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Exploration of Intelligent Building Planning for Urban Renewal

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Abstract: The spatial layout of urban villages seriously affects the living environment and integrated development of urban and rural areas. Using digital means to assist in the reconstruction of urban villages is necessary and urgent. This study built an urban renewal framework for intelligent building planning with a proposed multi-party collaborative pattern. First, villagers' needs, and relevant standards and regulations were merged into planning requirements, which were formulated into planning goals and criteria. With the quantitative goals and criteria, building planning and design algorithms were developed. Furthermore, the method was verified to achieve an intelligent layout of buildings. Finally, under certain conditions, the average difference between the plot ratio calculated by the program and the actual plot ratio was 0.02, and that between the building intensity calculated by the program and the actual building intensity was 0.02. Within 11.43 hectares, 500 buildings were generated with a total floor area of 27.72 hectares, and the average time taken for scheme generation was 10 s. This method can efficiently generate a plan similar to the actual floor area ratio and building density and optimize the problem of insufficient spacing. Moreover, adjusting the parameters can automatically generate a variety of schemes that can support the layout design of rural buildings.

Keywords: urban village; renewal and reconstruction; intelligent building planning; generative design

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1. Introduction

Since the start of rapid urbanization in China in 1980, urban spaces have been expanding outward and gradually encircling the adjacent rural areas. However, owing to multiple institutional, social, and economic factors, China's urbanization process has failed to simultaneously integrate these villages into the urban system, and they have gradually become 'islands' in urban space—urban villages. The urban villages are unique urban landscape features in Chinese cities, especially in the Pearl River Delta. They are rural-like settlements surrounded by urban spaces owing to rapid urbanization [1]. However, in China, the governance structure and its administrative functions are distinctly different between urban and rural areas [2]. This dual government structure has led to the birth of urban villages under rapid urbanization [3], which maintain a rural-like institutional system and collective property ownership despite being in urban areas [4]. Owing to the separation of administrative authority, these urban villages are subject to overlapping administrative management with ambiguous responsibilities, which eventually leads to the absence of planning management [5]. Under these circumstances, urban villages are mainly self-managed and constructed by village committees. Because of the lack of knowledge and experience in planning and construction, it is difficult for village communities to obtain professional guidance and standardized construction plans in the process of self-governance, resulting in the spatial pattern of urban villages failing to connect with the city in a timely manner. Consequently, in recent years, the issue of urban villages has attracted extensive attention from scholars. Through numerous field surveys and visits, in-depth research, and analysis on the demographic, institutional, land use, landscape, and spatial characteristics of urban villages in China have been initiated [6]. Urban villages are settlements of indigenous people and migrant workers. Under the management of the village committee, a considerable part of the buildable land is constructed as residential buildings. To maximize the use of space, these buildings are built close to each other. They are often separated by pedestrian passages of only approximately 1 m in width. The dense housing construction makes it impossible for enough light to penetrate and completely ignores fire and other safety considerations [7]. Consequently, these dense houses encroach on the space for public activities and necessary infrastructure [8], making the narrow streets very dirty. The landscape, high density, clustering of buildings, engulfed narrow streets, and poor social facilities are common features of these settlements [9]. Spatially, overall, these urban villages exhibit an irregular shape [10], with buildings arranged in no order and exhibiting many negative characteristics, such as crowding, high density, low land use efficiency, and poor living environment [11]. These disorganized spaces seriously affect the living environment and pose substantial fire safety hazards. Such characteristics are often considered a major challenge in urban planning and renewal. However, these negative spatial problems result from a lack of effective land use planning and control, with the root cause being a lack of planning caused by the institutional differences between urban and rural China. To achieve high-quality urban–rural integration and sustainable development, urban villages need to be transformed. In 2009, the Chinese Ministry of Land and Resources launched a policy called 'sanjiugaizao' [12], encouraging redevelopment for three categories of old areas, namely old towns, old industrial buildings, and old villages. With the support of national policies, different transformation models have been proposed. Some models take the form of real estate development, but this involves significant demolition and negotiation costs. Others take the form of government concessions: 'New housing + compensation' as compensation for villagers and giving the land to developers for development, although the government loses revenue from land concessions in this case [13]. There are also different transformation models led by different subjects. For example, for low-income groups, the government takes the lead in providing public goods, whereas for high-income groups, the market takes the lead [14]. Overall, these models can be categorized as government-led [15,16], market-led [17], and collective-led [18,19]. In addition, some studies have proposed a framework of governance models, summarizing the choices of and differences in different governance models [20]. All these models involve the roles and relationships of different stakeholders in the redevelopment process [21–23].

Overall, over the past decades, existing research has emphasized the following aspects: Spatial characteristics of urban villages and their development mechanisms and management-related measures for urban village governance and redevelopment [24,25]. The former emphasizes the spatial phenomenon and the evolutionary process, and its limitation is that the characteristics are generally analyzed qualitatively and descriptively based on actual surveys and information [26]. Based on real cases, numerous studies have explored models of urban village transformation from the perspectives of stakeholders, such as the government, private developers, and villagers, and examined the roles of different models in large-scale transformation projects through examples [27] and the social impacts of these redevelopments within urban villages [28,29]. However, these models often have far-reaching effects on the internal social structure of urban villages, such as a change in the social relations of the village and increased rent due to the high cost of land renovation, thus forcing those with low income to move out [30]. Although studies have proposed various models for transforming urban villages, these models remain largely context-specific in their presentation. They generally consider a special case as an example to summarize the planning and management path of policy formulation [5,31]. However, the redevelopment models vary owing to the specific conditions of each urban village and the different contexts. Therefore, these models are not applicable to all urban villages. Moreover, most of these research results are theoretical in nature, and they attempt to establish a win–win cooperation relationship between the government, village councils, and the market from the perspective of management mechanisms. The implementation of these models often requires a large amount of funding and involves the interests of multiple parties, making it difficult to popularize and promote these models. However, these models are often led by the government and developers, and the professional planning forms an invisible 'knowledge barrier' leaving the indigenous people (villagers) in a passive position. The results of related research are mostly theoretical, and less attention has been paid to the implementation of the actual process. Most of the studies are of limited assistance to the actual planning and design as they are based on traditional quantitative statistics and qualitative research from the perspective of humanities and social sciences.

