)≫Vi-5 (200 m road network)>Vi-2 (water network)≈Vi-3 (unit boundary)>Vi-1 (open space)>Vi-4 (500 m road network)

Table 5 and Figure 11 illustrate the variation of integration (Vi-x) after the implant operation. The results indicate that implant operation of 100 m and 200 m road network elements can significantly improve the spatial efficiency of the block, and the integration variation after the implantation of water network and unit boundary elements closely follows. The highlighted area of integration frequently reflects the structural center of the study area. The highlighted area shrinks after the implantation of 500 m road network elements, and the highlighted area shifts to the north after the implantation of 100 m road network elements. After the implantation of other elements, the integration degree highlight area in the study area exhibits a trend of balanced expansion, particularly after the implantation of water network elements, where the highlighted area exhibits a "#" shaped expansion. The computation results reveal that all types of external element contribute significantly to the spatial efficiency. The role of 100 m road network elements is crucial, but the core area after implantation is drifting. There are balanced expansion of "#" shaped as well as "丰" shaped after the water network elements and 200 m road network elements are implanted, indicating that the implantation relying on the 200 m road network elements and water network elements plays a significant role in improving the spatial efficiency steady and evenly.

Choice variation (Vc-x) and interpretation

The choice value indicates the frequency of the shortest path superposition and the least turning point selection between system nodes, as well as the street's crossing attraction. The overall choice value has improved after each type of external element has been implanted under varied radius parameters, and the change range of choice after the implantation of 100 m road network is significantly higher than that of other types of elements:

Vc-6(100 m road network)≫Vc-5(200 m road network)>Vc-3(unit boundary)≈Vc-2 (water network)>Vc-1 (open space)>Vc-4 (500 m road network)

Table 6 and Figure 12 illustrate the variation of choice (Vc-x) after the implant operation. It demonstrates that the small-scale road network elements play a leading role in the improvement of choice. The highlighted area of choice did not significantly sway after the implantation of four types of external elements, indicating that these changes were relatively mild rather than subversive and that the implantation of external elements works well in promoting the space attraction. It should be noted that, despite the enormous rise between 100 m and 200 m, the distribution of the center form has not changed noticeably within this range. The spatial structure adjustment is clearly visible when the unit boundary and water network elements are implanted. Overall, after the implantation of external elements, the highlighted area is distributed discretely according to the choice value. This demonstrates that different elements have varied spatial

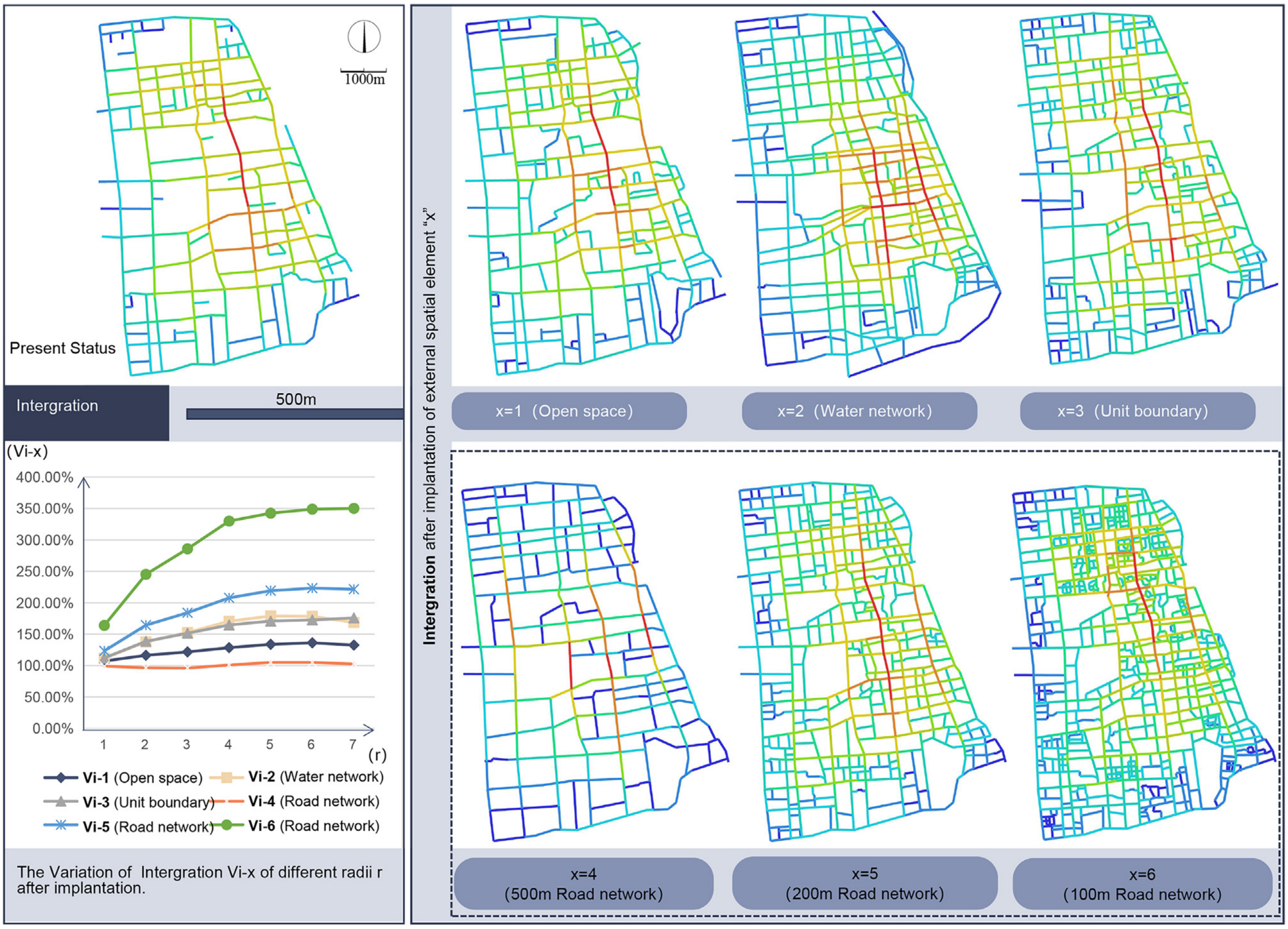

Figure 11. The variation of integration (Vi-x)

impacts, implying that a complementary combination of elements might be considered in the operation process to improve the balanced development of the block.

