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专业学位硕士学位论文

增强现实下的社区参与式设计方法—以广州环秀坊滨水空间改造为例

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Community Participatory Design Methods under Augmented Reality: the Revitalization of the Waterfront Space in Huanxiufang community

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摘 要

在中国城市建设逐步转向存量更新的大背景下，作为公共空间真正的使用者，社区的公共空间改造越来越强调公众的参与。同时增强现实技术的发展也为传统的参与式设计模式提供了新的思路。本文主要通过文献研究以及设计实践的方式探讨了如何将新技术手段作用于传统的参与式设计模式、如何提出适用于旧村改造的参与式设计策略两个问题，并通过量化实验的方式对增强现实参与式手段进行了可行性评估，并结合实践论证的方式对增强现实参与模式进行了实证研究。

本文的理论研究部分主要通过文献分析法和案例分析法对参与式设计的基础理论进行了剖析，并指出其在构成要素和方法工具上都具有利用增强现实手段进行优化的可能性；同时结合增强现实技术的理论研究来探讨其应用于参与式设计方法的可能性。最后结合案例和文献，探讨了将增强现实技术作为参与式设计方法的理论研究。

而后，本文结合了两处广州旧村改造的参与式设计案例推演提炼了增强现实参与式设计的策略和方法，并针对其进行了相关的可行性实验论证。本文确定了以空间功能、布局、尺度、色彩、界面、绿植等六个空间要素指标以及普遍性、易学易懂性、表达准确度、趣味性、满足感、效用性等六个主观评价指标。通过对指标进行相关性分析以及频数分析对传统参与模式和增强现实参与模式进行量化的对比评价，通过公众的满意度对比论证了增强现实技术应用于参与式设计的可行性。

最后，通过具体的实践论证，将上述策略与方法应用于广州环秀坊社区的改造更新，进一步优化了场地中四个节点空间以及道路系统，验证了增强现实参与模式的有效性。结合设计成果和公众反馈意见，本文对方法路径和流程提出了建议与展望。

关键词：增强现实；参与式设计；旧村改造；沥滘村

Abstract

As China's urban development shifts towards stock renewal, the transformation of community public spaces increasingly prioritizes public participation as the true users. Concurrently, augmented reality technology offers fresh perspectives on traditional participatory design models. This paper explores two main questions: how to integrate new technologies into traditional participatory design and how to develop strategies for renovating old villages. A feasibility assessment of AR participatory methods was conducted through quantitative experiments, alongside empirical research on AR participatory models based on practical evidence.

The theoretical research section of this paper primarily uses literature analysis and case studies to examine the foundational theories of participatory design, emphasizing how augmented reality can optimize its components and methods. It also integrates research on AR technology to assess its applicability in participatory design. Finally, the paper discusses the theoretical basis for using AR as a participatory design method, supported by case studies and literature.

Subsequently, the paper extracts strategies and methods for AR participatory design from two participatory design cases of old village renovations in Guangzhou, and conducts relevant feasibility experiments. The study identifies six spatial element indicators (spatial function, layout, scale, color, interface, greenery) and six subjective evaluation indicators (universality, ease of learning, accuracy of expression, engagement, satisfaction, utility). A quantitative comparative evaluation of traditional participatory models and AR participatory models was conducted through correlation analysis and frequency analysis of these indicators, and the feasibility of applying AR technology in participatory design was validated through public satisfaction comparisons.

Finally, through specific practical demonstrations, the above strategies and methods were applied to the renovation of the Huanxiufang community in Guangzhou, further optimizing four node spaces and the road system within the site, thereby validating the effectiveness of the AR participatory model. Based on design outcomes and public feedback, the paper offers suggestions and prospects for the methodological pathways and processes.

Keywords: Augmented Reality； Participatory Design； Renovation of Old Villages； Lijiao Village

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Chapter 1 Introduction

1.1 Research Origin

1.1.1 The old village faces the growing demand for renovation.

With the rapid development of China's economy and the accelerating process of urbanization, people's expectations for a better urban life are increasing. Community public spaces, as important places for residents' daily activities, are crucial components for enhancing a sense of belonging and increasing cohesion. In China, old residential communities and dilapidated urban villages, products of specific historical conditions, were constructed in large quantities as low-standard housing to quickly address the housing issues of the population during a relatively underdeveloped economic period. Today, they struggle to meet the growing living demands of the people[1]. The quality of public spaces in existing old villages is low, with frequent issues such as aging and damaged public facilities, limited space, and a lack of landscape greenery. These issues can no longer meet the increasing demands of the people. Against the backdrop of China's urban construction gradually shifting from expansion to renovation of existing stock, residents, as the true users of public space design, have diverse needs. Therefore, it is essential to fully consider residents' needs and clarify renovation goals in the transformation of old villages. This allows residents to transition from users of the design to participants in the design process, establishing a sustainable maintenance mechanism.

1.1.2 Public Participation as a Key Focus in Urban Renewal in China

In recent years, public participation has gradually become a core issue in the renovation of old communities. The policy level continues to strengthen the implementation path of this concept: In 2017, the Ministry of Housing and Urban-Rural Development explicitly advocated for the 'co-creation' model, aiming to stimulate residents' subjective awareness and mobilize the enthusiasm of all parties to participate actively in the renovation process; By 2020, the State Council systematically constructed a participation framework in the "Guiding Opinions on Comprehensively Promoting the Renovation of Old Urban Residential Communities", requiring the improvement of public participation mechanisms, particularly emphasizing the use of digital platforms such as "Internet + Co-construction, Co-governance, and Shared Benefits," to accurately grasp residents' needs through a diversified consultation mechanism led by party organizations, promote the formation of community consensus, and encourage multi-party collaborative construction.

This evolution from macro policy orientation to specific implementation strategies signifies that the public participation model is gradually extending to the micro-governance level of community renovation, and the necessity of public participation in design is continually increasing.

Under the principle of human-centered values, renovation must be based on full participation of residents. From the initial decision-making to participation in the intermediate processes, and finally to the usage and maintenance after the renovation is completed, the role of residents fundamentally determines the significance and effectiveness of the renovation or upgrading work. This work cannot be advanced through a top-down, government-led approach; instead, it should adopt a bottom-up mechanism primarily focused on resident participation[1]. However, during the practical implementation of renovations, the construction of public participation mechanisms still faces multiple dilemmas. The core issues are reflected in the superficial tendency of participation forms and the fragmented characteristics of participation levels. The methods and extent of public participation are not diverse or in-depth enough, necessitating the exploration of new ways of public participation to better understand the needs and wishes of community residents.

The effectiveness and quality of public participation is also a key issue. Theoretically, while public participation can enhance the democracy and inclusiveness of design renovations, this is premised on the full respect and recognition of the processes and outcomes of public participation. If the processes and results of public participation are not sufficiently recognized and respected, blindly advancing the design may instead lead to residents' resentment and resistance, ultimately affecting the implementation effectiveness of the renovation. Therefore, it is necessary to establish a scientific public participation mechanism to ensure the realization of the value of the participation process, while also improving residents' recognition and enhancing the effectiveness and quality of public participation.

1.1.3 Augmented Reality Technology Unlocks New Possibilities

Augmented reality (AR) technology, as an emerging technology, has been widely applied across various industries, with extensive application prospects in fields such as architectural design and urban planning. Designers utilize augmented reality technology in specific areas such as visual expression, professional education, green building analysis, and the preservation and renovation of historical buildings. Additionally, augmented reality can be employed in the early stages of architectural and urban design to help designers quickly understand site requirements and constraints, as well as the diverse demands of residents. Through augmented reality, designers can design and interact with proposed solutions in a virtual three-dimensional environment, saving time costs associated with waiting for actual construction and accelerating the design process.

Traditional spatial design methods focus on design thinking centered around drawings, utilizing tools such as text, hand-drawing, and models. However, the traditional techniques and approaches to spatial design can no longer meet the demands of modern society. Space planning and design primarily based on augmented reality technology have gradually become a social trend[2]. The emergence of augmented reality technology allows designers to think about design solutions within three-dimensional space and express design concepts.

In participatory design, traditional participatory methods have significant shortcomings in the presentation and interaction of spatial design. Participants are unable to intuitively express their opinions and suggestions through language, and designers find it challenging to accurately incorporate public feedback into design proposals. The emergence of augmented reality technology has created a bridge between designers and participants. As an important tool, augmented reality lowers the threshold of professionalism, allowing participants to immerse themselves in the experience of spatial scale and atmosphere. Additionally, the high interactivity of augmented reality enables participants to freely express their design intentions. Even ordinary individuals lacking professional knowledge can overcome cognitive barriers through virtual reality technology and actively engage in the design process, achieving participatory design and providing bottom-up design ideas.

1.2 Research Objectives and Significance

1.2.1 Research Objectives

The purpose of this study is to optimize traditional participatory design models through the application of augmented reality technology, enabling different groups to better contribute to the design process. For design users, augmented reality technology allows them to perceive the design elements of the spatial environment in a more intuitive and convenient way, providing designers with reasonable and diverse feedback. For designers, virtual reality technology facilitates the extraction of design requirements that need to be prioritized during the renovation process.

Additionally, this study evaluates the feasibility and public satisfaction of augmented reality technology in participatory design by analyzing its integration with traditional participatory design processes, costs, and understandability in the context of old village renovations. This exploration aims to address a series of issues currently present in the field of participatory design, highlighting the advantages and necessity of augmented reality technology in participatory design models. The ultimate goal is to summarize optimized application strategies for augmented reality technology in participatory design, providing better references and guidance for future urban renewal and old town renovations, while seeking more effective and valuable methods to rationally shape urban public spaces.

1.2.2 Research Significance

1. Theoretical Significance

At the theoretical level, research on existing traditional participatory design models for public spaces reveals that their development direction regarding emerging technologies, such as augmented reality, is still in the early exploratory stage. Therefore, this study employs empirical experiments within the community to quantitatively investigate and demonstrate the rationality of integrating augmented reality technology into traditional participatory design models, while also enriching the research content of this professional field by introducing new technologies.

At the same time, the participatory design model under augmented reality technology is a complex issue that encompasses multiple disciplinary fields. Therefore, this paper provides new ideas and directions for its theoretical research through practical project implementation, promoting the expansion of participatory design theory from a single disciplinary perspective to a direction of integrated technology. The research results not only deepen the understanding of public participation mechanisms but also propose potential pathways for theoretical innovation in community renewal driven by technology, offering new research dimensions for theoretical development in fields such as urban planning and digital technology.

2. Practical Significance

The practical significance of this research mainly lies in addressing some shortcomings of traditional participatory design. In the practice of participatory design for urban public spaces, designers typically need to formulate reasonable participation plans to achieve design goals. Compared to traditional participatory design models, the intervention of augmented reality technology can break through the representation of traditional 2D drawings, overcoming the professional limitations of flat representations, effectively enhancing the universality of participatory design while lowering the threshold for public participation in design, improving the effectiveness of public involvement in design and increasing the accuracy of feedback, which helps promote a bottom-up design decision-making model.

From the perspective of practical project implementation, the research on participatory design for public spaces requires the joint participation of multiple parties, making the entire process relatively complex and cumbersome. Therefore, it is essential to formulate reasonable design participation methods in the early stages to facilitate the progress of the design process. This paper optimizes the participation process, integrates technology to simplify complex collaborative steps, saving time costs and improving design efficiency, providing replicable operational paradigms for projects such as the renovation of old villages.

At the same time, this study summarizes the characteristics of different participatory modes of augmented reality technology, providing references for practitioners and helping them make more reasonable decisions in practice, thereby effectively saving time costs and improving design efficiency during the design process.

3.Social Significance

Urban public spaces are important places for recreation and social interaction for residents living nearby and local people. Since everyone has relatively fixed behavioral logics and specific needs in their daily lives, designers often cannot accurately anticipate the diverse needs of individuals. This can lead to a disconnect between the actual use of public spaces after design implementation and the original intentions of the designers. Therefore, researching participatory design for urban public spaces helps improve their quality and adaptability to meet the diverse demands of different community residents, thereby enhancing community vitality and cohesion. Additionally, the study of participatory design promotes public involvement in the collective construction and governance of communities, which also helps strengthen residents' sense of ownership and advance the democratization of society.