Currently, with the development of intelligent technology, rural construction has become an important component of the next stage of sustainable development. Intelligent technology provides an important tool for the sustainable renewal of urban villages and makes it possible to break the 'knowledge barrier' and enhance public participation [32]. However, the current application of intelligent technology generally focuses on the aspect of intelligent infrastructure construction [33,34] and the internal functional layout of buildings, with less attention to intelligent building planning, such as building layout, within a certain range [35]. Simultaneously, studies on intelligent building layout have mostly focused on urban areas [36] and less on the countryside as a target. The sustainable renewal of urban villages is an activity that focuses on the interests of residents. Simultaneously, public participation is increasingly emphasized as a key operation mode [37]. With the help of intelligent technology, we can improve the initiative and enthusiasm of villagers to participate in the renovation, make the renovation meet the public needs, make up for the deficiencies in the 'administrative-led model' of renovation, and make urban village renovation and construction sustainable [38].

This study aimed to use generative design to realize intelligent building planning for urban villages or residents, provide technical support for urban redevelopment, and assist in the implementation of the plans. From the general process of urban renewal, this article analyses the links in which villagers can participate, summarizes the factors affecting public participation in renewal projects, and constructs a framework for intelligent building planning-assisted urban renewal. Furthermore, according to the current planning and design standards, common rules were summarized, and the villagers' needs and wishes were transformed into planning conditions, and computer technology was used to realize the intelligent generation of building layouts. Finally, we selected Changban Village, an urban village with typical urban village characteristics, and adjacent to the urban center, and tested and applied the method to provide technical support for urban village renovation and transformation.

2. Data and Methods

2.1. Framework of Study

In China, the process of urban village renewal generally involves the government, planners, villagers, and developers. When an urban village regeneration plan is proposed, the government, planners, and developers conduct investigations and consultations with villagers based on the regeneration project, and the villagers make requests and provide feedback. This is an open and collaborative urban renewal pattern [39]. Villagers' participation includes public participation, announcement of the proposed plans, and holding a villagers' assembly to vote on the proposal. The final decision scheme is approved by the government and built by the developer.

In this process, public participation is essential in urban village renewal. However, limited by personal [40] and objective factors [41–43], the level and effectiveness of participation varies [44]. People are constantly looking for effective ways to achieve public participation [45–47]. At present, the changing planning concepts and decentralization, information technology, and intelligent technology provide an opportunity to improve the environment for public participation and enhance its effectiveness [48–50]. These technologies build a digital participation platform (DDP), a specific type of civic technology explicitly built for participation, engagement, and collaboration purposes, allowing user-generated content and containing a range of features [51,52].

If combined with intelligent technology, intelligent building planning is provided to help villagers and planners communicate in a public participation process (Figure 1). In this process, villagers define planning goals and criteria, which are entered into the intelligent building planning program in the form of constraints. Further, the program generates a compliant plan under the constraints. Villagers compare and choose among the generated solutions. Finally, the options are publicized, and a villagers' assembly is held to vote on them. With the assistance of intelligent building planning, villagers can not only become the 'designer' of the plan but also express their needs in a visual form, thus reducing the obstacles to communication and promoting better participation in the planning process.

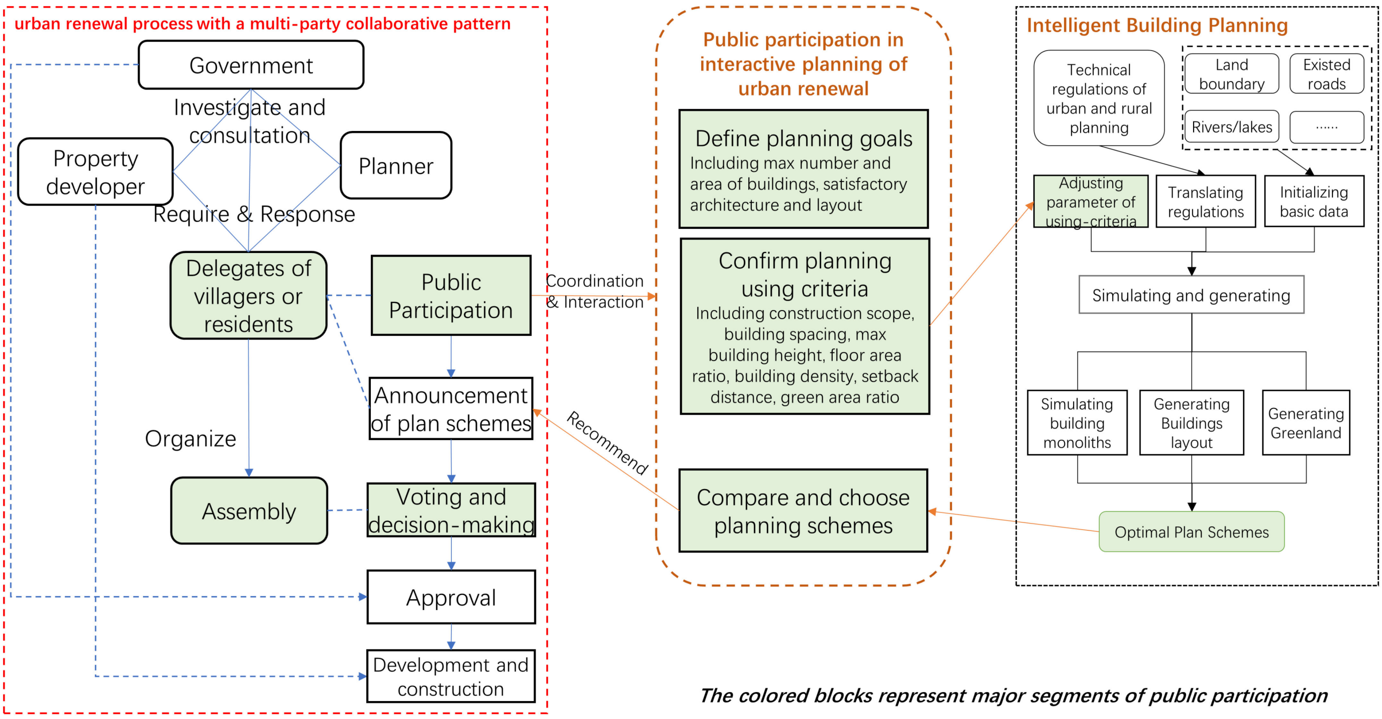


Figure 1. A framework of intelligent building planning-assisted urban renewal.