Total segment length variation (Vtsl-x) and interpretation

The TSL represents the length of the street axis within various radius ranges, and is directly proportional to the density of the road network. It effectively highlights the dominance and centrality of a location. The calculation results show that after each type of variable elements is implanted, the TSL is relatively balanced under different radius parameters:

Vtsl-6(100 m road network)≫Vtsl-5(200 m road network)>Vtsl-2(water network)>Vtsl-3 (unit boundary)>Vtsl-1 (open space)>Vtsl-4 (500 m road network)

Table 7 and Figure 13 depict a comprehensive variation of TSL (Vtsl-x) after the implant operation. It demonstrates that the density of the road network has increased following the implementation of each type of element. After implantation, the highlighted area of TSL expanded steadily rather than leapfrogged, indicating that the implantation of four types of external elements played a role in promoting the improvement of space attraction, and these changes were relatively mild rather than subversive. After the water network and unit boundary elements are implanted, the core structure expands relatively significantly, indicating that there are enough external elements to support the reconstruction of small blocks and may promote possible social interaction. However, the scope of the highlighted area is too concentrated after the implantation of external elements relative to the 100 m road network, indicating that the 100 m road network may be too dense in reality, which is not conducive to the spatial efficiency of the block.

Paired T-test

The study implemented a paired t-test, wherein each category of element was paired as the experimental group (Open space, Water network, Unit boundary, 500 m road network, 200 m road network, 100 m road network) with the control group (Original road network), to validate the

Table 6. Choice variation

Items		Implantation elements	Value/Change rate under different calculation radius r = 400m	r = 800m	r = 1200m	r = 2500m	r = 3750m	r = 5000m	r = 10000m
Choice value (Status quo)	c-0	–	1.84716	19.2642	66.8886	461.976	1137.66	2107.41	4275.91
Choice value after Implantation	c-1	Open space	4.04401	34.5159	111.942	817.408	2100.03	3816.71	7266.82
	c-2	Water network	4.66463	49.5386	162.296	1166.87	3004.21	5153.98	8867.64
	c-3	Unit boundary	5.58286	53.6708	174.168	1211	3113.28	5615.53	12386.2
	c-4	500 m road network	1.23043	15.0022	55.7472	438.698	1152.64	2020.17	3796.15
	c-5	200 m road network	9.47595	87.0258	274.47	1935.77	5092.24	9334.46	19428.9
	c-6	100 m road network	36.5845	261.256	806.206	5206.57	12747.7	22754.3	47368.9
Choice Variation rate (Vc-x)	Vc-1	Open space	218.93%	179.17%	167.36%	176.94%	184.59%	181.11%	169.95%
	Vc-2	Water network	252.53%	257.15%	242.64%	252.58%	264.07%	244.56%	207.39%
	Vc-3	Unit boundary	302.24%	278.60%	260.39%	262.13%	273.66%	266.47%	289.67%
	Vc-4	500 m road network	66.61%	77.88%	83.34%	94.96%	101.32%	95.86%	88.78%
	Vc-5	200 m road network	513.00%	451.75%	410.34%	419.02%	447.61%	442.94%	454.38%
	Vc-6	100 m road network	1980.58%	1356.17%	1205.30%	1127.02%	1120.52%	1079.73%	1107.81%

analysis indicated previously. Six sets of data values were compared after each element was implanted under the parameters of integration, choice, and TSL. The correlation analysis proves that all factors in the experimental group are correlated with those in the control group, with a correlation coefficient threshold of [−1,1]. This threshold represents the strength of the correlation, with the absolute value closer to 1