Secondly, participatory design, as a design strategy that spans different entities, requires communication and collaboration among multiple social groups to finalize the design scheme. This process necessitates reasonable communication and cooperation among various social groups, including local residents, designers, and government officials. Therefore, this study holds significant importance in promoting communication and collaboration among different social groups, contributing to the establishment of harmonious and orderly social relationships.

Through participatory design, residents can effectively engage in the discussions of urban public space design and planning, ensuring their status as primary users and designers. This, in turn, enhances their sense of participation and responsibility in the use and management of public spaces, making the development and management of urban public spaces more efficient and convenient. This will further elevate the city's image and quality of life, promoting urban economic development.

In summary, this study enhances the efficiency of traditional participatory design through the application of new technologies and summarizes the applicable scenarios and advantages of different participatory design strategies. This has significant implications for exploring the potential of digital technology in the fields of urban public space design and project management. Additionally, the results of design practice provide insights for promoting the development and application of digital technology across various domains, including architectural design, planning design, urban design, and project management.

1.3 Analysis of Related Concepts

1.3.1 Augmented Reality Technology

To elaborate on augmented reality technology, it is first necessary to distinguish between virtual reality technology and augmented reality technology. According to the "Reality-Virtuality Continuum" model (Fig 1-1) proposed by Paul Milgram and Fumio Kishino in 1994, the real environment and virtual environment form a continuous system, with each positioned at opposite ends of the spectrum[3]. The intermediate zone between the virtual and real environments is referred to as "mixed reality." The portion closer to the real environment is augmented reality, while the portion closer to the virtual environment is referred to as augmented virtuality. Thus, they represent different technological directions within the same system. Although they are distinct technological concepts, augmented reality and virtual reality technologies are often used interchangeably in many applications. Consequently, in various professional fields, some scholars discuss augmented reality technology as a subset of virtual reality technology.

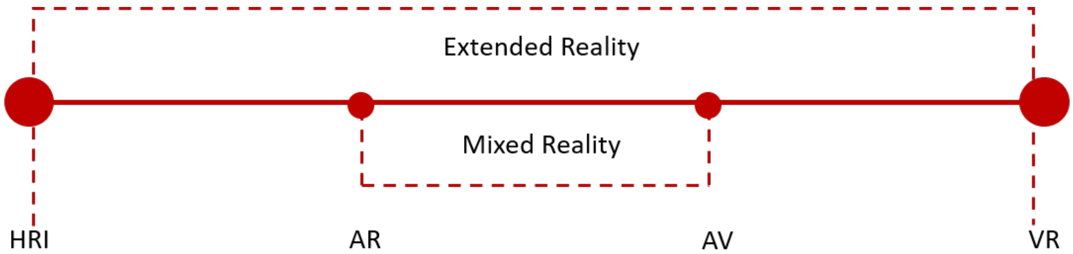


Fig 1-1 "Reality-Virtuality Continuum" (Source: by the author)

Next is the specific definition of augmented reality technology. The concept of augmented reality technology was first proposed by Tom Caudell and his colleagues at Boeing in the 1990s. For decades, universities, laboratories, research institutes, and enterprises around the world have continuously invested in research on augmented reality technology, achieving significant results[4]. According to research by Azuma published in 1997, three main characteristics of augmented reality technology can be summarized[5]:

Combining Real and Virtual: Virtual objects coexist within the user's field of view of the real world;

Real-Time Interaction: Users can interact naturally and in real-time with both the real world and virtual objects;

Three-Dimensional Registration: Virtual objects are accurately aligned with the real world.

Compared to virtual reality technology, the main distinction between augmented reality technology and virtual reality technology lies in the pursuit of "substituting reality" by virtual reality, while augmented reality focuses more on the concept of "enhancement." Augmented reality technology is a technique that allows computer-generated virtual images to be precisely overlaid on physical objects in real-time. It integrates multiple technological methods, including multimedia interaction technology, sensing technology, 3D modeling, and real-time tracking technology. By overlaying computer-generated media information (such as images, text, and 3D models) onto the real world through digital information simulation processing, the information from the virtual world and the information from the real world can complement each other, thereby enhancing the physical world with virtual elements. Unlike the complete immersion of virtual reality technology, the ultimate goal of augmented reality technology is to present virtual elements in real space for users and to interact with the real world, providing an engaging virtual content experience[6].

In recent years, with the advancement of technology, augmented reality technology has been widely used in mobile device applications[7]. Augmented reality technology can merge virtual scenes with real scenes and display them on the screens of smartphones and tablets through Video-See-Through (VST) displays, allowing for real-time user operations and interactions. At the same time, extended reality devices are continuously evolving towards miniaturization and cost reduction. Some suggested head-mounted displays that integrate with smartphones have also achieved significant technological breakthroughs. This has led to a decrease in the costs and limitations associated with the research and application of extended reality technology, providing new possibilities for research in the design field. Augmented reality and virtual reality technologies are increasingly being applied in the fields of architecture and urban design.

At the same time, augmented reality technology, as an innovative tool, has been widely applied in the field of participatory design, often serving as a tool for project presentation and experience. Its applications mainly include visualization, dynamic interaction, and enhancement of cross-spatial collaboration[8]. Numerous studies have shown that behavioral activities in virtual environments are largely consistent with those in real-world settings, which, to a certain extent, validates the feasibility of using augmented reality technology for experiential perception comparison.

1.3.2 Participatory Design

The theory of participatory design in public spaces originated from the concept of public space design in the 1960s. This concept advocates for urban residents to be involved in the process of public space design, while designers should consider various needs, visions, and factors such as community culture and historical heritage of the participants in their designs.

Broadly speaking, participatory design is often referred to as "public participatory design," with its core emphasis on "participation"[9]. The essence of participatory design lies in highlighting the subjective status of design users. By empowering users during the design process, they can engage in the design and planning of spaces, thereby genuinely influencing designers' decisions. The advantage of this design approach is that users are not passively accepting the "professional" design and reconstruction of their living environment by the government or designers; instead, they actively participate in the creation of their environment, effectively expressing their demands and even determining the construction plans for the environment[10].

Beyond focusing on the functionality and practicality of the space itself, participatory design also considers the users of public spaces, the community spaces themselves, and the relationship between the community and its surrounding environment. Furthermore, participatory design allows all stakeholders related to the design to have the opportunity to participate, engage in discussions, evaluations, and provide feedback, effectively promoting multi-party involvement and improving design quality. This drives public space design to better meet community needs and residents' expectations. Therefore, participatory design can play a crucial role at every stage of urban design practice.

Traditional participatory design methods include graphic questionnaires, focus group discussions, co-creation workshops, site visits, and design exhibitions. The advantage of these methods is that the public can directly participate in design discussions, while designers can gather valuable information about public needs and opinions. However, these methods also have certain drawbacks, such as high costs, difficulty in obtaining comprehensive feedback, and lengthy processes. Currently, practices in China advocate and attempt to encourage resident participation, but there is no consensus on how residents should participate and at what levels. The phenomenon of resident participation is often "one-time," and most "participatory design" is merely "design with participation"[11]. Therefore, the emergence of new technologies, such as virtual reality and augmented reality, provides a new perspective for traditional participatory design methods and can be used to improve participatory design approaches.

1.4 Current Research Status at Home and Abroad

1.4.1 Current Research Status of Participatory Design at Home and Abroad

Participatory design is an important design method that has undergone several decades of development abroad (Fig 1-2). Research indicates that participatory design methods can help architects and urban designers create solutions that better respond to user needs and visions[12]. As a design approach, participatory design intervenes in urban renewal processes, allowing for better listening to public opinions and suggestions, which can be incorporated into design decisions, leading to more human-centered urban public space design. In recent years, with continuous technological advancements and innovations, an increasing number of participatory design methods have emerged, such as the application of new technologies like virtual reality and augmented reality. These advancements make participatory design more efficient and convenient, lowering the threshold for public participation in urban renewal and providing more diverse avenues for participatory design.

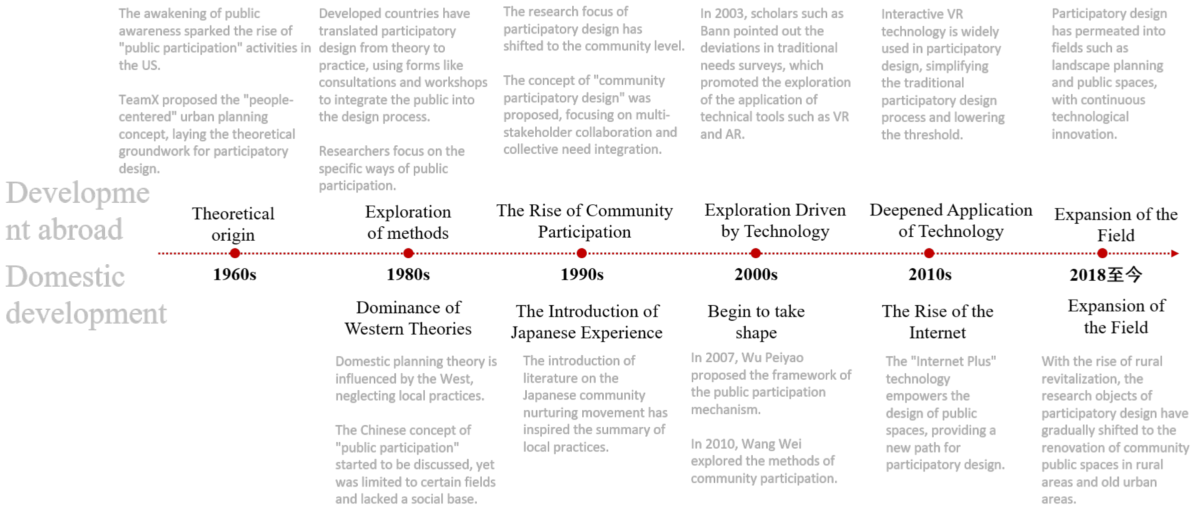


Fig 1-2 The Development History of Participatory Design Research at Home and Abroad (Source: by the author)

Participatory design originated early abroad, with its development traceable to the post-war 1960s, when public awareness began to awaken, and citizens started demanding participation in urban planning decisions. It is generally believed that the concept of "public participation" first emerged in the field of urban sociology and planning in the United States during the 1960s[13]. During this period, scholars represented by TeamX clearly proposed a "human-centered" urban planning philosophy, emphasizing that design should respond to user needs and systematically advocating for participatory design for the first time. In 1965, American scholar Davidoff introduced the theory of advocacy planning, establishing a theoretical foundation for public participation in planning. Subsequently, Lindblom's theory of incremental planning further expanded the research dimensions. By the 1980s, developed countries began exploring the feasibility of participatory design methods, gradually transitioning from theory to practice. The cooperative planning theories proposed by scholars such as Habermas and Foucault marked a progressive evolution from the nascent to the mature stages of the "participatory" concept in both academic discussions and practical applications. In the 1990s, the focus of participatory design research shifted to the community level, where scholars concentrated on how to more effectively promote the involvement of diverse stakeholders in design decisions, formally introducing the concept of "community participatory design," which emphasizes integrating diverse interests at the community level and expanding design from individual needs to collective needs.

Since the 21st century, participatory design has entered a new era driven by technology and expanded into diverse fields such as landscape planning and public spaces. In 2003, scholars like Bann pointed out the limitations of traditional needs assessment methods (such as surveys and interviews), noting that participants' "stated preferences" may deviate from their "actual preferences"[14]. This finding has spurred the exploration of technological tools, such as using augmented reality to visually present design proposals, which helps non-professional members of the public express their needs more accurately. In recent years, interactive virtual reality technology has been widely used in participatory design practices, with advantages that include simplifying participation processes, lowering the threshold for understanding professional symbols, and enhancing communication efficiency.