Based on the above analysis, intelligent building planning makes it possible for villagers to build planning goals and criteria. At this point, the villagers can communicate with the planner to determine the planning wishes, such as the need to build a certain number of houses within a certain area, including house form, area size, number of floors. These will be entered into the program as constraints. Simultaneously, because these requirements have to meet the statutory codes, the code standards need to be translated, for example, architectural design fire codes, technical standards for rural planning, etc. Further, the program quickly generates a planning and design plan based on the input constraints. At this point, the planner and villagers can communicate about the generated solutions. The villagers vote to compare and select possible satisfactory solutions. Finally, the government approves the submitted solutions and decides whether they are adopted or not. In this process, the villagers are really involved in the planning instead of just verbally giving feedback and filling out questionnaires.

Therefore, in the present study, we combined intelligent technology to build the framework of intelligent design, which mainly includes the following four steps: Basic construction, intelligent adjustment, intelligent generation, and coordination and interaction. Among them, basic construction and intelligent adjustment are the processes of inputting basic data about the plot and its demand conditions, including boundaries, roads, and building spacing. These two processes translate the needs and desires of the executor into planning conditions that fully involve the villagers (executors) in the urban village renovation. Next, intelligent generation and coordination interactions can generate and output multiple scenarios based on the conditions, providing the executors with multiple scenario comparisons and decision aids to guide specific implementation.

2.2. Case Study of Urban Renewal

As an example, Guangzhou has 1104 urban villages (In the next 3 years, Guangzhou's 83 urban villages and 285 old neighborhoods will be renewed. Retrieved 11 June 2022, from QQ News website: https://new.qq.com/rain/a/20200925A0J2VL00 accessed on 11 June 2022). Since Guangzhou proposed the goal of transforming urban villages in 2009, a policy was released in 2020 once again proposing the urban renewal of 183 urban villages (Figure 2a), which were mainly located in urban suburbs, key transportation routes, or functional areas.

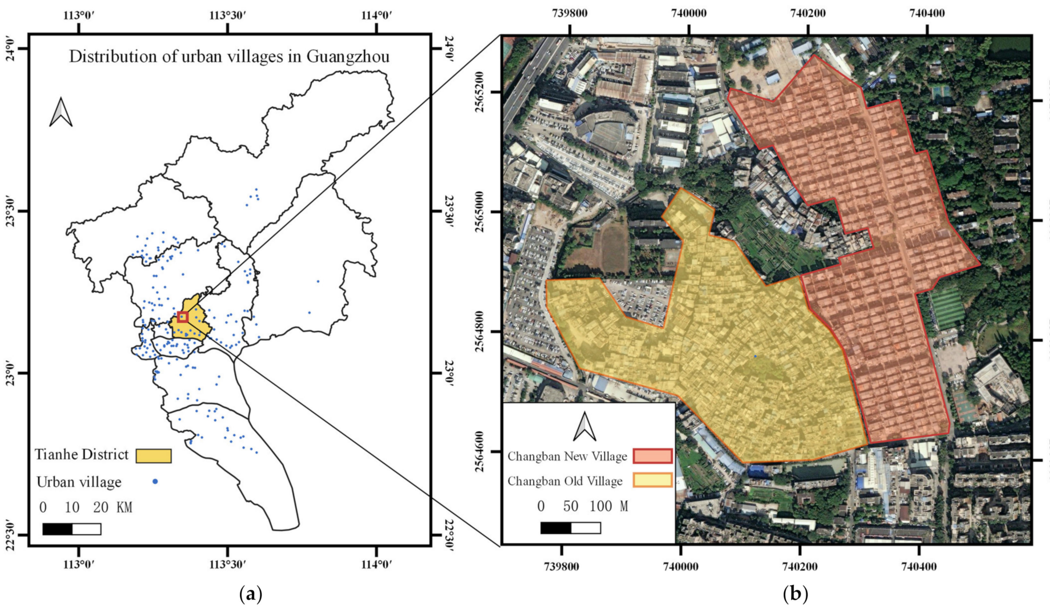


Figure 2. Geographical location of the study area. (**a**) Distribution of urban villages in Guangzhou. (**b**) Location of the Chanban village.

Changban Village is an urban village located in Tianhe District, Guangzhou City. It is divided into Changban New Village and Changban Old Village (Figure 2b). Owing to its proximity to the city center and convenient transportation, Changban Village has become a settlement for many migrants, with the typical characteristics of an urban village. With the continuous improvement of housing demand and the quality of the living environment, many villagers use vacant land to build houses to meet their needs, such as the newly built 'Changban New Village', whose layout looks cleaner than that of the old Changban Village. The above phenomenon is not an individual instance but is widespread in the suburban or village communities of the Pearl River Delta, which has important implications for the optimization of the spatial layout of urban villages. To solve the above problems, the intelligent design and verification of the old and new Changban villages were carried out using the computer intelligent generation method to provide technical support for the optimization and renovation of urban village buildings.

2.3. Criteria for Translating the Design Specifications

From the analysis in the first section, numerous environmental problems in urban villages are related to excessive building density and small spacing. To achieve fire prevention, sunlight penetration, ventilation, lighting, greenery, sanitation, and other living needs, the building density in urban villages should be controlled within a reasonable range, and the necessary distance between buildings must be maintained, which is necessary for planning and designing a good building layout. Each city has different standard calculation criteria for building spacing. Therefore, in this study, the building spacing standards and their calculation methods were compared among three major cities in China: Beijing, Shanghai, and Guangzhou, located in North China, East China, and South China, respectively. As shown in Table 1, in southern China (e.g., Guangzhou), where sufficient light is more easily available, a fixed minimum value is used directly for farmhouses (residence in the village) with fewer floors, whereas in Shanghai and Beijing, which are at higher latitudes, we must multiply the building height by a certain factor to maintain a larger spacing to obtain sufficient light. For the calculation of building spacing in these cities, 'building height × coefficient' is generally chosen, whereas the choice of the coefficient is related to the demand for light in houses. To achieve efficient land use and meet the environmental needs of light, ventilation, and sanitation, the building layout in different areas has different characteristics. Furthermore, the layout of farmhouses in various places is neatly arranged according to the prescribed building spacing. However, Guangzhou, which is in the southern region, uses a fixed value as the building spacing, and the overall layout shows a neat, compact, and high-density feature. The farmhouses in Shanghai and Beijing are also arranged more sparsely to obtain more adequate light. The difference in building spacing is crucial for the difference in building layouts in settlements.