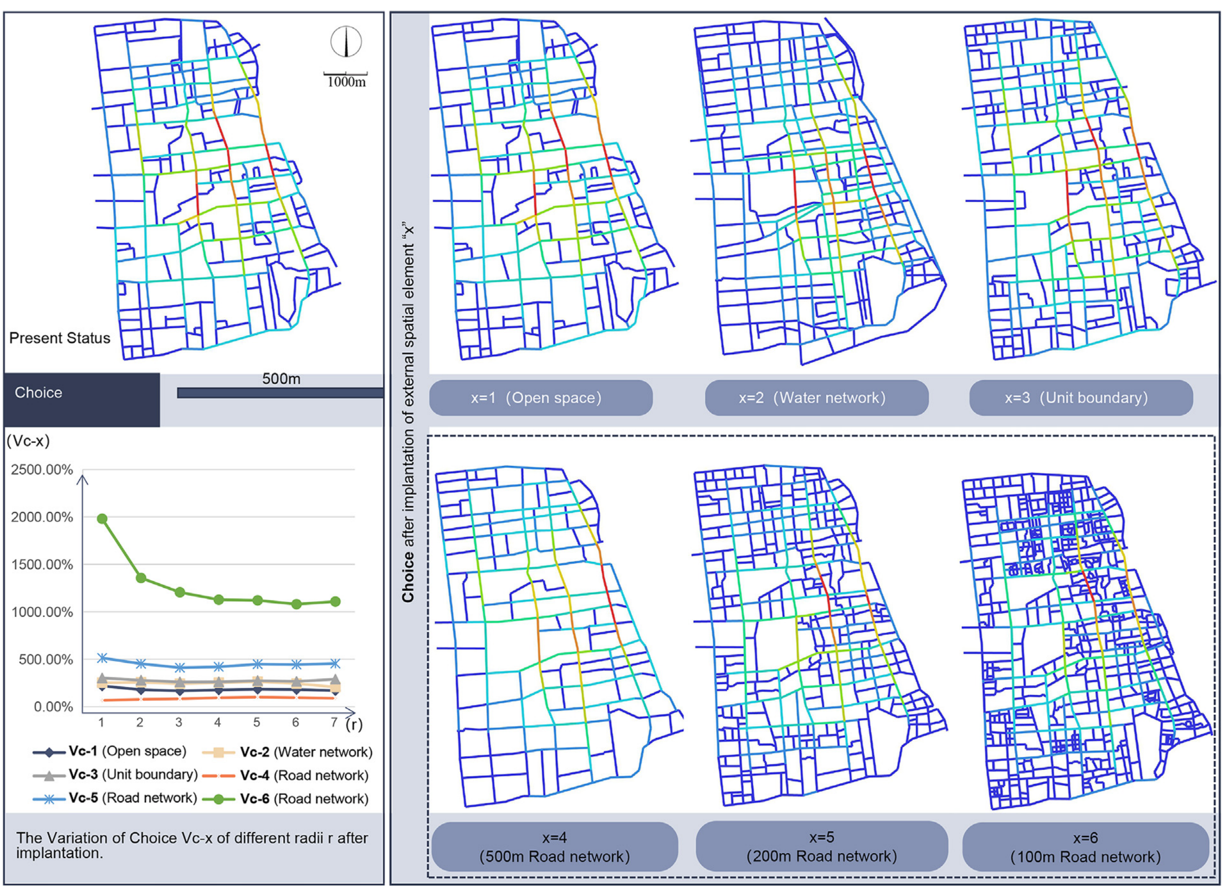

Figure 12. The variation of choice (Vc-x)

Table 7. Total segment length variation

Items		Implantation elements	Value/Change Rate under different calculation radius						
			r = 400m	r = 800m	r = 1200m	r = 2500m	r = 3750m	r = 5000m	r = 10000m
Total Segment Length value (Status quo)	tsl-0	–	1384.55	4401.86	9228.74	33108.3	60177.9	86822.8	133125
Total Segment Length value after Implantation	tsl-1	Open space	1547.67	5000.72	10459.7	39466.5	74108.8	108150	160798
	tsl-2	Water network	1731.95	6408.43	13808.7	51483.4	96792.3	138640	202521
	tsl-3	Unit boundary	1714.99	6102.96	12838.5	46508.7	85675.9	122541	187489
	tsl-4	500 m road network	1336.96	4360.48	9310.7	34456.8	64099.1	91286.1	136804
	tsl-5	200 m road network	1913.27	7031.39	14830.1	53894.1	100331	144042	213235
	tsl-6	100 m road network	2632.22	9567.45	20463.2	73355.2	132844	189570	283304
Total Segment Length Variation (Vtsl-x)	Vtsl-1	Open space	111.78%	113.60%	113.34%	119.20%	123.15%	124.56%	120.79%
	Vtsl-2	Water network	125.09%	145.58%	149.63%	155.50%	160.84%	159.68%	152.13%
	Vtsl-3	Unit boundary	123.87%	138.65%	139.11%	140.47%	142.37%	141.14%	140.84%
	Vtsl-4	500 m road network	96.56%	99.06%	100.89%	104.07%	106.52%	105.14%	102.76%
	Vtsl-5	200 m road network	138.19%	159.74%	160.69%	162.78%	166.72%	165.90%	160.18%
	Vtsl-6	100 m road network	190.11%	217.35%	221.73%	221.56%	220.75%	218.34%	212.81%

indicating a stronger correlation. The findings reveal the spatial effects of different elements following their implantation into the original road network. The results of the correlation analysis and significance analysis show that the implantation of water network elements has a noteworthy effect, whereas the implantation of road network elements within 500 m has no significant effect. This is consistent with the outcomes of Space Syntax in the implant-reconstruction comparison. The specific analysis is as follows.

(1) **T test of Integration:** With the exception of the 500 m road network, the experimental group's significance value was less than or equal to 0.05 when compared to the control group, showing a significant difference in integration between the two groups. According to the results of paired sample testing (Table 8; Table 9), the significance value of original road network & water network was 0.031, indicating that the water network had the greatest impact on integration, whereas original road network & 500 m road network did not produce any statistically significant results. It is shown that all types of elements have a correlation with the original road network, and the implantation of five elements except for the 500 m road network has a significant impact on the integration degree, with the water network element having the most obvious impact after implantation.

(2) **T test of** Choice: According to the results of paired t-test (Table 8; Table 10), the significance values for each paired sample are all over 0.05, indicating that there is no significant difference in selectivity between the experimental groups (Open space, Water network, Unit boundary, 500 m Road network, 200 m Road network, 100 m Road network) when paired to the control group (Original road network). It demonstrates that the implantation operation of open space, water network, unit border, 500 m road network, 200 m road network, and 100 m road network has no substantial effect on selectivity.

(3) **T test of TSL:** According to the results of paired t-test (Table 8 and Table 11), the experimental group's significance value was less than or equal to 0.05, indicating that there is a significant difference in TSL between the experimental groups (Open space, Water network, Unit boundary, 500 m Road network, 200 m Road network, 100 m Road network) and the control group (Original road network). The significance value of the experimental group's Water network and 100 m road network compared to the control group is 0.043, indicating that the implantation of water network and 100 m road network element have the greatest impact on the TSL.