Compared to the development of participatory design abroad, research on public participation design in China started relatively late, and there are relatively few practical applications. The term "公众参与" in Chinese is a translation of the English term "public participation." In the 1980s, discussions began in China, but these efforts have largely been limited to specific fields and groups, lacking the broad social foundation and extensive actions seen in the United States and Canada[15]. Since modern times, the exploration of planning theory in China has undergone a series of influences from colonial cities and Western urban planning practices and theories. The academic community's admiration for "Western learning" has led to Western theories dominating the development of urban planning theory in China, while local practices and explorations have been largely overlooked. Beginning in the 1970s, with the deepening and development of Japan's community cultivation movement, relevant literature and planning ideas have increasingly had a profound impact on urban planning and construction in China. This indicates that if local practices can be timely summarized and fully respected, they may lead to the formation of theories that have a lasting impact on future domestic practices, providing valuable insights for the development of planning theory in China[16].

Around the year 2000, the early forms of participatory design began to emerge in China. In 2007, Wu Peiyao proposed the essence and methodological foundations of public participation mechanisms and designed an overall framework for practical application[17]. In 2010, Wang Wei introduced research methods for community participation in public spaces, leading to a deeper exploration of urban public space design involving community residents in China. With the advancement of technology, the rise of the internet and related new technologies in 2017 began to be gradually applied to participatory design in urban public spaces, providing new possibilities for the design and transformation of these spaces[19]. After 2018, with the implementation of the rural revitalization strategy, the focus of research on participatory design shifted towards the community public space renovation in rural areas and old urban districts. After 2020, against the backdrop of the pandemic, the continuous maturation of virtual reality and internet technologies further promoted the development of participatory design in community public spaces.

1.4.2 Research Status of AR Supported Participatory Design

In recent years, with the continuous innovation and development of technological means, an increasing number of participatory design methods have emerged. The participatory design approach supported by augmented reality serves as a design thinking framework that guides the entire design process in the virtual world. Regarding the theoretical research on the involvement of digital technology in participatory design, scholars have been exploring the feasibility of integrating augmented reality technology with urban renewal for over twenty years.

In 2002, Al-Kodmany provided a detailed overview of the evolution of technology in planning and design, summarizing the various planning and design tools from traditional methods like pen and paper to digital implementations, from paper maps to computer-supported Geographic Information Systems (GIS), from photographs to digital images, and from physical models to digital 3D models, while exploring the possibilities of integration with the virtual world[21]. In 2007, Gong Yong discussed how virtual reality can enhance public participation in urban planning, arguing that the combination of virtual reality technology, GIS, and the internet will fundamentally change the way the public engages in urban planning[22]. In 2010, Silva defined the inclusion of certain digital technologies, such as augmented reality and virtual reality, in participatory urban renewal as "digital participation," emphasizing that the extensive use of information and communication technologies in the planning process is a characteristic of what he termed digital planning or digital participation. He also added GIS, electronic participation devices, and digital information media to the list of technological tools applicable to participatory urban planning processes[23]. Silva's research significantly expanded the boundaries of participatory design and laid the foundation for the ongoing development of participatory design methods. Regarding the feasibility of spatial perception in virtual scenarios, Portman et al. (2015) demonstrated that the sense of presence provided by virtual reality and augmented reality devices creates a spatial perception similar to the actual experience of physical spaces, allowing for a more reliable, in-depth, and intuitive understanding of space[24]. According to Portman's research, the perception of virtual scenes can replicate spatial cognition in real-world settings and also reflect emotional feedback from elements like landscape greenery in real scenarios. Additionally, Portman's experimental results proved that virtual reality offers intuitive appeal and high efficiency compared to traditional participatory design, further validating the feasibility of augmented reality technology in spatial perception and laying a foundation for future research.

Subsequently, several scholars, including Falco (2016), Hanzl (2007), and Söbke & Londong (2014), have proposed various innovative technological tools and participatory methods for participatory design in urban renewal[25]. These tools include Web 2.0 media, open-source software, open data, collaborative mapping tools, decision support systems, blogs, GTFS data, and public open data. Research by Van Leeuwen et al. (2018) demonstrated the significant advantages of applying augmented reality technology in participatory urban design. Through augmented reality and virtual reality technologies, policymakers, local communities, urban planners, and stakeholder groups can collaborate to experience and better understand the environmental changes in planning before development occurs, thereby achieving information sharing and consensus-building throughout the planning process. In agreement with Falco et al., Hirscher (2017) also emphasized the importance of using new technological means in the early stages of planning to enhance information communication and increase public participation, further confirming the preemptive advantages of augmented reality technology in the initial stages of design and the feasibility of virtual reality technology in participatory design[26]. In 2018, Yao Jingyi drew on international experiences to suggest applying AR technology at different stages of public participation in urban planning, proposing that the integration of augmented reality with other methods could address the low level of public participation, insufficient engagement, and passive participation in urban planning in China[6]. Augmented reality is gradually being widely applied in urban planning. In 2019, Bartosh & Clark suggested that using augmented reality combined with urban data visualization in participatory urban design would bring numerous benefits and considered this a prerequisite for purpose-driven urban planning[27].

1.4.3 Summary of the relevant literature

Based on the above organization of the relevant literature, the following conclusions can be drawn:

There are still significant shortcomings in the empirical research on participatory design in public spaces. Although scholars like Al-Kodmany and Gong Yong explored the application of technological tools in planning in earlier studies, empirical research has mainly focused on the feasibility of technology, lacking quantitative analysis of residents' actual participation behaviors. For instance, while Portman's experiments demonstrated that virtual spaces can enhance spatial perception efficiency, they did not delve into the participation differences among various groups. Moreover, the issue of a singular participation channel is prominent, with traditional methods such as hearings and surveys still dominating, while the adoption of emerging tools remains insufficient. In the current process of old village renovation, villagers often find themselves in a state of low participation. However, by introducing new technological means, this situation can be changed, increasing villagers' participation and bringing new possibilities to traditional participatory design models. Additionally, the introduction of augmented reality technology can facilitate information sharing and communication, providing broader participation channels and enhancing the substantive involvement of villagers.

The application of augmented reality technology in participatory design holds considerable potential. Currently, the theories related to participatory design supported by augmented reality are continuously being refined. With the development of technology, the tools applied in participatory design methods are showing a trend of diversification, aligning more closely with public participation needs. Existing research has demonstrated that the technological advantages of augmented reality can address the issues of traditional participatory design, making it an important development direction for participatory design methods.

1.5 Research Methods and Framework

1.5.1 Research Methods

This article mainly consists of four parts: theoretical research, strategy derivation, experimental design, and project practice. In the theoretical research section, a literature analysis method is employed to systematically review the relevant theoretical studies and methods of participatory design in urban public spaces, discussing the components and commonly used methods of participatory design. Subsequently, the potential application of augmented reality technology in participatory design is explored through its development, characteristics, and its role in promoting spatial design approaches. Finally, through literature research and case studies, the theoretical framework for augmented reality as a method of participatory design is established, laying the theoretical foundation for subsequent strategy derivation and validation.

In the strategy derivation section, case analysis is primarily employed to examine the practical cases of traditional participatory design strategies in the renovation of old villages in Guangzhou. By summarizing case experiences, the augmented reality participatory design strategy is derived.

The experimental design section primarily verifies the validity of augmented reality participatory methods. Firstly, literature analysis is employed to collect and organize spatial element indicators of public participation in urban public space design from various research perspectives. Subsequently, relevant literature on interactive experiences is used to construct subjective evaluation indicators suitable for assessing participatory methods. In terms of the specific experimental process, a comparative analysis method is primarily adopted to conduct subjective evaluation analyses of traditional participatory design and augmented reality participatory design. Frequency analysis and correlation analysis methods are used to analyze the relationships between public needs, spatial elements, and participants' evaluations.

The research methods in the project practice section primarily involve field study and interviews. By conducting on-site research and personal experiences, the needs of public spaces from the designer's perspective are gathered. Subsequently, the augmented reality participatory model invites local residents to engage in co-design, providing practical validation of the augmented reality participatory model.

1.5.2 Research Framework

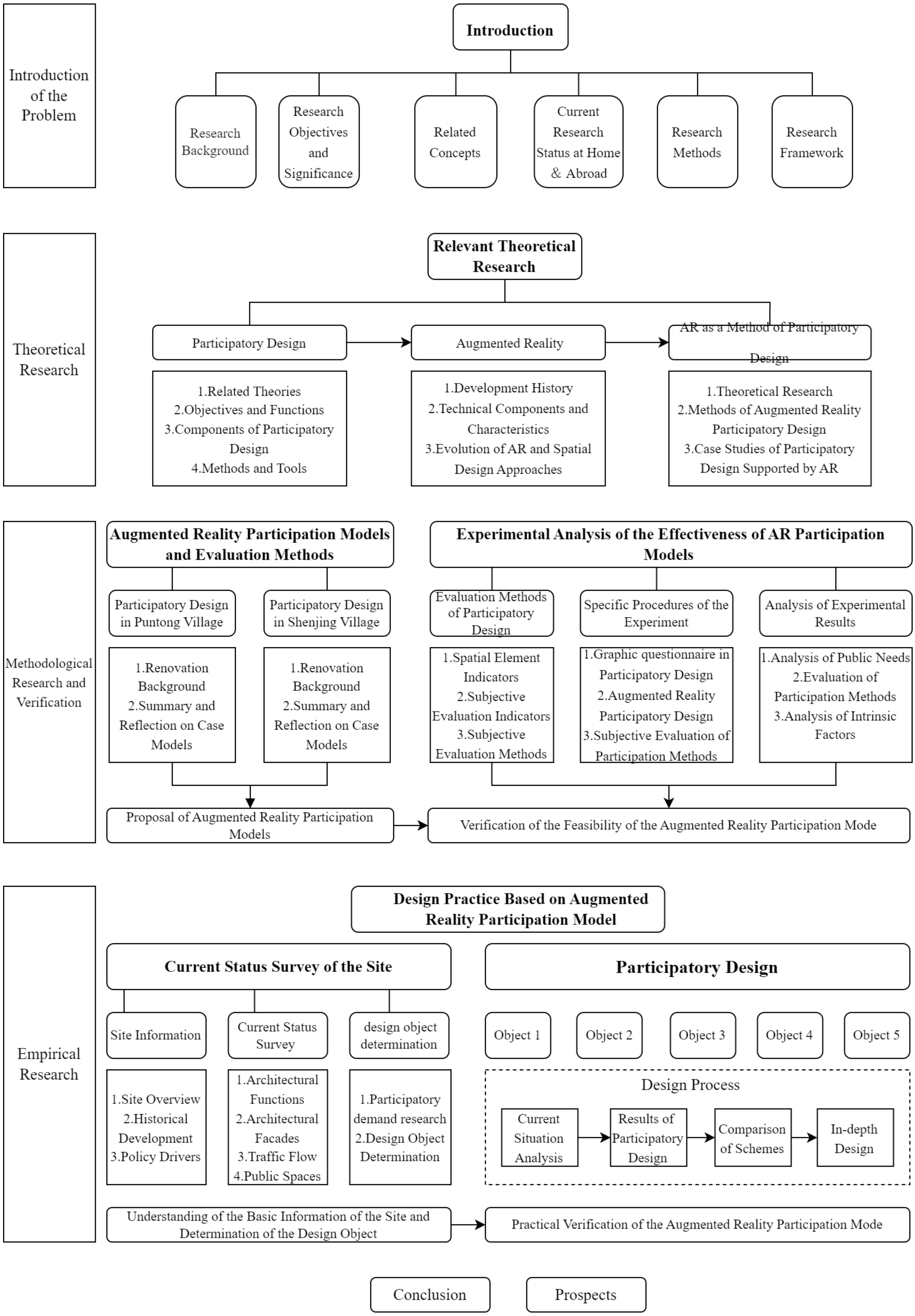


Fig 1-3 Research framework (Source: by the author)

Chapter 2 Relevant Theoretical Research

2.1 Theoretical Research on Participatory Design

2.1.1 Related Theories of Participatory Design

Participatory design is a comprehensive product of multidisciplinary collaboration, and thus there is no singular definition in academia[28]. From the perspective of industrial design, Spinuzzic (2005) theorizes that participatory design is a "rigorous research methodology" that emphasizes the interactions among people, practices, products, interactions, and knowledge[29]. Men Liang (2006) approaches the concept from the perspective of computer science, suggesting that participatory design is based on constructivism, positing that knowledge arises from the contextual interactions between people and society, thereby improving human life[30]. Jia Weiyang (2008) examines the operational model of traditional participatory design from the standpoint of architecture and planning, reflecting on its shortcomings and proposing the application of participatory design in interactive design through digital platforms to enhance communication and collaboration between designers and the public, thus realizing the concept of interactive design[31]. In 2012, Wen Jun explored the necessity of public participation in enhancing barrier-free design from the perspectives of residential comfort and inclusivity, systematically organizing the methods and frameworks for public participation in universal design[32]. In 2013, Lin Wanyi proposed that participatory design arises from a reflection on traditional rational planning that neglects space users, enabling designers and participants to collaboratively engage in the entire process of design, planning, and construction through creative and interactive methods[9]. In 2014, Randy Hurst, from the perspective of landscape studies, suggested that participatory community design is an environmental improvement mechanism that addresses issues such as uneven ecological resource distribution, social alienation, environmental degradation, and ineffective public space through citizen participation in the environmental design process[33]. In 2017, Peter Hasdell defined participatory design from a sociological perspective as the "aggregation of social material," repositioning it as an effective tool for sustainable development[34].