Table 1. Comparison of building spacing calculation and layout patterns in different cities.

	Guangzhou	**Shanghai**	**Beijing**
Longitude and latitude	113.25E 23.12N	121.46E 31.22N	116.40E 39.91N
Residential building classification	multi-story building and low-rise building high-rise building farmhouse	multi-story building and low-rise building high-rise building farmhouse	tower-type building plate-type building farmhouse
Spacing coefficient	multi-story building and low-rise building: 1.1/0.8/0.5/0.3 high-rise building: 0.8/0.5/0.3 farmhouse: Fixed minimum value	multi-story building and low-rise building: 1.2/1.0/0.8/0.7 high-rise building: 0.5/0.4/0.3 farmhouse: 1.2/1.4	plate-type building: 1.7/1.6/1.4/1.0 tower-type building: 1.7/1.5/1.2 farmhouse: 1.0
Spacing calculation method	multi-story building and low-rise building: H × Spacing coefficient high-rise building: H × Spacing coefficient farmhouse: Fixed minimum value	H × Spacing coefficient	H × Spacing coefficient
Farmhouse constraints	H ≤11 m floors ≤3	H ≤10 m floors ≤3	H ≤7.2 m floors ≤2
Rural settlement patterns			

Note. 'H' is the height of the building.

As observed in the calculation of building spacing, building height is also a key factor that affects building spacing. Building height and building spacing further affect the plot ratio and building density of a building within the settlement area. Furthermore, considering the green area ratio and setback of the buildings on the road, these are traditionally key indicators in planning and design and directly influence the effectiveness of the design scheme. Therefore, these indicators are used as conditions that influence the program and indicators that can be adjusted in the villagers' participation process. Six important indicators were selected in this study: Maximum building height, building spacing, floor area ratio, building density, setback distance from the road, and green area ratio. With further reference to the Technical Provisions on Urban and Rural Planning of Guangzhou (referred to as Guangzhou), the Technical Provisions on Village Planning of Shanghai (referred to as Shanghai), and the Planning and Design Standards for Urban Residential Areas (referred to as national standards), the control ranges in the local standards were selected, and the constraint ranges for the three types of buildings (residential, commercial, and industrial) were summarized. In the subsequent applications, the metrics and metric-value constraints should follow the constraints in Table 2.

Table 2. Using-criteria constraint system.

Indicators	Control Ranges	Summarized Ranges
Maximum building height	Residential: ≤10 m/11 m (Shanghai/Guangzhou rural non-apartment detached houses); 18–80 m (city, national standards) Commercial: ≤12 m (Shanghai): No restrictions on the rest, in harmony with the surrounding environment Industrial: No restrictions on the rest, in harmony with the surrounding environment	Residential: ≤11 m (rural); 18–80 m (city) Commercial: ≤12 m (rural); No limitation on city Industrial: No limitation
Building spacing	Residential: Main orientation ≥6 m; minor orientations ≥2 m (Guangzhou) Commercial: ≥10 m (increases with the number of floors) Industrial: ≥13 m (increases with the number of floors)	Residential: Main orientation ≥6 m; minor orientations ≥2 m Commercial: ≥10 m Industrial: ≥13 m
Floor area ratio	Residential: ≤1.8 (Guangzhou), ≤2.9 (Guangzhou), 1.0–3.1(national standards) Commercial: 1.0–1.5 (Shanghai) Industrial: ≤4.0 (Guangzhou)	Residential: ≤1.8 (rural), 1.5–6.0 (city) Commercial: 1.0–1.5 (rural), 1.6–15.0 (city) Industrial: ≤4.0 (city/rural)
Building density	Residential: ≤50% (Guangzhou) Commercial: ≤60% (Guangzhou) Industrial: 35–50% (Guangzhou)	Residential: ≤50% Commercial: ≤60% Industrial: 35–50%
Setback distance	Residential: ≥2 m (rural, Guangzhou), ≥5 m (city, Guangzhou) Commercial: ≥5 m (Guangzhou) Industrial: ≥5 m (Guangzhou)	Residential: ≥2 m (rural); ≥5 m (city) Commercial: ≥5 m (city) Industrial: ≥5 m (city)
Green area ratio	Residential: ≥25% (Guangzhou) Commercial: ≥10% (Guangzhou) Industrial: ≤20% (Guangzhou)	Residential: ≥25% Commercial: ≥10% Industrial: ≤20%

Note. 'H' is the height of the building.

2.4. Building Planning Algorithm and Its Implementation

The algorithm comprises the following parts (Figure 3): Getting building blocks, building monolith generation, building layout generation, and green space generation. Based on the input information, such as existing roads, land boundaries, floor heights, and maximum building heights, location points and building monoliths are generated, and layouts are further generated. Subsequently, the algorithm judges whether the conditions are satisfied and finally outputs the scheme information.