DISCUSSION

On the one hand, the study examined the block scale and openness of the study area and visually portrayed those features. Operational exterior space elements based on region were extracted and then substituted to explore structural updates of built-up areas. Potential analysis demonstrates that the structure of the study area is susceptible to the four types of external elements. The Potential analysis and the implant-reconstruction model based on Space Syntax have contributed to the simulation benefit of Space Syntax, expanding and supplementing the types of external spatial elements that can be used in research on the structural renewal of relevant blocks, and proposing that water network elements play an important role in promoting the scale renewal and openness improvement of blocks through subsequent analysis. It is conceivable to broaden the scope of future study on operational external spatial elements by including actual situations from other regions (Figure 14).

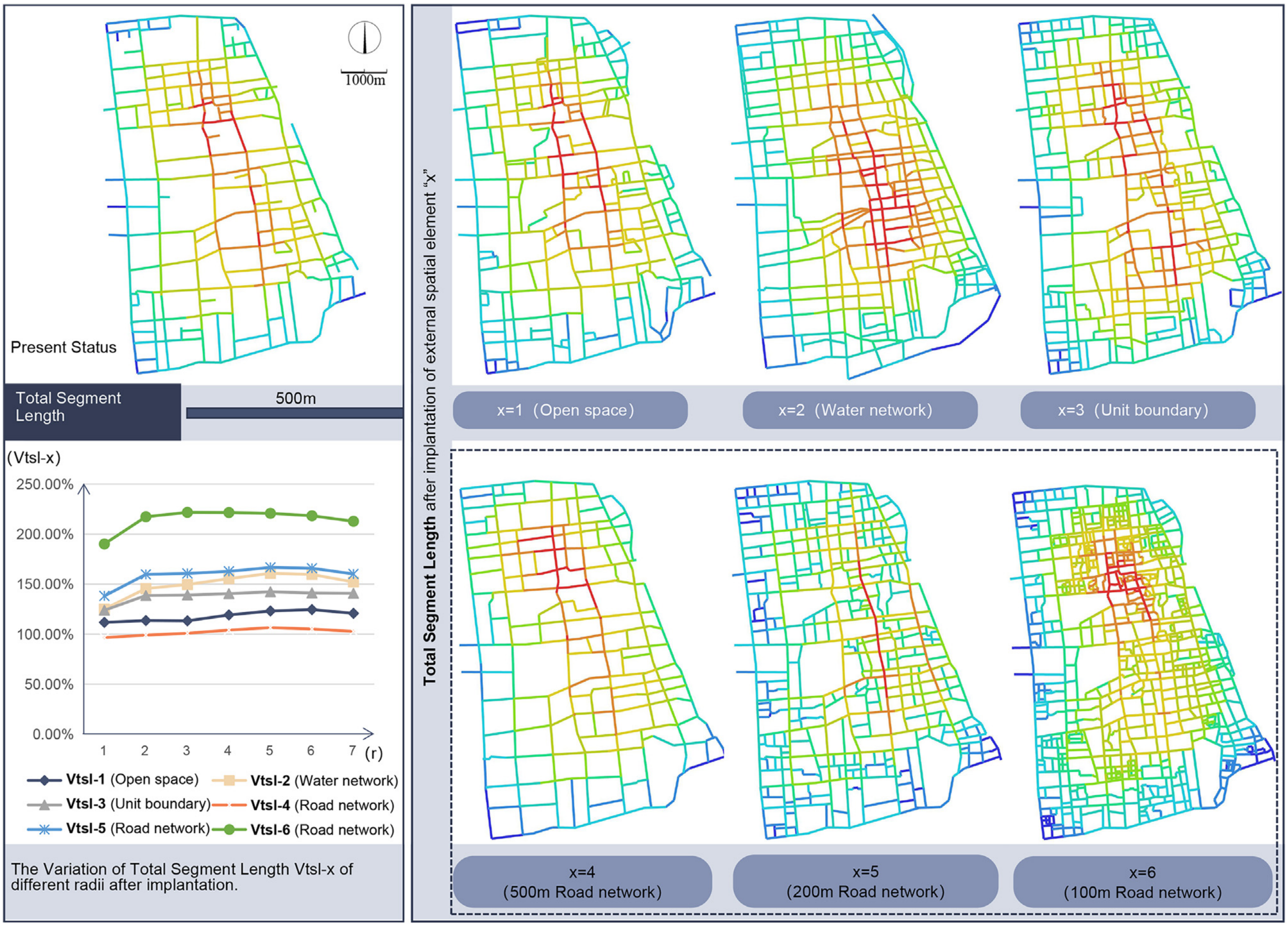

Figure 13. The variation of total segment length (Vtsl-x)

On the other hand, the study presents an implant-reconstruction model and employs grouping and classification analysis to graphically demonstrate the potential path of external space element implantation and the outcomes of spatial optimization. The classification comparison reflects the potential influence of external elements implantation in the current road network via connection (connecting with the road network), expansion (expanding based on the existing form and coupling with the road network), activation (participating in street activities via form, function transformation, and so on), and so on. Group comparison displays the measurement results of the block spatial structure under different scale guidance, and all types of assessment value (Integration, Choice, TSL, etc.) are sensitive to small-scale road networks.

(1) According to the classification comparison, the choice value among them is most sensitive to changes in small-scale road network (100–200 m road network). The integration and TSL value are also sensitive to the four types of variables to varying degrees, but not to the same extent as the former. The influence of the road network, water network, and unit boundary is dominating in the implant-reconstruction process, implying that these elements have a significant role in the small-scale optimization of the study area.
(2) According to the group comparison, the study compares the superimposition of road network elements at different scales. The findings support the study's hypothesis about the scale of urban blocks (a 200 m road network is highly operational) and are substantially consistent with China's current road network density construction guidelines. Specific to the scale level, the external components of the 100 m road network bring the most significant change after implantation, and the degree of change follows a parabola as the calculation radius increases. However, while external elements of the 100 m road network type can play an essential role in the process, the spatial center is overly concentrated after implantation and has a large-scale gap with external elements of other types. External elements of the 200 m road network type, on the contrary, can interact effectively with other external elements.
(3) The paired t-test not only confirmed a high correlation inertia between each type of element and the original road network, but also indicated operational potential in water network elements and the 200 m road network based on the significance results. Taking into account the results of the quantitative analysis, the characteristics of the existing condition, and the viability of the implant operation of the elements, combining and implanting the external elements of road network (around 200 m), water network, and unit boundary has some advantages, and the combination of implant elements can be modified based on existing spatial parameters.