Overall, participatory design theory is a comprehensive and multidisciplinary framework that encompasses various research areas, including participation theory, social design theory, and community development theory. Participation theory focuses on how user involvement can enhance public space optimization, improve spatial experiences, and stimulate public enthusiasm and interest in participating in public space design, thereby increasing public vitality and engagement. Social theory addresses how design can be utilized to improve social welfare and promote societal development. Lastly, community development theory emphasizes leveraging community self-development to invigorate public space, enhance community environments, and strengthen community cohesion through cultural activities, thereby fostering positive self-improvement within the community. In summary, these three theories collectively form the theoretical framework for participatory design in public spaces, providing a solid theoretical foundation for its practice.

2.1.2 Objectives and Functions of Participatory Design

Participatory design is a collaborative process in which architects and urban planners work interactively with the general public to jointly engage in planning or design. Its primary aim is to empower ordinary citizens with a certain degree of control over their living environments[35]. Through participatory design, users are no longer passive observers; designers no longer unilaterally determine the living conditions of others. Instead, the process awakens the latent creativity of individuals by fostering collaboration, allowing users to participate in the design of residential spaces, public facilities, urban public spaces, and overall urban planning. This approach creates richer spaces that are more human-centered and better meet user needs. Additionally, the personal experiences gained from participating in the design process strengthen users' sense of agency, encouraging them to take on community responsibilities and thereby fostering a more harmonious, stable, and self-sufficient community environment.

In the specific practice of urban design, participatory design can be applied at various stages and play a significant role (Fig 2-1). The typical participatory design process can be roughly divided into four stages: needs assessment, feedback, optimization, and consensus. To align with social development and the demands of the times, we should accelerate the establishment of public participation systems and the evolution of participatory design.

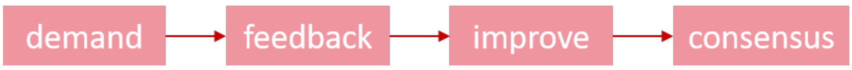


Fig 2-1 Common Participatory Design Process(Source: by the author)

The fundamental purpose of participatory design is to enhance communication, enabling design outcomes to better meet users' needs and expectations. Specifically, the role of participatory design can be summarized in the following six aspects:

1.Accelerating Information Exchange and Communication

Participatory design can help participants understand the purposes, processes, and relevant methods of urban design practices. Additionally, through user participation, research progress and results can be disseminated in a timely manner, along with the publication of evaluation data related to the design.

2.Identifying Diverse User Needs and Their Importance

Through user participation, designers can more quickly identify the factors and issues that are significant to the community regarding the design site, as well as rapidly ascertain public needs, the scope of issues, and other design-related concerns.

3.Diversity of Solutions

Participatory design allows the public to engage further in discussions of validated proposals and the evaluation of alternative solutions, while also providing input on shortcomings in original concepts, leading to the iteration of higher-quality design solutions.

4.Rapid Collection of User Feedback

Through participatory design, designers can quickly gather users' perceptions of important influencing factors and their experiences of spatial perception, gaining insights into participants' views on the relationships among various aspects of the design site and urban social activities.

5.Evaluation of Alternative Solutions

Participatory design enables the comparison of multiple proposals through evaluations conducted by various users.

6.Conflict Resolution and Negotiation

Participation allows for the identification of conflicting issues, facilitating conflict resolution and compensation efforts, and reaching consensus on the optimal solution, thereby avoiding unnecessary disputes later on[36].

2.1.3 Components of Participatory Design

Regarding the components of traditional participatory design, there is currently no singular definition or answer provided by scholars. Based on the theoretical research of Arnstein and Sanders, this paper roughly categorizes the components of traditional participatory design into the following aspects: scope of participants, design cycle, site scale, means of participation, and design purpose.

1.Scope of Participants: This primarily refers to the design subjects and objects, which change according to the objectives and usually serve the intended design. For example, the participants in the participatory design of community public spaces are the permanent residents of that community. However, traditional participatory design often tends to overlook the substantial participation of certain marginalized groups, such as individuals with disabilities and digitally disadvantaged populations. In traditional participatory design models, these participants are often regarded merely as information providers rather than co-creators as described in Sanders' theory[37].

2.Design Cycle: The time cost required for participatory design. The design cycle in traditional participatory design models is generally linear, comprising research-proposal-feedback-modification. Additionally, traditional drawings and models often struggle to respond quickly to changes in demand, resulting in longer design cycles and consequently leading to gaps in participation. As Arnstein pointed out in his ladder of citizen participation theory, residents often only engage in the initial research and final confirmation phases[38].

3.Site Scale: The scope of the site involved in participatory design and the area covered by the design participants. The site for participatory design in urban public spaces is typically a public space area within the city, covering the surrounding target area. This study mainly focuses on participatory design in public spaces, with the site being the internal streets or parks of the community, covering the entire community. Traditional participatory models often use two-dimensional drawings that are highly technical and difficult for residents to understand, which can lead to discrepancies in spatial perception.

4.Means of Participation: The methods through which the public engages in design, which also serve as the primary basis for classifying traditional participatory design. Traditional participatory design typically employs verbal, written, and graphic media; this singular mode of expression makes it challenging to convey an accurate spatial experience.

5.Design Purpose: The subject of public participation in design. This paper focuses on the renovation of public spaces within communities.

In summary, while traditional participatory design has developed as a design concept and method over many years, it does have several shortcomings that need urgent improvement. The emergence of augmented reality technology can provide innovative enhancements to the five elements. For instance, regarding the scope of participants, augmented reality enables participants to transition from passive respondents to active design agents, allowing marginalized groups to engage in the design process and expanding the range of design participants. In terms of the design cycle, the application of augmented reality can assist designers in rapidly iterating designs, accelerating the production of design prototypes. Regarding site scale, augmented reality allows the public to better understand the scale of design. Currently, numerous studies have integrated digital technologies and spatial perception devices (such as eye trackers) to facilitate large-scale site perception and gather participants' perceptual preferences.

2.1.4 Methods and Tools of Participatory Design

In terms of methods and tools for participatory design, this paper primarily references SeveB's summary of traditional participatory design methods and tools[39].

1.Drawing: Drawing is a commonly used tool for public participation, often employed in the early stages of data collection or sketching. Its advantage lies in the ability to capture participants' thought processes and emotional feedback in real time.

However, overly open forms of expression may lead to ambiguity in information transmission due to individual differences in thinking or insufficient drawing skills.

2.Writing: Written records serve as a method in participatory design and are often used in conjunction with discussions. They systematically document the framework and design pathways of public exchanges regarding design decisions.

The advantage lies in the ability to provide detailed records; however, the abstract nature of written symbols limits their visual representation.

3.Interviews: Interviews serve as a tool for in-depth research and are typically conducted in one-on-one or small group formats. Through progressively deeper discussions on topics, they can explore participants' inner thoughts and more accurately reflect public demands.

However, the results of interviews are constrained by participants' expressive abilities, leading to individual differences. Additionally, achieving more precise results requires a longer time investment, resulting in noticeable inefficiencies (Fig 2-2).

Fig 2-2 Interviews and Public Opinion Surveys (Source: reference[51])

4.Public Opinion Surveys: Public opinion surveys typically use questionnaires to quantify group demands. The advantages lie in efficient data collection and convenient distribution methods.

However, the accuracy and reliability of the surveys are constrained by the professionalism of the questionnaires, which imposes high demands on the expertise of the research team.

5.Discussion Forums: Discussion forums facilitate the exchange of design opinions and decision-making through group formats. The public can participate in meetings by electing representatives to discuss design proposals and share various opinions and ideas.

Compared to interviews, discussion forums are more representative and suitable for policy-making, but they still have limitations in expression.

6.Open Urban Public Spaces: Through regular meetings, the public can decide on the functions and aesthetic expressions of spaces within public areas, such as murals, installation art, or park landscaping.

The innovation lies in opening creative dimensions, stimulating public participation, and enhancing a sense of belonging. However, balancing public creative expression with urban management regulations requires policy support and a certain level of urban public space resources, which can be conceptually challenging and cumbersome.

7.Route Mapping: By employing certain technological methods, the walking and cycling routes of participants over a specified period can be visualized to identify the movement patterns and demand trends of the public within urban public spaces.

Additionally, it involves investigating the spatial functions, walkability, and road accessibility of the relevant areas.

8.Community Workshops: Through the organization of creative public space model-making events, community residents can have their practical abilities and innovative thinking fully stimulated. Models act as the most straightforward way to convey ideas during design discussions and when making decisions.

Nonetheless, considering the intricate nature of the model-building process and the relatively steep learning curve involved, this method might not effectively represent the diverse perspectives of all community members, as it could be challenging for some to participate.

9. Professional Outcome Presentation: Designers actively sketch, draft, and present models, directly communicating their work to the public. Although this designer-driven discourse is firmly rooted in scientific and professional principles, the top-down nature of the approach somewhat undermines the potential benefits of participatory design, limiting the degree of public engagement and input that could enrich the design process.

In conclusion, the advantages and problems of traditional participatory design tools are summarized as follows (Table 2-1).

Table 2-1 Summary of Different Participatory Design Methods (Source: by the author)

Means	Definition	Advantages	Issues
Drawing	Express ideas through drawings	High degree of freedom and convenience	not easy to control
Writing	Express ideas through words	Detailed	Unable to express intuitively
Interview	Obtain intentions through conversations	High level of in-depth investigation	Low efficiency
Public Opinion Survey	Obtain needs through questionnaires	High efficiency and wide scope	High in difficulty
Discussion Forums	Express opinions through representative conferences.	Possess group representativeness	The form of expression is restricted.
Open Urban Public Spaces	Implement open regulation on the functions of specific spaces.	Have a high degree of public autonomy	The process is cumbersome and the operation is difficult.
Community Workshops	Express ideas through models.	Express intuitively	High demand for capabilities
Outcome Presentation	Designers display models or drawings for communication.	High level of professionalism	The level of public participation is relatively low.

2.2 Theoretical Research on Augmented Reality Technology

2.2.2 Development History

In 1956, American scientist Morton Heilig created the prototype of the first virtual reality device, earning him the title of "father of immersive virtual reality." However, since the concept of "virtual reality" did not exist at the time, this prototype was referred to as the "Sensorama" [40]. In 1965, Dr. Ivan Sutherland, known as the "father of computer graphics," developed a new type of image display technology and, three years later, created a head-mounted stereoscopic display with a tracker, which served as a prototype for later AR glasses[41]. In 1982, science fiction writer William Gibson introduced the concept of an "ideal state" and "parallel worlds" in his novel, which could, to some extent, transcend the limitations of time, money, and geography, marking the beginning of public awareness of virtual worlds[42]. In 1984, NASA developed a virtual world visual display for Mars exploration[43]. In 1990, Tom Caudell of Boeing invented goggles capable of projecting wiring diagrams, which were used for virtual tours and professional training for the company's electricians (Fig 2-3).