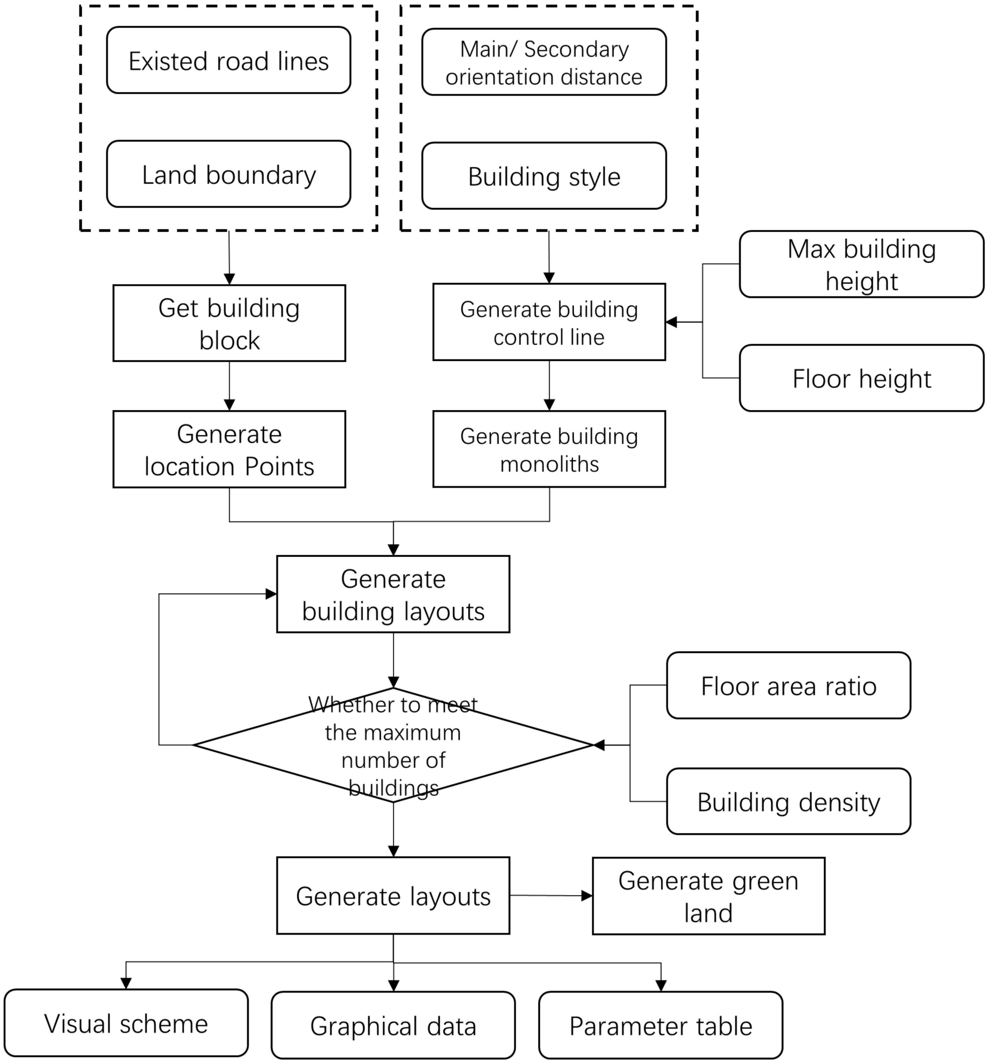


Figure 3. Flowchart of the algorithm implementation.

Building monolith generation is performed first. Based on the maximum building height and floor height information entered by the villagers, the actual building height is calculated, and building monoliths are generated. Further, the corresponding building control line is generated based on the information on building style and distance (a and b) of primary and secondary orientation entered by villagers (Figure 4).

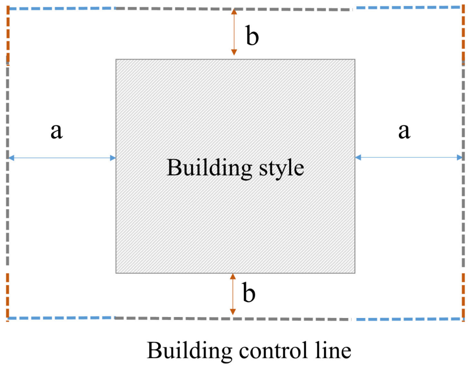


Figure 4. Establishment of building control line.

After generating building monoliths and building control lines based on criteria and planning objectives entered by villagers, the possible location points are generated in the building block based on the shape of the control line. Further, building monoliths are generated at the generated location points. The building layout is generated when the constraints are satisfied. Finally, green areas are generated within the plot and beyond the buildings (Figure 5).

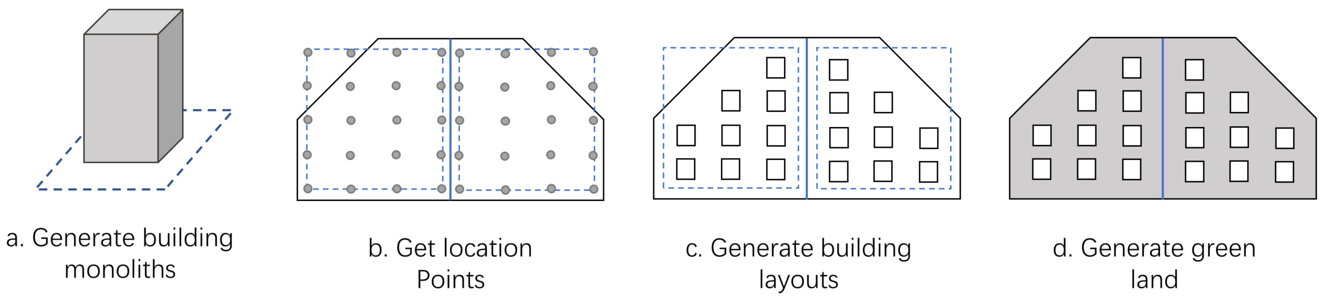


Figure 5. Building layout process.

3. Results

In this study, the remote-sensing image data of the study area and the current building information projection were converted. According to the main internal roads, Changban New Village was divided into four major building layout plots. As can be observed from the satellite images, the building outlines of the houses in Changban New Village were approximately rectangular, and the building outline area was approximately 85–95 m^2. Therefore, rectangles of areas 90.71, 87.60, 95.34, and 95.34 m^2 were randomly generated as the architectural outlines of the simulation schemes for each block. Moreover, based on field research and code requirements, the number of floors of each building was unified to three.

Combined with the rules in Table 2, it is necessary to input planning conditions into the intelligent generative design algorithm, such as land boundaries, building spacing, building layers, and the number of buildings to be generated. As there was no clear requirement for the setback of rural land in the specification, the setback distance was set at 2.5 m here. Furthermore, it is assumed that all areas within the site area except for buildings are green areas. The building layout parameters were adjusted according to the general rules of architectural design as outlined. For example, we set the main orientation spacing of the building to 6 m and the secondary orientation spacing to 2 m, and we ran the program to generate the design results (Figure 6). Finally, we obtained the intelligent layout design of the building and related specific technical indicators, such as plot ratio and building density.