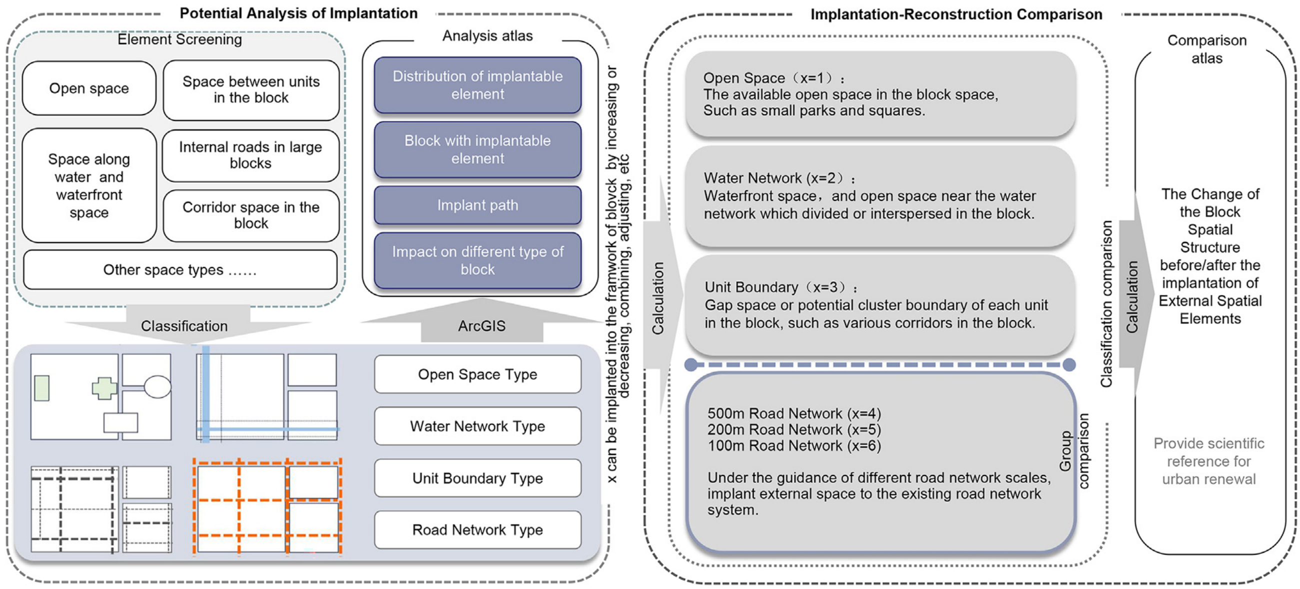

Figure 14. The implant-reconstruction model

(4) The potential analysis of this study provides ideas for the selection of operational elements in urban renewal projects, and the implantation-reconstruction analysis provides ideas for block construction scale guidance. It also visualizes structural changes following possible procedures, giving a visual reference for structural block renewal in urban regeneration. However, it should be noted that the results of the model calculations must be further interpreted in accordance with the demands of urban planning, given the inherent limitations of Space Syntax calculations, such as the impact of the calculation range on the calculation results and the inability of the axis map to fully display the level of motion in reality. A multi-participant assessment procedure can be used in practical project applications by enlisting the help of resident volunteers, planning and architectural experts, staff members from planning management units, and other professionals to establish a review team and choose the best course of action.

Conclusion

This study offers a systematic method to urban revitalization. It highlights the systematic interaction link between the external space and the block structure, and it attempts to lead the targeted design through simulation computation to accomplish urban built-up area order guidance. Using a calculation and comparison atlas, the "implant-reconstruction" model provided in this study compares the influence of typical elements on the spatial structure of the block. According to the results, the study indicates that the water network and road network are of great significance to block renovation and provides new ideas and breakthroughs for the reconstruction of built-up areas. It can refer to the traditional "river and street" isomorphism relationship in Jiangnan region, explore the implantable external elements, lead the secondary division of the block structure, and simultaneously repair the texture, inherit the context, and stimulate the vitality of the block.

Furthermore, this study provides a diagnostic urban design method for structural renovation. The "implant-reconstruction" model suggested in this paper may be useful for precise structural optimization. The quantitative analysis and simulation prediction based on ArcGIS can be used to lead a feasible "tailoring" approach for small block reconstruction. On the one hand, it can assess the multi-level interactions of complex external elements in the block using the causal logic of scientific quantitative analysis and produce targeted

Table 8. Correlation analysis of paired elements

		r		
Paired Subject		Integration	Choice	Total Segment Length
1	Original road network & Open space	1	0.999	1
2	Original road network & Water network	0.999	0.995	0.999
3	Original road network & Unit boundary	1	0.999	1
4	Original road network & 500 m road network	1	0.999	1
5	Original road network & 200 m road network	1	1	1
6	Original road network & 100 m road network	1	1	1

Table 9. Paired T-test (integration)

Paired Subject (Integration)		Paired differences				
		Mean	SD	SEM	t	sig.(2-tailed)
1	Original road network & Open space	−25.37216	24.84664	9.39115	−2.702	0.035
2	Original road network & Water network	−56.27907	52.90894	19.9977	−2.814	0.031
3	Original road network & Unit boundary	−55.3532	54.93473	20.76338	−2.666	0.037
4	Original road network & 500 m road network	−2.31986	3.35967	1.26984	−1.827	0.117
5	Original road network & 200 m road network	−91.49726	89.45104	33.80932	−2.706	0.035
6	Original road network & 100 m road network	−188.82299	181.71025	68.68002	−2.749	0.033

optimization strategies to guarantee coordination with urban development. On the other hand, the digital platform can be used to simulate and predict the reconstruction of small blocks, to visually and dynamically display the feasible path of "local-overall" reconstruction of small blocks, and to provide a scientific basis for the orderly deployment and dynamic adjustment of block reconstruction.