In the 21st century, augmented reality (AR) and virtual reality (VR) technologies entered a period of rapid development. The annual convening of international conferences such as the International Workshop on Augmented Reality (IWAR), the International Symposium on Augmented Reality (ISAR), and the International Symposium on Mixed and Augmented Reality (ISMAR), among others, has continuously advanced the development of AR technology. For instance, Google launched the augmented reality wearable smart glasses known as Google Project Glass in 2012, followed by the release of a low-cost VR prototype device called Cardboard in 2014, which allowed users to experience virtual reality using their smartphones as a platform. In 2015, Microsoft introduced the HoloLens augmented reality headset, which, compared to AR glasses, featured holograms, high-definition lenses, and stereo sound, quickly becoming popular and advancing research in AR technology.

Currently, augmented reality (AR) and virtual reality (VR) technologies are widely used as visualization tools in the field of architecture. As early as the early 1980s, these technologies were introduced into urban planning abroad. Among the countries conducting research and practical applications of AR technology, the United States has the most advanced and extensive research, focusing mainly on aspects such as perception, interface, and hardware/software. At the virtual simulation laboratory of the University of Strathclyde in the UK, Maver, T, and others used a panoramic projection system to achieve visual simulation displays of different environmental scenarios[44]. Architect Brian Hopkins from Ennead Architects in the United States loaded building models and environmental information into a VR system to simulate lighting effects, studying the role of VR technology in visualizing non-specific data[45]. Researchers such as Schnabel at Victoria University of Wellington in New Zealand have explored modeling techniques based on 3D simulation and roaming interaction technologies[46].

In recent years, to quickly narrow the gap with foreign technological levels, Chinese scientists and government departments have gradually begun to focus on research into the core technologies of augmented reality (AR) and their practical application value. In the mid-1980s, several cities in China introduced this technology into urban planning; however, to date, AR technology is primarily used to enhance promotional effects, mainly showcasing planning proposals during processes such as planning, design, bidding, and approval, providing a collaborative platform for government planning departments, project developers, and engineering personnel. In 2006, Wang Yongtian and others from Beijing Institute of

Technology used AR technology through various AR devices and methods to digitally reconstruct the Old Summer Palace, overlaying scenes from before its destruction onto the real ruins, thus recreating its former splendor. These studies affirm that computer graphics simulation technology can simulate the real information of buildings through digital information, intuitively reflecting the intentions of architects, making it easier for non-professionals to understand and accept, thereby facilitating repeated modifications and refinements during the design process, assisting in design and construction processes[8].

In the " Outline of the national medium and long term science and technology development program " released by the State Council, virtual reality (VR) and augmented reality (AR) technologies are identified as key technologies for China's future development [47]. The main applications in design include research on the application of VR technology in urban landscapes and research on the application of VR technology in urban spatial interfaces. These studies primarily aim to enhance public awareness of and participation in the mesoscopic and microscopic aspects of urban design, improving people's ability to understand and evaluate urban design content[48].

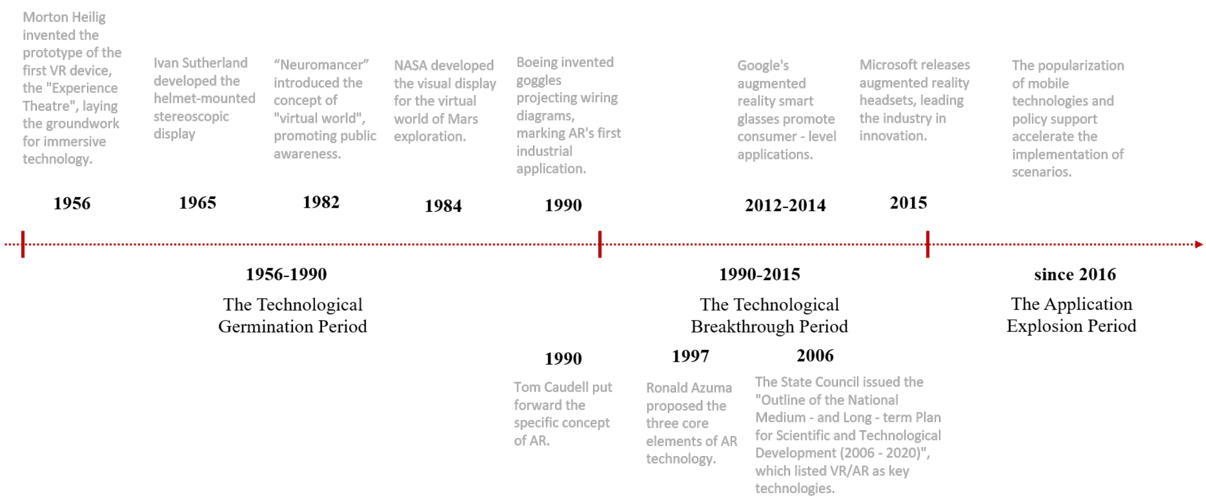


Fig 2-3 The Development Process of Augmented Reality Technology (Source: by the author)

2.2.1 Technical Components and Characteristics

1. Technical Composition

The technology of augmented reality primarily consists of two components: tracking registration and display technology.

As the core technology of augmented reality systems, tracking registration technology ultimately affects the performance of augmented reality outcomes. Tracking registration technology refers to the use of corresponding algorithms to quickly calculate the mapping relationship between the coordinate systems of virtual and real spaces, achieving precise alignment so that virtual information can be perfectly overlaid onto the real world[4]. Tracking registration technology can be divided into tracking technology and registration technology. Registration involves establishing a transformation relationship between the virtual space coordinate system and the real coordinate system in the environment, allowing digital information to be presented in the real world with correct positional relationships. Tracking, on the other hand, involves real-time acquisition of data from the current scene and reconstructing the coordinate system based on factors such as the user's position, perspective, and orientation.

Currently, there are three commonly used tracking registration technologies: visual tracking, sensor tracking, and hybrid tracking that combines visual and sensor methods.

Visual tracking can be further divided into marker-based tracking and markerless tracking. Marker-based tracking typically relies on predefined markers, such as Quick Response codes (QR codes) or preset images, to establish the mapping relationship between the virtual and real spaces through visual recognition. This method is commonly used in industrial assembly guidance, such as Toyota's use of QR codes to locate parts. Its advantages include simple computation and fast positioning, while its disadvantages are the reliance on predefined markers and limited application scenarios.

Markerless tracking, on the other hand, is based on natural feature points and achieves tracking through affine transformations of real images. This method does not require predefined markers and can adapt to dynamic environments, but it has higher algorithmic demands, lower real-time performance, and higher costs.

Sensor tracking primarily involves collecting motion or position data through physical sensors (such as IMU, GPS, and magnetometers) and implementing fast positioning using filtering algorithms, resulting in better real-time performance. However, it may encounter positioning errors in areas with high-density buildings or numerous trees.

Hybrid tracking is currently a key area of research, as it integrates visual and sensor data to enhance the real-time performance and accuracy of tracking through multimodal data complementarity.

The display technology of augmented reality determines the sense of immersion and user experience in the fusion of virtual and real elements. It can be divided into the following four categories:

Projection Display: This method projects virtual content directly onto the surfaces of real-world objects (such as walls and tables). While it has a wide range of applications, the equipment is bulky and cannot move with the user's perspective.

Video Perspective Head-Mounted Display: This type captures the real scene using external cameras on a VR headset and displays the combined virtual content on the headset screen. Due to certain computational processing, the integration of virtual and real elements is relatively good, but it is sensitive to latency.

Optical Perspective Head-Mounted Display: This method uses semi-transparent and semi-reflective optical devices to overlay virtual images directly onto the real field of view, as seen in Google Glass. Its advantages are light weight and high real-time performance; however, it has a narrow field of view and the brightness of the virtual image is affected by ambient light.

Screen Processing: This approach captures the real scene using a camera and displays the fused virtual and real images on screens such as smartphones and tablets (camera capture + virtual rendering). It is simple to implement and provides a lower sense of immersion, but due to its high prevalence (relying on smartphones) and low development costs, it is widely used in the market and is the primary presentation method selected for this research.

2. Equipment

As a form of computer simulation technology, augmented reality typically involves several components, including computer hardware, software that supports augmented reality technology, and visualization devices[49].

Common visualization devices can be categorized into host computers, tablets, smartphones, and head-mounted devices. VR devices are further divided into two types: one type is head-mounted virtual reality display devices that support two-point laser positioning, represented by HTC Vive; the other type is all-in-one virtual reality devices that use image positioning, represented by Oculus Quest and Pico. The former can provide a more powerful immersive experience, but it has significant limitations regarding space requirements and necessitates the connection to a desktop computer.

Therefore, it is not suitable as the primary device for participatory design under virtual reality technology. The latter, however, has seen technological advancements in recent years, resulting in lower procurement costs while maintaining an immersive experience and reducing indoor space requirements, making it more suitable for large-scale outdoor participatory practices.

Devices such as smartphones and tablets are more applicable for participatory research under augmented reality technology. Augmented reality primarily captures real scenes through cameras and overlays digital information with digital 3D models to create augmented reality images. As a result, these devices have fewer usage restrictions and are better suited for large-scale and extensive site research, making them one of the primary tools for participatory design in this study.

3. Technical Characteristics

The interactivity of augmented reality technology is one of its core characteristics. As a form of digital technology, augmented reality enables interaction between users and virtual scenes, thereby enhancing users' sense of immersion in virtual environments and improving their sense of participation. Research in user experience, human-computer interaction, and affective computing indicates that emotional experiences of participants when using products and services are crucial for virtual environments. The incorporation of emotional elements can make users' levels of engagement and experience closer to real-life experiences. Through augmented reality technology, participants can interact with virtual environments in real-time via electronic devices, deepening user engagement and shifting design from "passive acceptance" to "active co-creation."

The second characteristic of augmented reality technology is its conceptual nature. The conceptual nature of virtual reality refers to the reconstruction of the real world by combining virtual environments with imaginative capabilities, allowing designers' blueprints to be perfectly presented in virtual scenes. From the perspective of user participation and user experience, the conceptual nature of augmented reality technology can help us better provide user experiences. For instance, studies have shown that systems incorporating conceptual designs in virtual scenes can effectively enhance participants' attraction to and immersion in the experience, while also suggesting that designers should consider how to involve users in the design and customization decisions of scenes to foster creativity and imaginative thinking.

2.2.4 Evolution of Augmented Reality and Spatial Design Approaches

Since ancient times, space has been a key topic of exploration for architects, and the methods used for spatial design have continuously evolved and changed. With advancements in technology and the development of theoretical research, the ways to explore space have increased significantly.

Currently, the design thinking and representation methods for public space planning can be roughly divided into four stages: the textual stage, the hand-drawing stage, the modeling stage, and the computer-aided design stage.

1. the textual stage

With the development of the times, humanity gradually developed language and writing. In the early stages of architectural design, architects primarily relied on oral transmission for knowledge sharing. Some architects would also document their design outcomes and construction techniques in books, describing architectural spaces and summarizing architectural objects using complex and comprehensive professional terminology to further convey architectural design concepts.

However, due to the inherent complexity of spatial design and the limitations of language and writing, which cannot adequately convey sufficient spatial information, architects relying solely on textual descriptions cannot clearly communicate the complexities of design in time and space. Additionally, without tangible recognition, it is challenging for architects to effectively perceive and articulate spatial qualities.

2. the hand-drawing stage

For a long time, designers have primarily relied on hand-drawn drawings to explore the relationships between architecture, space, and environment. Compared to language and writing, hand-drawn drawings align more closely with human cognitive processes, allowing for a more vivid and direct expression of design effects such as spatial proportions, rhythms, scales, orders, sequences, balances, harmonies, and axes. Therefore, hand drawing is one of the most fundamental methods of expressing design concepts and is also one of the best ways to inspire designers' creativity, becoming a foundational skill in design practice.