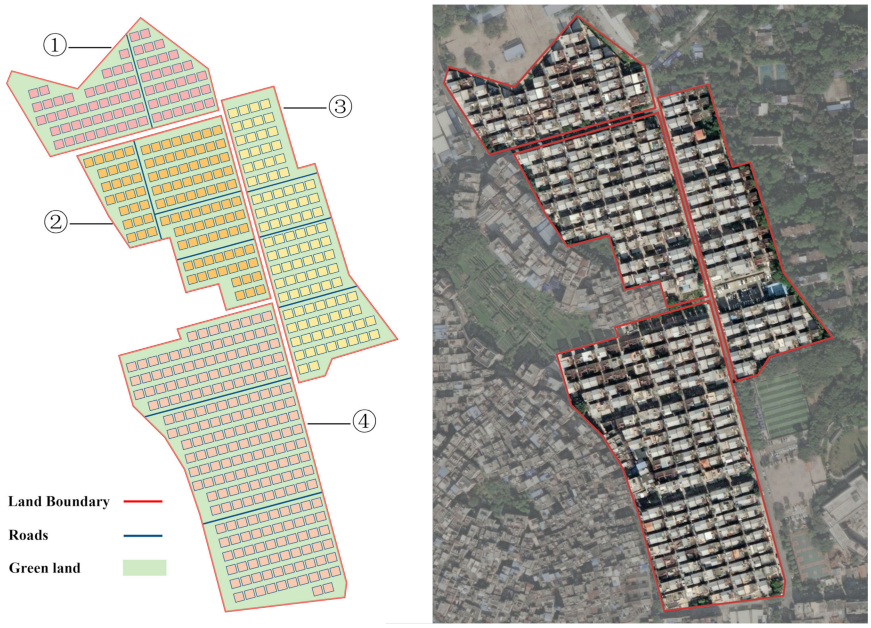


Figure 6. Comparison of simulated and actual scenarios.

From the comparison between the layout-design results and the actual layout in Table 3, the absolute values of the differences in the plot ratios of the four building layout sites were 0.02, 0.02, 0.10, and 0.02, respectively, with an average value of approximately 0.04, and the absolute values of the differences in building density were 1%, 1%, 4%, and 1%, respectively, with an average value of approximately 2%. The plot ratio and building density are important evaluation indicators for evaluating the building layout. From the comparison between our results and the current layout in Figure 6, the plot ratio and building density of both were similar, and the difference was within the controllable range, indicating that the model can generate buildings that meet the needs. Further comparison revealed that the architectural group division of the design results was similar to that of the actual layout. At the same time, the simulation result was more regular, and the building spacing was more appropriate when the number of buildings in the simulation result and the actual condition was similar. By analyzing the difference between the simulation results and the actual layout, the main orientation spacing of some buildings in the actual layout did not strictly follow the rule of 6 m or more, and even the main orientation spacing of some buildings was only 2 m. In contrast, the building outlines used for simulation in this study were randomly generated rectangles with a similar area and shape after combining them with the existing measurement. Additionally, the building outline area was unified to a certain fixed value. However, the building area and shape of each house changed according to the specific environment so as to maximize the use of the plot within the same land use range. In terms of the generation efficiency of the simulation design, the generation time of the design solutions of the four major plots was within 10 s, which greatly saves the time required for manual planning and design compared with the traditional planning and design means.

Table 3. Comparison of simulated and actual scenarios.

	①		②		③		④	
	Simulated	**Actual**	**Simulated**	**Actual**	**Simulated**	**Actual**	**Simulated**	**Actual**
The land area	17,740.05	17,740.05	24,155.51	24,155.51	25,079.23	25,079.23	47,321.8	47,321.8
Floor area	90.71	90.71	87.6	87.6	95.34	95.34	95.34	95.34
Architectural building number	75	76	108	106	104	96	213	216
FAR	1.15	1.17	1.17	1.15	1.19	1.09	1.29	1.31
Building density	38%	39%	39%	38%	40%	36%	43%	44%

Note. FAR: Floor area ratio, it refers to the ratio of the total floor area of a parcel to the area of the parcel.

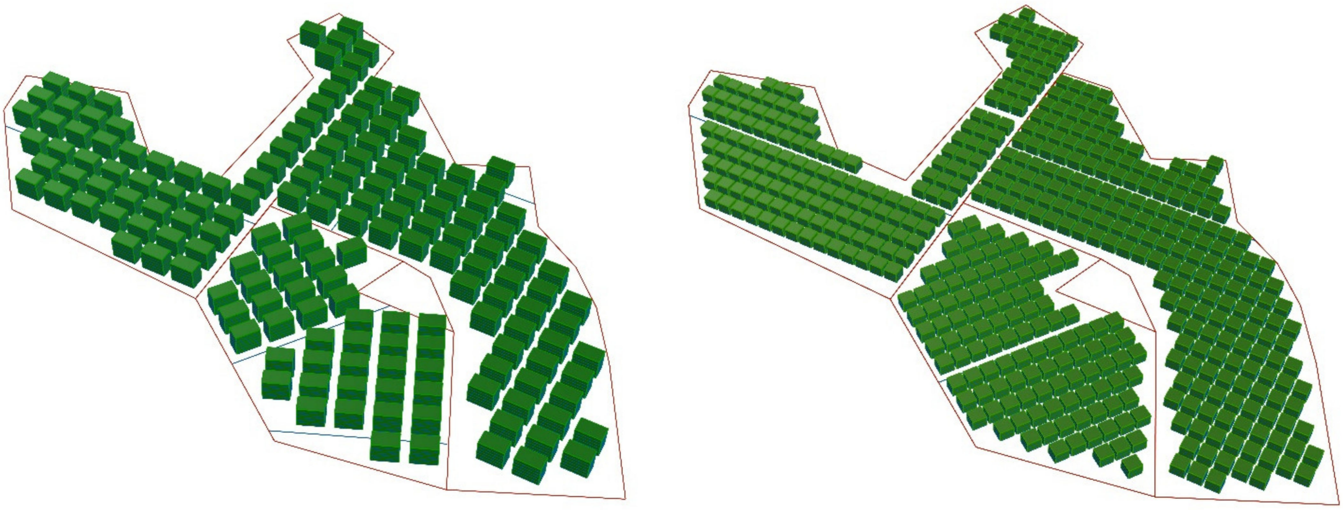
As land resources become increasingly precious, decreasing vacant land is available for building houses. However, the demand of villagers to acquire their own houses increases. Simultaneously, attracted by the cheap rent, an increasing number of migrant workers is living in urban villages. In this situation, to meet the housing demand and improve the efficiency of land use, the government is promoting village committees to build apartment-style houses that can replace the old pattern of 'one house per family'. In this study, the old village of Changban Old Village was considered as an example and applied to apartment-style houses and non-apartment-style houses. Finally, the application of the method and the areas for improvement have been discussed.

This method was applied to a piece of land in Changban Old Village to generate both apartment-style and non-apartment-style residential designs. According to the regulatory requirements, the number of residential floors was set to six for apartment-style and three for non-apartment-style residential, considering the building height of the surrounding environment. The relevant parameters and results are listed in Table 4. By modifying the input parameters, the program can quickly generate design schemes with different requirements (Figure 7), and the output results meet the specification requirements. Therefore, this method can generate many architectural layout design schemes that meet the requirements and specifications in a short period and can provide strong technical support and feasible planning and design schemes for rural planning and rural managers.