However, because the urban block and its physical structure hold various social meanings, it is still challenging to adequately capture the block's genuine spatial-social composition for the modeling and calculation of abstract spatial features. In practical operation, public involvement and multi-subject collaboration can be adopted to accomplish multi-party coordination such as planning advice and public engagement, and promote the systematic improvement of "Spatial Form, Function and Social Efficiency". Small block planning can be predefined in conjunction with water network characteristics to ensure system development, optimization, and upgrading. In addition, public investment can be increased by taking advantage of "urban events" and "urban catalysts", such as the use of "water network renovation", and "shed reform" policy to promote the reconstruction of blocks. For some extra large-scale blocks, strategies should be formulated in combination with management and operation to guide the construction of small blocks with multiple clusters.

Limitations of the study

Because a city is a complex "organism," the morphological measurement data can only serve as a reference for one characteristic. As a result, the implant-reconstruction model provided in this study has several shortcomings, especially in terms of the urban economy, local relationships, and other social issues that are not fully addressed. According to this study's comparison of the indicator system with weighted data of urban morphology, the quantitative indicators that reflect the local needs of inhabitants are still weak. At the outset of this study, numerous factors were considered, including the urban variety index and the social inequality index, which are closely linked to social cohesiveness, to

Table 10. Paired T-test (Choice)

Paired Subject (Choice)		Paired differences				
		Mean	SD	SEM	t	sig.(2-tailed)
1	Original road network & Open space	−868.64485	1128.43529	426.50845	−2.037	0.088
2	Original road network & Water network	−1476.8919	1783.63005	674.14879	−2.191	0.071
3	Original road network & Unit boundary	−2069.78224	2960.08271	1118.8061	−1.85	0.114
4	Original road network & 500 m road network	84.47402	177.35952	67.0356	1.26	0.254
5	Original road network & 200 m road network	−4013.05511	5582.25746	2109.895	−1.902	0.106
6	Original road network & 100 m road network	−11587.22293	15818.57697	5978.86011	−1.938	0.101

Table 11. Paired T-test (Total segment length)

Paired Subject (Total Segment Length)		Paired differences Mean	SD	SEM	t	sig.(2-tailed)
1	Original road network & Open space	−10183.17714	11039.03602	4172.36343	−2.441	0.050
2	Original road network & Water network	−26162.37571	27119.8554	10250.34185	−2.552	0.043
3	Original road network & Unit boundary	−19231.7	20363.27714	7696.59531	−2.499	0.047
4	Original road network & 500 m road network	−1914.99857	2040.85388	771.37026	−2.483	0.048
5	Original road network & 200 m road network	−29575.38714	30690.97154	11600.09688	−2.55	0.044
6	Original road network & 100 m road network	−54783.84571	56504.36418	21356.64223	−2.565	0.043

guarantee the effectiveness of the structure renovation of blocks from a social perspective. However, due to the mismatch between the scale of this study and the accuracy of the data itself, it has not been included in the model discussion for the time being.

Further in-depth research can be undertaken on this basis. Expanding the variety of elements that can be employed for implantation, for example, based on different urban scales and basic requirements. The use of sociological indicators related to block structure can help to investigate underlying contradictions and difficulties in urban activities, as well as providing quantitative data support for urban redevelopment and urban "acupuncture and moxibustion." Incorporate research into the scope of compact cities, conduct additional study on the suitable scale of open blocks, and optimize and adapt the block scale by investigating the influence of varied scale road networks and block openness on residential space compactness.

STAR★METHODS

Detailed methods are provided in the online version of this paper and include the following:

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AUTHOR CONTRIBUTIONS

Conceptualization, F.Z. and X.Z.; methodology, F.Z. and X.Z.; software, X.Z.; validation, X.Z.; formal analysis, F.Z. and X.Z.; investigation, F.Z.; resources, X.Z.; data curation, X.Z.; writing – original draft preparation, X.Z.; writing – review and editing, F.Z.; visualization, F.Z. and X.Z.; project administration, F.Z.; funding acquisition, F.Z. All authors have read and agreed to the published version of the manuscript.

DECLARATION OF INTERESTS

The authors declare no conflict of interest.

INCLUSION AND DIVERSITY

We support inclusive, diverse, and equitable conduct of research.

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STAR★METHODS

KEY RESOURCES TABLE

REAGENT or RESOURCE	SOURCE	IDENTIFIER
Deposited data		
Raw and analyzed data	OpenStreetMap	N/A
The scale data for the historical towns in China	Baidu Baike	https://baike.baidu.com/
The scale data for the historical towns	Wikipedia, Googleearth	https://encyclopedia.thefree dictionary.com/
Baidu POI	This paper	http://lbsyun.bdu.com/
Population data	This paper	http://tjj.suzhou.gov.cn/
Traffic grade	Baidu map	https://map.baidu.com/
Water network information	Baidu map	https://map.baidu.com/
The basic data of Land use function of the Study area	SND Management Committee	http://www.snd.gov.cn/hqqrmzf/ggl/list1.shtml
Software and algorithms		
Space Syntax	https://spacesyntax.com/	N/A
Adobe Photoshop	https://www.adobe.com/products/photoshop.html	N/A
Auto CAD	http://www.autodesk.com.cn/	N/A
QGIS	http://www.qgis.org/	N/A
ArcGIS	http://pro.arcgis.com	N/A
IBM SPSS Statistics 26	https://www.ibm.com/cn-zh/spss?mhsrc=ibmsearch_a&mhq=spss	N/A
Other		
Road Information	https://lbsyun.baidu.com/index.php?title=open/custom	N/A

RESOURCE AVAILABILITY

Lead contact

Further information and requests should be directed to and will be fulfilled by the lead contact, Xi Zhou (zhouxi@usts.edu.cn).