Although hand-drawn drawings can capture designers' creative inspirations and convey some effects, they still remain too abstract to fully express the overall spatial effects after construction. In the process of presenting three-dimensional architectural ideas in two-dimensional drawings, information about design elements such as spatial scale, order, and stylistic features inevitably diminishes, while dynamic information like changes in light and shadow, sound environments, and temporal variations tends to be lost. Moreover, the effectiveness of hand-drawn drawings varies from person to person; the level of hand-drawing skill does not necessarily reflect the level of design ability, which can easily skew people's focus on the design itself.

3. the modeling stage

When two-dimensional drawings fail to meet the expressive needs of designers, three-dimensional physical models gradually come into play. Physical models compensate for the shortcomings of hand-drawing in conveying overall effects, allowing people to experience the overall result of a constructed space. Additionally, in terms of style, color, spatial dimensions, material textures, and lighting and shadow effects, physical models outperform flat two-dimensional drawings, facilitating design assistance and helping designers identify errors that hand-drawing often overlooks.

However, the main drawback of physical models is that they only allow for an overhead view, making it impossible to truly experience the effect of walking through the spatial environment. This results in a lack of immersion and a limited perspective for evaluating the space. Furthermore, creating physical models is time-consuming and labor-intensive, making it challenging to quickly adjust and revise designs based on viewer feedback.

4. the computer-aided design stage

With the advancement and development of computer technology, spatial design has gradually begun to utilize computers for scheme and effect design. Since the 1990s, computer-aided design (CAD) has become widespread in China's design industry. Although the essence of computer drawing has not fundamentally changed from traditional manual work, still providing a static experience and evaluation interaction, computer-aided drawing is more efficient and accurate than hand-drawn drawings and physical models, saving human, material, and financial resources. The application of this technology has liberated designers from the tedious and labor-intensive process of hand-drawing, marking a revolutionary significance for the design industry.

Although computer 3D modeling technology can assist architects in creating complex spatial forms, the limited amount of information contained in digital data often fails to adequately represent aspects such as area, scale, and weight. This can significantly affect designers' accurate assessment of design proposals. Furthermore, the complexity of modeling software operations also somewhat restricts architects' ability to express their creative thinking[50].

Two-dimensional drawing, three-dimensional modeling, geographic information systems, and augmented reality technology serve as the main computer-aided technologies, significantly enhancing design efficiency, improving the quality of works, and extending design concepts. In particular, in recent years, augmented reality technology has rapidly developed and is increasingly integrated with architectural and urban design, with a deeper level of application.

5.The Intervention of Digital Technology

With the development of China's economy and advancements in computer technology, digital technologies such as augmented reality and virtual reality have been widely applied across various aspects of urban planning. Among these, augmented reality technology is primarily utilized for simulating urban environments, geographic information systems, wayfinding systems in large public spaces, and for the planning and design of large public buildings that involve investment risks.

As an emerging technology, augmented reality is often combined with other technologies to achieve varying degrees of integration between digital information and the real environment, resulting in entirely new experiential modes. For instance, by combining augmented reality with Geographic Information Systems (GIS), and leveraging the internet, public participation in urban planning can be significantly broadened and deepened. Compared to augmented reality, GIS possesses powerful spatial analysis capabilities, such as regional studies, urban traffic analysis, and socioeconomic analysis, which facilitate the management of complex planning information and provide precise spatial data support.

Therefore, integrating augmented reality with GIS through the internet for data consolidation and dissemination can enhance the public's understanding of both visual and non-visual information in urban planning, fundamentally transforming the way the public engages in urban planning.

However, the development of augmented reality technology does not exclude traditional methods of public participation in planning. Combining augmented reality with conventional approaches often yields better results. For instance, integrating augmented reality systems with forums and consultation meetings can provide a platform for communication between planners and the public. The public can intuitively understand some unclear or abstract issues through the representation of augmented reality technology; meanwhile, planners can explain non-visual issues that cannot be represented through augmented reality to the participating public. This will significantly enhance public engagement.

2.3 Augmented Reality as a Method of Participatory Design

Participatory design is a design approach based on the opinions and feedback of participants, aiming to enhance the efficiency and quality of the design process by fully incorporating user perspectives and suggestions. With the continuous advancement of technology, augmented reality has significantly developed and emerged as an important tool in participatory design.

Compared to traditional spatial design methods, augmented reality technology can effectively enhance public participation in urban planning design and improve user feedback. By providing an immersive experience, this technology allows participants to intuitively understand design proposals in a virtual environment, thereby encouraging more active involvement in the design process. Augmented reality offers new pathways and tools for participatory design, enabling designers to better collect and integrate user opinions.

Therefore, the effective application of augmented reality methods in urban planning design holds substantial supplementary significance and profound practical implications. This integration can promote broader public engagement, enhance the adaptability and sustainability of design outcomes, and ultimately provide more scientific and human-centered solutions for the future development of cities.

2.3.1 Theoretical Research on Augmented Reality Participatory Design

In terms of the advantages of augmented reality technology in participatory design, first, it enhances the convenience and enjoyment of participation, effectively stimulating public enthusiasm. Participants can interact directly with the design in a virtual environment and make immediate modifications to design proposals, allowing designers to receive feedback more quickly. This level of interactivity significantly increases participant engagement and makes the overall design process more efficient and accessible.

Second, augmented reality technology improves the reliability of participatory data through technical means. Diverse data can be rapidly disseminated in both directions across the internet, allowing for the efficient, accurate, and comprehensive collection of target information within a specific scope, and facilitating quick dissemination. More data samples mean higher data accuracy.

Finally, the spatial representation presented by augmented reality technology is more intuitive, overcoming the limitations of traditional 2D drawings. The public gains a more direct understanding of space, effectively lowering the barriers to participation in design. By overlaying virtual environments with real sites, participants can experience the space from the designer's perspective, gaining more intuitive insights, which allows them to modify proposals and derive results, thereby bridging the gap between designers and the public.

At the same time, from the perspective of the components of traditional participatory design, augmented reality technology can address the shortcomings of traditional methods in various elements and improve participation efficiency.

In terms of the object element, the introduction of augmented reality technology allows marginalized groups to participate more effectively in the design process, thereby expanding the range of participants. Regarding the design cycle, the rapid iteration methods provided by augmented reality technology break the traditional linear design process, enabling residents to engage at all stages of the design cycle. In terms of site scale, augmented reality technology enhances participants' spatial awareness through better representation of the surveyed area. Finally, concerning participation methods, augmented reality technology transforms the singular expression mode, thereby facilitating bidirectional communication.

In the theoretical research of applying augmented reality technology to participatory design, in 2007, Chen Weixiong carried out urban community planning and design by combining virtual reality technology with traditional community planning[52].He utilized augmented reality technology to set up spatial layouts of virtual buildings on a real desktop, which not only reduced material costs but also facilitated presentation and modification of proposals, thereby expanding the application and development of augmented reality technology in the field of planning.

In 2012, Yuan Sinan and colleagues from Tianjin University conducted cognitive experiments on urban street grid perception using virtual reality technology, studying spatial cognitive behaviors of individuals within urban environments. Ultimately, they established a connection between the spatial form of street networks and subjective cognition, deepening the relevant theories of urban spatial morphology and proposing methods and workflows for applying virtual reality technology in urban and architectural research[53].

In 2014, Tan Jun validated the feasibility of using augmented reality technology for the restoration of architectural model scenes through small-scale architectural design experiments. He argued that augmented reality technology facilitates designers in making more rational evaluations of architectural design proposals[54].

In a cultural heritage preservation project in 2016, Marc Aurel Schnabel and colleagues linked architectural history with participatory gaming experiences through augmented reality technology, creating a nonlinear interactive game narrative aimed at encouraging non-professionals to engage in the restoration of Kashgar's historical and cultural heritage in a new way[55].

In 2017, Erath A from the Future Cities Laboratory at ETH Zurich created a highly realistic virtual neighborhood environment and collected public perceptions of bicycle-oriented street space design proposals using bicycles and head-mounted augmented reality displays, thus achieving a proactive design evaluation[56].

In 2018, Imottesjo and Kain collaborated to develop the augmented reality application Urban CoBuilder, which was used in urban renewal projects and leveraged crowdsourcing platforms to facilitate public decision-making[57].

In 2019, Xu Lei-qing conducted a healing-oriented street design study using augmented reality and virtual reality technologies combined with electrodermal activity data, summarizing the impacts of green visibility and street interfaces on human sensory and psychological experiences[58].

In the same year, Mauricio Loyola conducted a participatory design experiment using augmented reality technology in an urban park in Santiago, finding that participants in virtual scenarios exhibited higher spatial understanding, a more precise grasp of the project's form and spatial quality, and greater engagement compared to traditional methods[59].

In 2022, Chen Zhiming and colleagues conducted a study on the walkability of certain streets in Guangzhou using augmented reality headsets and electromyography devices, resulting in design guidelines for micro-updates of the streets[60].

In summary, the high interactivity and immersive virtual spaces provided by augmented reality technology enable designers to present their proposals more intuitively, while participants can more easily evaluate and modify the design schemes.

Furthermore, the incorporation of augmented reality technology optimizes the shortcomings of various elements in traditional participation methods, allowing participants to better predict the effects and impacts of the designs.

2.3.2 Methods of Augmented Reality Participatory Design

Currently, the application of augmented reality technology in participatory design for public spaces can be broadly divided into two categories based on the level of interactivity: outcome presentation and interactive modes (Table 2-2).

1.Outcome Presentation Mode

The outcome presentation mode has relatively low interactivity. Designers pre-design multiple proposals and then use augmented reality techniques to overlay corresponding images, videos, and 3D models onto the real world via screens, showcasing them to the public and collecting relevant feedback. Participants can provide feedback through graphic and textual questionnaires or interviews, making this mode primarily suitable for investigating public sensory experiences.

As an exhibition method, outcome presentation typically requires the public to view from various perspectives. However, compared to virtual reality, augmented reality has limitations in controlling the scale and volume of interior spaces, which is why outcome presentation modes generally employ virtual reality techniques.

2.Interactive Mode

The interactive mode utilizes an interactive platform, allowing the public to engage in design interactions that convey their design needs, thereby optimizing design proposals. Augmented reality technology is commonly used to construct this interactive platform. Participants can interact with design proposals through the augmented reality platform, gaining a more immersive spatial experience (Fig 2-4).

The advantage of the interactive mode lies in its ability to transform the design process into a modular collage process, facilitating collaborative design.

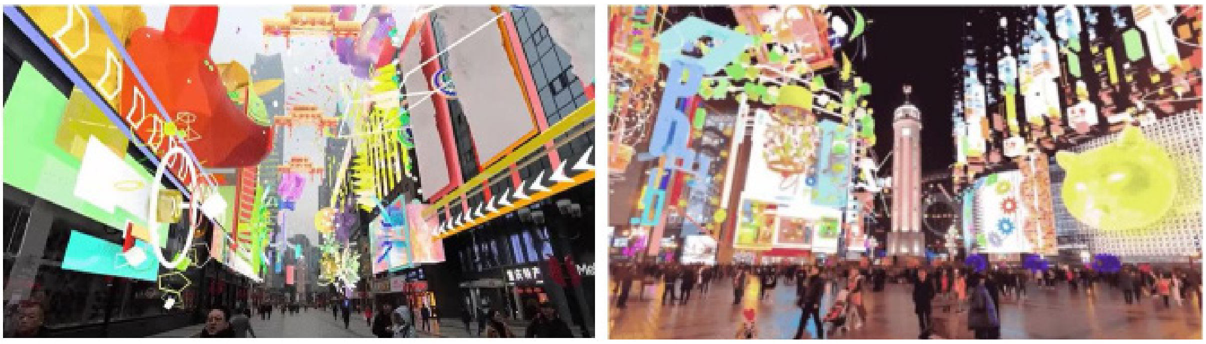


Fig 2-4 The Integration of AR Technology into Urban Street Landscapes(Source: https://zhuanlan.zhihu.com//69473574)

Table 2-2 Application Methods of Different Participatory Designs in Augmented Reality (Source: by the author)

	Categories	**Usage Characteristics**	**Modes of Participation**
Outcome Presentation Mode	Roaming of the VR solution	Participants freely stroll and experience the space.	Use VR devices and computers to roam the scene
	VR scheme fixed route display	There is a fixed route, which can provide a certain degree of guidance.	Use VR devices and computers to experience a fixed route
	Virtual reality panorama	Simple to make and convenient to use, but it lacks a sense of immersion.	Use portable VR devices to experience specific scenes
Interactive Mode	interactive platform	It has a relatively high communication efficiency.	Interact through the web interface of a computer or mobile phone
	Virtual reality interactive program	Can interact with the virtual environment and scenes, and has a high level of immersion.	Use VR devices and computers to roam the scene and interact with the scene through the controller
	Augmented reality interactive program	By overlaying virtual scenes on real scenes, it is easy to operate and the device is portable.	Interact through portable devices such as mobile phones or tablets and conduct it in a real venue
	Mixed reality interactive program	It integrates the scene experiences of virtual reality and augmented reality.	Interact through mixed reality devices

3.Advantages of the Two Participation Modes

In an era of continuous technological advancement, the integration of digital technology into participatory design is an inevitable trend. Virtual reality, augmented reality, and mixed reality technologies serve as tools that merge with participatory design methods, each possessing unique advantages:

Virtual Reality provides a free spatial experience, creating an unrestricted creative environment.