Table 4. Layout plan for apartment houses and non-apartment houses.

Input Parameters	**Apartment-Style Housing Scheme**	**Non-Apartment-Style Housing Scheme**	**Results**	**Apartment-Style Housing Scheme**	**Non-Apartment-Style Housing Scheme**
Building base area (m^2)	198.81	90.71	Architectural building number	167	487
Main orientation spacing (m)	9	6	Site area (m^2)	114,529.22	114,529.22
Sub-orientation spacing (m)	6.8	2	Total construction area (m^2)	199,207.62	132,527.31
Floors	6	3	Building density	29%	39%
Floor height (m)	2.8	2.8	FAR	1.74	1.16

Note. FAR: Floor area ratio, it refers to the ratio of the total floor area of a parcel to the area of the parcel.



(**a**) Apartment-style housing scheme (**b**) non-apartment-style housing scheme

Figure 7. Two layout designs in Changban old village.

These results indicate that the number of apartment-style dwellings was lower than the number of non-apartment-style dwellings. However, for the same land area, the floor area of apartment houses was 66,680.31 m^2 more than that of non-apartment houses, the building density was 10% less than that of non-apartment houses, and the floor area ratio increased by 0.58. From these values, apartment houses greatly improve the efficiency of land use and can better meet people's housing needs.

Furthermore, the method was applied to another urban village (Xiaoping Village) in Guangzhou (see Figure 8). Therefore, in this study, we estimated the floor area ratio of the village based on the building data and field conditions, which indicated that the floor area ratio of Xiaoping Village was approximately 2.89 and the building density 48%. To satisfy their own needs and to pursue more economic benefits (e.g., more income from renting out their houses), we assumed that the villagers aim to obtain more floor area (i.e., floor area ratio >2.89 for the simulated scenario). Therefore, according to the requirements presented in Table 2, the intelligent building planning generation constraints are set as follows: Number of floors is nine, primary orientation is equal to 14 m, secondary orientation is equal to 6 m, building density is less than 50%, and input an area of 280 square meters of building footprint for simulation. The result generated 114 buildings for a floor area ratio of 3.02 and a building density of 36%. The generated scenario can satisfy all the constraints in terms of the current situation and the generated results. The generated scenario has a lower building density and provides more floor space. This means that the villagers have more floor space for renting, thus increasing the economic income. Subsequently, as the number of residential floors increases, the spacing between buildings increases, and the building density decreases, allowing more public space for public facilities and activities in the same area, as well as higher lighting requirements for the buildings. Therefore, according to the needs and wishes of the villagers, this method can use computer technology to complete the process of mapping and basic numerical calculation and intelligently generate construction solutions in different forms, providing the villagers with blueprints and references for urban village renovation and construction. By entering simple parameters as constraints, this method can quickly generate a plan that meets the target, greatly improving the 'operability' of the plan and making it possible for villagers to 'design' the plan, thus breaking the 'knowledge barrier' and allowing villagers to actively participate in the transformation of urban villages, changing their previous passive position. In addition, applying the method to the planner's initial communication with the villagers allows them to efficiently establish the design goals of the future program.

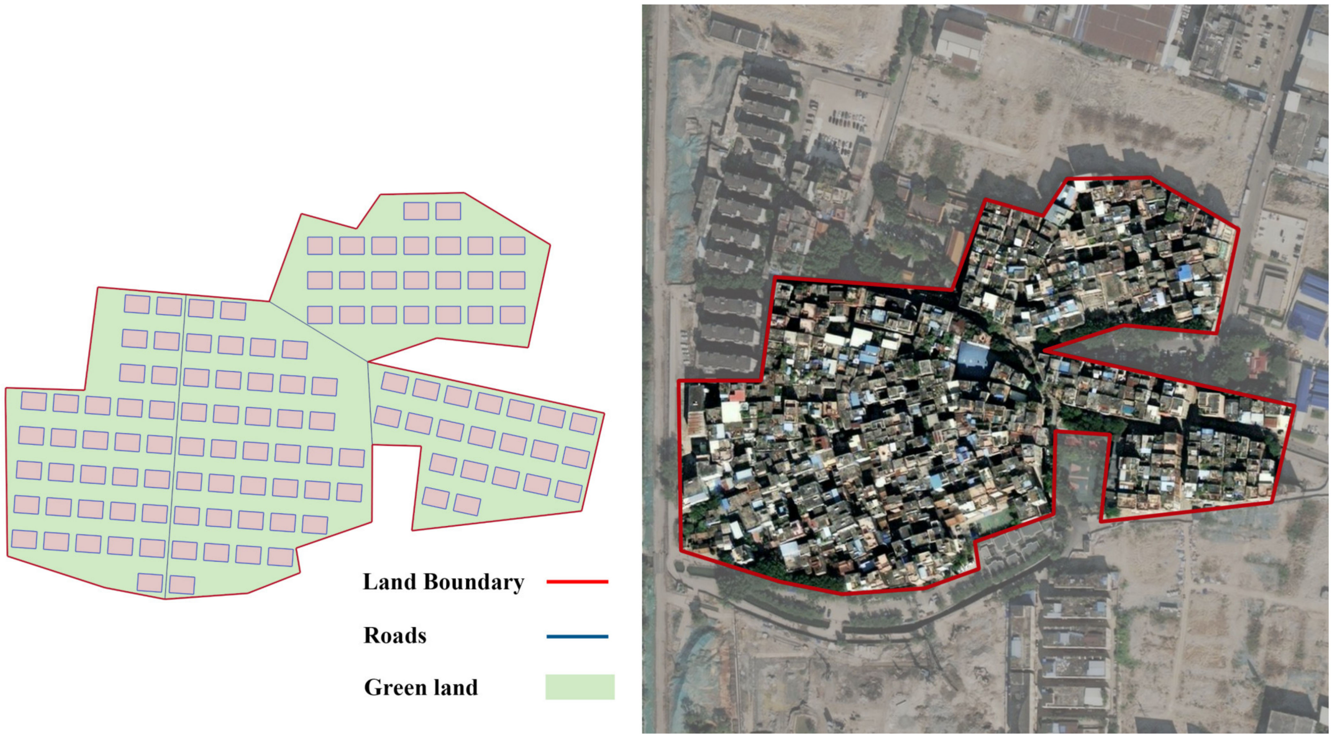


Figure 8. Layout design of Xiaoping Village.