Materials availability

This study did not generate new unique reagents.

Data and code availability

- Raw microscopy data reported will be shared by the lead contact upon request.
- Code: This paper does not report original code.
- Data/code accession links are listed in the key resources table.
- All other requests: Any additional information required to reanalyze the data reported will be shared by the lead contact upon request.

EXPERIMENTAL MODEL AND STUDY PARTICIPANT DETAILS

This study presents a model of "Implant-Reconstruction" based on the interaction between the external space and the block structure. This model allows for the graphic simulation of the potential outcomes of block structure reconstruction, through changes to the connection, expansion, and other elements of the external space. The study delves into the operational external elements (control points), assesses the structural impact of each control point within the block system, estimates the potential outcomes of external space implantation (targeted supplement and optimization of secondary trunk roads, branch roads, etc.), and offers a dynamic and visual reference for the reconstruction of the block's scale. Some system comparison atlases can be obtained by analyzing and simulating the changes of block spatial structure under the circumstances of increase, decrease, combination, adjustment, and other operation in external spatial elements to provide visual graphic information for the optimization of reconstruction schemes of small blocks.

METHOD DETAILS

Data filtering and integration

Currently, the following are the most critical issues in promoting urban regeneration and transformation: The basic framework of built-up areas has already been established, with dense structures, and demolition costs are still considerable. The public is generally skeptical of the block system, and public opinion is inconsistent there are gaps in the legal theory of land property rights in the reconstruction process.[69] As a result, appropriate operational components must be selected based on the location, and the operation's sustainability must be discussed in conjunction with the quantity, form, and distribution of the elements.

The study utilizes remote sensing images of Suzhou and the open street map database, OSM (Open Street Map), to collect urban data. It employs the OSM map interface provided by QGIS software to capture vector data of the research region and urban roadways in batches.[2] Field data such as road network name, grade, and geographical position are gathered and exported to the ArcGIS platform for preprocessing. In order to compare the effects of the implant operation of external elements (increase, decrease, combination, adjustment, etc.) on the spatial structure and environmental quality of the study area, the study uses ArcGIS to parameterize the urban road network, streets, corridors, green spaces, squares, water bodies, and so forth in the area under investigation.

For subsequent prospective implantation analysis and simulation, this study applies ArcGIS for data integration, and establishes an External Spatial Element Database. To create a screening principle that combines universality and pertinence, field investigation is needed to inquire into the explicit or implicit external elements (control points) suitable for the implant operation in the reconstruction process of small blocks. In addition to containing a single space type, external space objects should also combine different space types, with some blocks acquiring special attention for specific space types. The objects to be researched are preliminarily selected to establish an External Spatial Element Database based on the urban survey and the spatial pattern of densely distributed water networks, overlapping rivers and highways, and water-land interaction in urban built-up areas in Jiangnan area.[42,67] It mainly incorporates: ① Open space in the block; ② Space along the water network and waterfront space; ③ Space between units in the block; ④ Internal roads in large blocks; ⑤ Corridor space in the block; ⑥ Other space types.

Subsequently, the study imports the relevant information about the prospective external elements into the electronic map and categorizes them into four groups according to the clustering formed by their shape, size and other characteristics:

- Open space type: It is primarily made up of the public space within the block, with the exception of the waterfront land, which is categorized under the Water Network type, considering the relevance of the implantation operation.[2] The external elements of the Open Space type have a random distribution throughout the sample range, and the quantity is medium and more in the four types of elements. In order to assess the viability of "implant" operation, this study chose the open space element larger than 1 hectare that can meet the needs of people's activities and has a certain traffic potential in the block.
- Water network type: It refers to the external space that is inextricably linked with water or water network.[42] In the Jiangnan region, the open space associated to the water network and the space that can be connected to the existing road network by increasing the channel connection is referred to as the water network element in this study. In comparison to the former, these external elements have a more homogeneous discrete distribution and a larger number.
- Unit boundary type: It is mostly made up of the gap space or possible cluster border of each unit in the block, as well as numerous corridors.[1] The majority of them have the ability to connect to the urban road network and can be linked together. These components are distributed reasonably uniformly and in significant quantities, which might constitute a secondary partition of the block.
- Road network type: It comprises primarily of internal roads in substantial blocks, together with some block-wide corridor space, which can be seen as an expansion of the road network system.[34,39] Through the adjustment of management openness or simple path connection, it is easily accessible via the existing road network system. Its quantity is closely related to the scale of road network, and the element quantity will rise as the block's target scale decreases. Therefore, it is necessary to compare the rationality of the scale of the road network after the implantation operation using quantitative analysis in conjunction with the actual situation because the scale of the road network is not "the smaller, the better".

Quantitative analysis and graphic overlay

As computational thinking in urban design and research advances, the structuralist exterior space evaluation and design system may be used as a guide to examine the spatial interaction between the local and external aspects in the rehabilitation of small blocks.[16,49] Based on this point of view, the study provides an "Implant-Reconstruction" model to illustrate the relationship between block structure and external space. When the external elements are implanted into the road network, it can simulate and anticipate the block structure form and space efficiency. By using the digital overlay approach, it may visually depict the spatial influence of probable operations and establish the linkage study of "evaluation-design", improving the scientific rigor and measurability of the research on the renovation of small blocks.