Augmented Reality offers a more realistic scene restoration through the digital overlay of physical spaces.

Mixed Reality bridges the gap between virtual and physical interactions, bringing participants closer to designers.

2.3.2 Case Studies of Participatory Design Supported by Augmented Reality

Based on the two categories of augmented reality participation modes mentioned above, this paper selects several relatively mature practical cases in the field for reference and summary.

1.Virtual Reality Participatory Design of Public Waiting Areas[61]

The purpose of this project is to explore and test the role and advantages of a virtual reality application platform in collecting public opinion data. The author developed a customized VR platform using existing VR resources, aimed at providing an immersive spatial experience of public waiting areas while gathering participants' design preferences (Fig 2-5). This platform can collect expectations regarding the design of public waiting areas from participants with varying cultural backgrounds, ages, and levels of expertise.

First, the author conducted a preliminary investigation into the design of public waiting areas through relevant literature and theoretical research. Based on the research data and theoretical literature, the author designed a virtual reality scenario simulating a public waiting area and invited stakeholders to participate in the design and construction of the platform, laying a solid foundation for subsequent research work and data collection.

Subsequently, the author designed a series of interactive elements on the VR platform, including spatial scale, environmental color, lighting, and foot traffic, and invited participants to experience the waiting area under different elements. During the testing process, the designer continuously monitored and recorded participants' behaviors and reactions in the virtual scenario, and after the test, inquired about preferences and opinions regarding various elements of the public space.

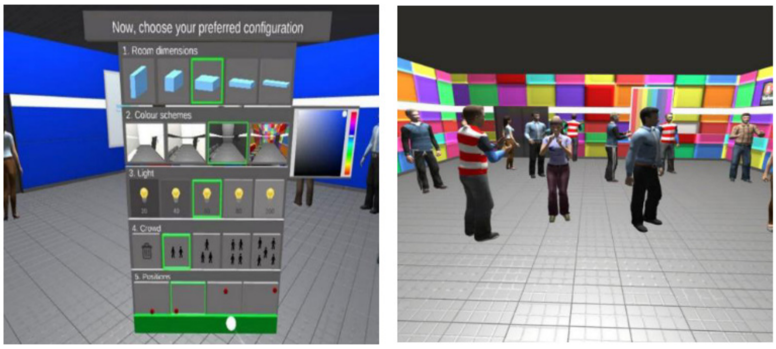


Fig 2-5 Virtual Waiting Room Scene (Source: reference[61])

After the experiment, the author drew the following conclusions based on the analysis of the experimental data:

The VR platform provides a more immersive spatial experience; the realistic and intuitive spatial perceptions brought by virtual reality technology help participants better understand and express their design preferences.

Participants can engage in more proactive data collection and real-time interaction through the VR platform, which helps improve the accuracy and comprehensiveness of data collection and allows designers to understand participants' needs more quickly.

Although the VR platform takes more time for data collection, the accuracy and reliability of the data collected reduce the likelihood of repeated trials, indicating that in certain cases, using virtual reality technology may be a more efficient data collection method.

Currently, the VR platform still faces certain limitations and challenges in design and research, such as the need for further study on platform standardization and applicability.

The author also proposed systematic design guidelines for the practical application of virtual reality technology in data collection, including elements to consider when designing the platform, the platform usage process, and the selection and guidance of participants. Additionally, the author emphasized that interactive virtual reality technology should ensure the design of appropriate virtual scenarios to meet research objectives and participant experience needs. The scenarios should include furniture, spatial layout, color materials, lighting design, and atmosphere creation as much as possible. Furthermore, the realism and fluidity of the virtual reality scene should be ensured, allowing participants to experience the scene smoothly and naturally. During platform usage, it is also essential to consider participants' subjective experiences and engagement levels, provide adequate guidance, and minimize unnecessary external distractions and misguidance.

2.Virtual Reality Display Project for Urban Parks[59]

In the urban park design project “Parque Articulador,” the author utilized display-based virtual reality technology for participatory design. In the experimental process, the author first guided participants on-site and conducted comparative experiments based on public feedback during a hearing. One group engaged in participatory design using traditional paper-based presentations, while the other group utilized VR technology for participatory design. Participants in the second group wore head-mounted VR devices to experience spatial scenarios along a fixed path.

Given that the users of the selected community public space generally have lower educational levels and limited understanding of new technologies, the experimental results indicated that participants exhibited a higher level of spatial comprehension compared to those engaged in traditional paper-based participatory design. They provided designers with more accurate, effective, and valuable feedback.

The author also noted that the fixed-path display might limit participants’ perceptual range, thereby affecting their evaluation results. In a free-roaming virtual reality scenario, participants can choose their viewing angles and positions freely, allowing them to provide more critical suggestions regarding the spatial design proposals. However, this approach imposes higher demands on the initial modeling and research work, as well as increased cost requirements (Fig 2-6).

Fig 2-6 The Evaluation Process of the Virtual Scene of the Project (Source: reference[59])

3.Collaborative Decision-Making in the Design of the New City Hall[62]

The design background of this project stems from the German city of Olpe's plan to demolish the existing town hall and redesign it. As the planning process requires balancing historical culture with modern needs, augmented reality technology is employed to showcase different architectural proposals to the public and gather residents' preferences regarding the new town hall design.

The introduction of augmented reality technology in this project serves two main purposes: 1. To enhance citizens' intuitive understanding of the planning, thereby reducing opposition due to information asymmetry; 2. To provide a real-time interactive platform that allows residents to experience the design proposals through augmented reality technology and collect public feedback on the designs, thereby increasing decision-making transparency.

In terms of specific technical implementation, the main development tools used are Unity3D and Adobe Aero. The project constructs three-dimensional architectural models and interaction logic using Unity3D, followed by prototype design and interface optimization with Adobe Aero. Finally, by integrating Vuforia SDK technology, natural feature tracking is achieved (such as landmark recognition of the old building site), ensuring precise alignment of virtual models with the real scene (Fig 2-7).

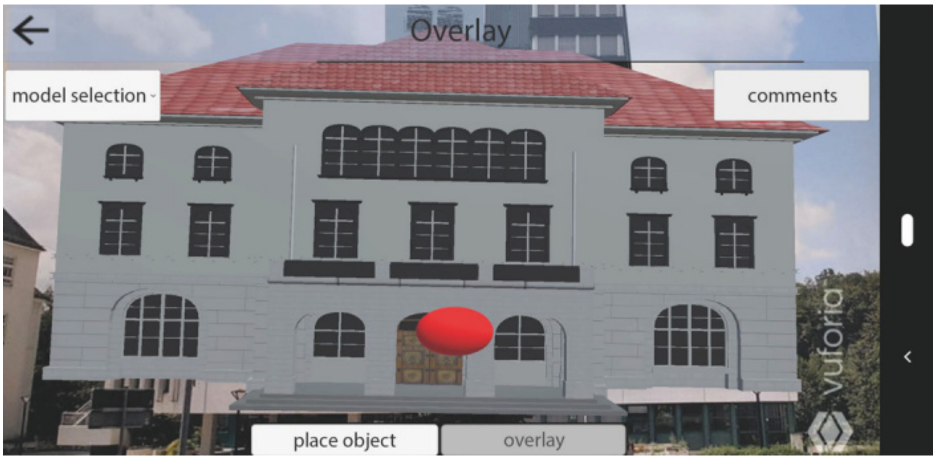


Fig 2-7 Participatory Design of the Town Hall Conducted via AR (Source: reference[62])

The program primarily offers two interaction methods. The first method allows participants to overlay the 3D architectural models designed by architects as digital objects onto existing buildings in the real environment, showcasing the appearance after renovation. Participants can comment at any point on the digital object and provide feedback to the designer for iterative improvements. The second interaction method enables participants to enrich the physical environment with digital objects, reflecting their spatial design needs and ideas. Users can utilize pre-set models for site arrangement. In addition to placing and deleting objects, users can interact with created objects through scaling and rotating, allowing for flexible design of the external environment and visualization of their ideas.

In terms of the participatory design process, the project invited 50 citizens from various age groups and professions to participate in internal testing, collecting feedback on operational smoothness and functional requirements. Subsequently, the AR application download link was published on the city government’s official website and social media, with tablet experience stations set up in the town hall for formal project promotion. Additionally, multiple discussion sessions were held, inviting local residents to bring their phones or AR devices for on-site augmented reality experiences and to provide feedback.

Quantitatively, the project achieved over 2000 downloads within two months of launch and collected 327 valid feedback responses. After several iterations, over 82% of residents provided positive feedback on the outcomes of the participatory design, addressing issues such as excessive building height impacting the surrounding landscape and the lack of rooftop gardens and public exhibition spaces for citizen activities.

Through this project, the author presents several conclusive findings regarding augmented reality participatory design. For example, the project demonstrates that the augmented reality participation model increases engagement among younger demographics through its technological appeal and comprehensibility. Furthermore, public feedback indicates that the introduction of augmented reality tools has allowed citizens' voices to be better heard, reinforcing their sense of agency in the design process. However, the project also identifies some shortcomings, such as the overly complex technology hindering participation from older adults who may not be proficient with electronic devices, necessitating simpler and more understandable guidance.

Additionally, the lack of standardized spatial element evaluations has led to many feedback responses lacking objectivity, with a significant amount of unstructured feedback (e.g., subjective comments like "it looks bad") being difficult to use for design optimization. Therefore, the author suggests establishing specific objective evaluation criteria, such as appearance and functionality of spatial elements, enabling the public to provide more targeted feedback.

4.Redesign of the Lakeside Area[62]

The design background of this project originates from the lakeside area of Siegen, Germany. Due to years of neglect, residents have been calling for renovations. However, traditional methods of gathering opinions resulted in only about 30 suggestions. In response, the designers proposed to introduce augmented reality technology to inspire citizen creativity and enhance participation, while balancing ecological protection with recreational needs.

The primary purpose of introducing augmented reality technology in this project is to enable local residents to engage in the design of the lakeside space in a more immersive manner. Additionally, the technology facilitates participatory collaboration for the elderly community (Fig 2-8).

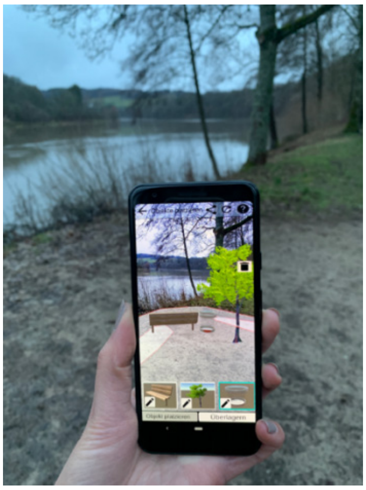


Fig 2-8 Lakeside Participatory Design Platform (Source: reference[62])

In terms of specific technical implementation, the project primarily utilizes Unity3D and ARFoundation as development tools to achieve physical localization and object anchoring, ensuring that digital objects can be accurately placed in the lakeside environment. Additionally, an online collaboration platform has been created, allowing users to upload their design proposals for multi-channel dissemination.