4. Discussion

The use of computational methods to facilitate design exploration can support an iterative design process to find appropriate solutions to the requirements and needs of users and regulations. In the field of planning and design, design generation methods are considered 'auxiliaries' where the computer becomes a design generator in addition to its traditional role as a drafter and visualizer [53]. Despite the growing interest in generative design approaches, insufficient research has been conducted in the field of urban villages. In this study, we analyzed the mechanism of urban village transformation in China, constructed a generative design framework suitable for urban village transformation and tested and applied the framework through practical cases. In contrast to the common framework of urban village transformation summarized from a management perspective, in this study, we first analyzed the formation of urban villages and the motivation for transformation, and then combined that driving process to build a generative design framework from the perspective of specific implementers (villagers). The villagers' housing and environmental needs were translated into design conditions, that is, the number of houses and the spacing between houses, to provide suitable solutions for the implementation of urban village renovation. The theoretical framework and algorithm implementation were verified by considering Changban Village as an example, and the results better generated a design solution that meets the demand. Guangzhou, a core city located in the Pearl River Delta, has numerous urban villages in urgent need of renovation. These urban villages, similar to Changban Village, have similar characteristics such as high density and poor living environment [54], and the villagers have the desire to improve their living environment. Therefore, the method is also applicable to the generation of renovation plans for other urban villages in Guangzhou, providing villagers with solutions that satisfy their needs and regulatory conditions for their own construction. In addition, in this study, we translated the rules of industrial land and commercial land according to the regulatory conditions so that villagers can input the parameters of planning conditions and obtain the corresponding design plans according to their needs.

The framework presented in this study was mainly applied to the consultation and communication process between planners and villagers and plays the role of improving the efficiency of communication, which can enhance the effectiveness of villagers' participation in planning to some extent. However, factors affecting public participation also include social influence (e.g., the degree of promotion and publicity in the community). The use of multimedia tools can solve this problem to some extent. However, the framework built in this study does not incorporate multimedia elements. The influence exerted by the intelligent design tool is mainly between the planners and the villagers who actively participate in the consultation. If the framework further incorporates multimedia elements, the impact of intelligent design-assisted renewal and participation may be more profound.

In addition, this study mainly conceptualized a framework for intelligent design-assisted urban village renewal but does not further explore the details of the interaction interface, which may be related to the user's perception [55]. In reality, a good application cannot be achieved without a good interactive interface and easy-to-understand text and symbols on the interface. In other words, the next step can be to further explore how to popularize the terminology so as to combine it with intelligent design and improve the effectiveness of villagers' participation.

In terms of the target audience for the application, the framework constructed in this study does not consider the role of the government. However, the government acts as a manager in renewal. In general, one of their responsibilities is to review the compliance of planning schemes with statutory standards and requirements. Again, this review process can be performed with the help of computer arithmetic. The key lies in translating the normative guidelines into a scientific computing language, which is one of the directions for future research.

Finally, in the specific application process, the study only represents the building outline via rectangles. However, in the actual planning scheme, the building outline is often a complex polygon at this stage. For this reason, the method of 'minimum external rectangle' can be used to calculate the minimum external rectangle of complex building outlines and then to calculate the building spacing. However, this method only uses the same type of building (same shape and area) for simulation and does not involve the combination of multiple types of buildings. In reality, buildings of the same type are often clustered (concentrated). Therefore, it is possible to take the lead in zoning different types of buildings when entering the planning area and then perform scenario generation. In addition, the spacing between buildings may change with the environment. Therefore, it is necessary to further refine the setting of the program and further consider environmental factors such as water, green space, and soil.

5. Conclusions

A renewal system cannot be implemented without the guidance of planning schemes. However, for a long time, the planning schemes have been designed by professional urban planners. It is difficult for the non-specialized public, especially those in rural areas, to obtain professional and reliable plans, thus creating many environmental and spatial layout problems. Although villagers can be involved in the planning process in many ways, there are problems such as 'knowledge limitations' and 'misunderstandings' that affect the extent and effectiveness of villagers' participation in the planning process. Therefore, in this study, we explored the role of smart planning in improving public participation in conjunction with the basic process of regeneration and constructed a regeneration process under the influence of smart planning. Meanwhile, the potential of intelligent design generation to assist in urban village renovation and planning was further explored. The proposed framework and basic methods of intelligent design performed well during validation and concrete application. In this study, the method and process were used to conduct experiments in the village of Changban. The major findings were as follows: (1) The results of the simulated layout were similar to those of the actual layout, and the floor area ratio and building density of the simulated results were similar to the actual values, which indicates the effectiveness of the rules of the transcription and the design of the program. (2) The number of households (number of buildings) in the generated design plan was similar to the actual number of households, which means that the method meets the demand for 'new houses' in villages while generating a layout plan that meets the planning conditions and optimizes the problem of small spacing between some buildings. (3) The method is efficient and can quickly generate multiple scenarios.

Therefore, using this method for renewal planning and design can quickly generate a variety of building layout plans with feasibility and practicality according to certain needs. This can improve the effectiveness of communication between villagers and planners and provide a reference for decision-making in urban village renewal. Second, the method adopts a visual parameter design, which has the characteristics of strong interactivity. The user can quickly grasp the operation while the design results can be output visually. This method helps to realize the intelligence of urban village planning and construction, allowing more non-professional planners (such as villagers) to participate in the actual planning and design process and allowing villagers to better express their needs and become the 'designers' of the plan. Therefore, this model of using intelligent technology to assist urban village renewal can make up for the limitations of 'government-led' or 'market-led' models and improve the villagers' enthusiasm and initiative to participate in urban village renewal, making this model more sustainable.

Finally, this study has some limitations (see Section 4). In future research, the following aspects should be further explored. Intelligent design to improve the effectiveness of villagers' participation can be further developed in terms of multimedia and interactive interfaces. The current framework mainly uses villagers and planners as users. However, in reality, the role of the government is indispensable. In the future, the role of the government should be considered, and the government can be integrated into the intelligent planning and design process to realize the whole process of intelligent planning and design. In addition, the algorithm implementation can be extended in the future. More types of buildings and environmental elements than those in this study should be considered to yield intelligently generated rich results.

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