Firstly, the Network Analysis module based on GIS is employed, to reproduce the actual urban road network structure and provide a basis for subsequent potential analysis and implantation comparison. Secondly, this study assesses the openness and scale of each unit and measures the implantation potential of each type of external space by using the External Spatial Element Database of the study area, the urban road traffic network database, land use information, POI data, closed management, and other factors. Thirdly, the alterations in spatial organization both before and after implantation are demonstrated using the Space Syntax axis model. Axis models of SND (in CAD version) are loaded into the Depthmap and calculated based on data gathered about the road network. Finally, A comparative atlas of external spatial elements before and after the implant operation is established using the graphic overlay, buffer generation, and thematic map production features of the digital platform. This shows the potential effects of the implantation of various external elements on the block structure by simulating changes in spatial form, central area distribution, traffic flow line, etc.

Implant-reconstruction model

The Implant-Reconstruction model consists of two main parts: Potential Analysis of Implantation and Implant-Reconstruction Comparison (Figure 14). The former focuses on the exploration of elements and analyzes its operational potential and scope of influence, while the latter uses Space Syntax (Depthmap) to explore the impact of different elements. There are many indicators in the calculation of the axis model of Space Syntax, such as Integration, Choice, Segment Length, Total Segment Length, Node Count, Total Depth, etc. In the preliminary study, the changes of each indicator were compared, and the non-significant indicators at the block scale were eliminated. Finally, the Integration, Choice, and Total Segment Length were selected for comparative analysis.

The Integration is to express the connection between roadways and the portions of roadway that surround them. It calculates the likelihood of a certain path within a given radius being chosen as a destination by the population. In general, the higher the integration value in a system, the more probable it is for the population to choose it as a destination, and the greater the accessibility of the region. The Integration Core (the 10% most integratedlines) is a grouping of the most accessible roadways. It is normally the center of economy and popularity.[27] The Choice indicates the likelihood of a specific road segment within the research scope being chosen and traversed by the crowd, based on a certain activity radius. In general, the more options available in a research system, the higher the likelihood of it being chosen and accepted by the majority. The Choice is also referred to as selectivity, through-movement, transit traffic, and trafficability. The Total Segment Length refers to the calculation of the total length of roadway axes and the total number of axes within different radii, reflecting the density of road networks under different modes of transportation.

Potential analysis of implantation

The OSM database and field research are used in the study to gather data on urban external space. The precise urban information is retrieved and quantified, and an abstract model with the block as the basic scale is built. The stock or possible external spatial elements will be imported into the electronic map, which will be labeled with basic information such as the plane layout form, forming an External Spatial Element Database. The possibility of establishing an effective connection with the existing road network by adjusting the shape and scale will also be investigated, in order to construct a "Implant-Reconstruction" comparison system of external elements and block structure, which will serve as the foundation for subsequent model calculation.

- Classification comparison: After a preliminary examination, the operable external elements that could potentially affect the reconstruction of a block are categorized into four groups and subsequently loaded into the model for calculation. These groups include open space (x=1), water network (x=2), unit boundary (x=3), and road network (x=4-6). Calculation and simulation are used to examine the impact of spatial shape, function, and quantity on the block. These comparisons of these data can be used to determine how the block's spatial structural characteristic changed before and after the implantation of external element "x".
- Group comparison: Due to the intricate correlation among the scale of road network, land use degree, and structural efficiency in urban blocks, road network parts will be further grouped for comparison, in order to compensate for the lack of a single road network scale. According to statistical data on road network density,[61] this study uses a 500-meter reference size for block status which is determined by the typical block scale of modern urban built-up areas in SND. Therefore, in the model calculation, a 500 m road network (x=4) is considered as the ideal current state, while 200 m (x=5) and 100 m (x=6) are chosen as the target road network variables, to simulate changes in the spatial structure of the block following the implant operation of potential road elements in the scaling framework.

Implant-reconstruction comparison

The calculation can graphically display the impact of different properties and forms of external elements, as well as their combinations, on the block space structure and social behavior, and output the comparative atlas before and after the implantation. The Depthmap (Space Syntax) is used to compare the influence on block structure before and after the implantation of "x". It can demonstrate the impact of local external space and its constituent elements on macroblocks in terms of function enhancement, space optimization, order reconstruction, and vitality stimulation, along with other things. By comparing the atlases, it is possible to examine and determine whether the adjustment of the selected external elements can encourage the structural reconstruction of small blocks. It can be judged from the following three aspects comprehensively.

- Spatial form: Check if the spatial shape of the block exhibits a small scale, referencing to the *Standard for Green Urban Area Planning and Construction*.[67] Verify whether the distribution of the road network is balanced with the addition of the external space and whether the road network density has increased to a reasonable range significantly. While Total Segment Length graphically depicts the density of the road network under various modes of transportation, the highlighted area of Integration demonstrates the core structural elements of the area.
- Spatial distribution: Whether the position of the current central area of the study area shifts after the implantation of external element "x", whether the scope broadens, and whether the new expansion's direction is consistent with urban growth. Specifically, positional changes in a two-dimensional comparison atlas are also analyzed together with changes in various sorts of data.

- Traffic streamline: Whether the main structure of traffic has changed, whether the newly added traffic space can handle the traffic flow efficiently, and whether the overall traffic convenience of the urban area has improved after the installation of external element "x". The Integration Value reflects roadway accessibility and the structural characteristics of central places. When compared to Integration, Choice Value places more emphasis on transportation issues based on the psychology of human behavior.

Referring to the *Code for Transport Planning on Urban Road*,[60] the road network gradient and the status of road network in this study, when the external spatial elements are implanted, the highlighted area of the two-dimensional diagram expands by more than 10% of the original highlighted area, which can be considered as a certain change. When it exceeds 20%, it can be considered as a significant change. The relative significance of each element in Implant-Reconstruction process can be verified from a data perspective using the Paired T-test.