The core functionalities of the project are threefold: First, participants can enrich the real environment with digital objects to showcase their ideas. The project provides a prefabricated library of digital objects containing various interactive spatial elements, from which users can select, place, delete, rotate, and scale objects for interaction. Second, this participatory approach supports multiple users designing simultaneously in the same AR scene, enabling real-time viewing of modifications made by others for rapid iteration. Finally, the platform supports online comparison of proposals, allowing users to like or oppose design proposals and provide reasons and suggestions for improvement.

The specific implementation process of the project also incorporates traditional participatory methods, such as offline workshops. Designers organize workshops where participants use LEGO models to build initial concepts, which are then digitized using augmented reality tools for comparison. Additionally, an online proposal comparison is conducted to gather feedback on citizens' design proposals. Ultimately, the development team integrates this tool into traditional participatory modes. In existing civic meetings, a desktop solution with AR is provided as a reference for final planning (Fig 2-9).

Fig 2-9 AR Desktop Solutions in Citizen Meetings (Source: reference[62])

Through these methods, the concept of "AR-guided routes" proposed by young citizens in the participatory design of the lakeside public space was subsequently developed into a lakeside tourism mini-program. Moreover, the cross-generational collaboration led to the design combination of "elderly fitness areas + children's playgrounds," which became a core highlight of the community public space design.

5.Urban Cocreation Lab Platform in Gothenburg[63]

This project represents a re-innovation of traditional urban design models by a group of designers, aiming to facilitate clear communication among different stakeholders in urban planning and community development through immersive visualization technologies. The project integrates both Virtual Reality (VR) and Augmented Reality (AR) technologies, allowing the platform's functionality to extend beyond physical architectural models to be utilized in a 1:1 scale real-world environment (Fig 2-10).

Fig 2-10 Visualization platform that adopts AR technology (Source: reference[63])

The system offers participants various participatory design modes for urban development projects, enabling them to collaboratively review and adjust elements such as buildings, roads, and vegetation in a virtual environment. By integrating virtual environments with augmented reality technology, participants can collaborate on-site while also achieving remote collaboration across different locations.

The core functionalities of the platform are divided into three aspects: First, it features real-time collaboration capabilities based on the internet, supporting multiple users to simultaneously modify 3D models and share perspectives. Additionally, the platform provides annotation features that allow users to add text, images, or voice comments, as well as mark Points of Interest (PIO). Second, the 3D modeling function offers basic placement, scaling, and rotation capabilities, along with built-in editing for various architectural blocks and terrains based on urban design characteristics, supporting color and texture adjustments. Lastly, the platform provides basic sunlight and shadow analysis, as well as ecological assessments of the urban environment to assist designers in decision-making.

Taking the Gibraltarvallen campus development project currently on the platform as an example, this project primarily focuses on optimizing and upgrading undeveloped plots. Various stakeholder groups, including developers, architects, and students, can use the platform to test different building layouts and functional zones. Additionally, the platform offers mobile Augmented Reality (AR) capabilities to support 1:1 scale design validation on-site, such as adjusting the location of parking lots to minimize their impact on the landscape.

Based on the outcomes of participatory design, the project has improved the connectivity of campus spaces and addressed issues related to the obstruction of sightlines caused by certain building layouts. Research has shown that participatory design based on augmented reality technology can significantly enhance the willingness of students and faculty to participate, providing effective feedback on issues related to shared green spaces and bike lanes.

This project provides several insights: First, it lowers the barriers to participation through a platform-based approach. The platform allows users to modify 3D models with simple drag-and-drop operations and incorporates gamified elements, such as task challenges and achievement systems. This design greatly reduces the technical barriers for non-professional users to engage in urban design, enabling more ordinary citizens to easily express their thoughts and needs regarding urban spaces. Second, by utilizing augmented reality technology, citizens can conduct 1:1 scale design validation in real environments, such as directly adjusting the location and height of buildings on their mobile devices. This approach offers the public a more immersive and intuitive feedback channel, allowing designers to capture citizens' actual needs and preferences more accurately.

6. Summary Conclusions

Based on the practical characteristics and issues identified in the above case, the following conclusions can be drawn:

1.Suitability of Augmented Reality Technology

Augmented reality applications are well-suited for residents to express their diverse demands. By providing an operational platform and integrating participatory design outcomes, the design process can be more effectively advanced, allowing residents' opinions and needs to be fully represented.

2.Simplification of Participation Processes

Research indicates that a significant portion of the elderly population still faces challenges in operating digital devices. Therefore, it is essential to simplify the participation process to enhance the involvement of digitally disadvantaged groups, enabling them to engage more easily in the design process.

3.Establishment of Design Indicators

Since most participants are not professionals, to ensure the objectivity and efficiency of data collection, as well as the usability of the collected data, designers should propose a set of design indicators suitable for participants' subjective evaluations. These indicators will help achieve a more scientific assessment of the design, thereby improving the quality and practicality of the design outcomes.

2.4 Summary

This chapter primarily engages in a theoretical discussion on the application of augmented reality technology as a method of participatory design through literature review and case studies. By analyzing the shortcomings of traditional participatory design models and the advantages of applying AR technology, the chapter discusses the potential for AR as a method in participatory design.

The first part of this chapter systematically reviews the relevant theories of participatory design, summarizing the components, methods, and tools of traditional participatory design, and proposing the possibility of optimizing traditional participatory design using AR technology.

Subsequently, the chapter introduces theoretical research on AR technology, exploring its technical composition, characteristics, and its role in advancing spatial design methods, thereby providing theoretical support for the integration of AR technology into participatory design.

Through the theoretical research in the above two sections, the third part of this chapter proposes AR technology as a method of participatory design. Based on literature research, it summarizes participatory design supported by AR technology and outlines methods for AR participatory design. Finally, by analyzing and summarizing practical cases, it lays a theoretical foundation for the strategies of future AR participatory models.

Chapter 3 Augmented Reality Participation Models and Evaluation Methods

3.1 Case Studies and Reflections on Traditional Participatory Design

3.1.1 Participatory Design in Puntong Village

1.The Renovation Background of Puntong Village

Puntong Village is located in the historical cultural district of Liwan Lake in Liwan District, Guangzhou, on the western edge of the historical urban area, covering an area of approximately 4 hectares. As one of the rare rural settlements from the Qing Dynasty that still exists in Guangzhou, Puntong Village has preserved traditional street patterns, blue-brick residences, and a simple architectural style, which hold significant historical and cultural value[64].The site retains intangible cultural heritage such as the "North Emperor's Birthday on the Third of March." These traditional activities continue the customs of clan organizations and local folklore, forming a unique community cultural ecology.

Despite experiencing multiple waves of urban renewal (Fig 3-1), approximately half of the privately owned residential properties in Puntong Village have persisted. These residences maintain the grassroots organizational structure that spans from production teams to economic cooperatives, reflecting a complex web of social networks and spatial ownership relationships.

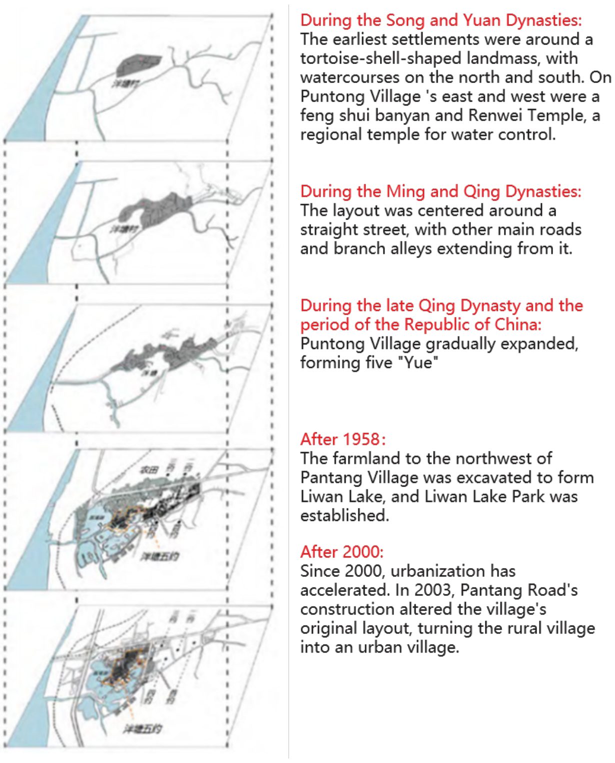


Fig 3-1 Schematic Diagram of the Historical Layout Changes of Puntong Village (Source: reference[65])

The background of the renovation and transformation of Puntong Village can be divided into three stages (Fig 3-2):

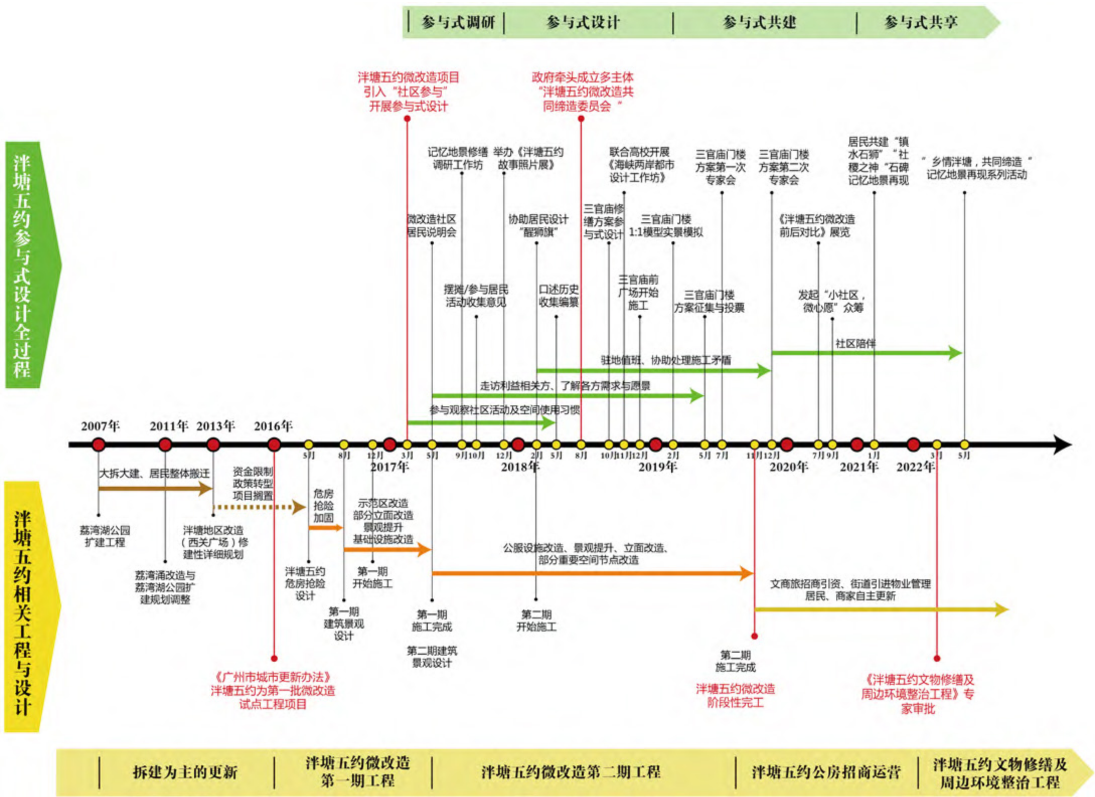


Fig 3-2 The Process of Co-creating the Micro-renovation of Puntong Village (Source: reference[65])

Stage 1: Comprehensive Renewal Focused on Large-scale Demolition and Construction (2007—2013)

In this initial stage, the approach was guided by "comprehensive renewal," primarily advancing the overall relocation of residents through projects such as the expansion of Liwan Lake and the renovation of Lizhi Bay Stream. However, due to financial pressures and shifts in policy, the expropriation work was repeatedly postponed, resulting in approximately half of the public housing remaining vacant for an extended period, with the traditional fabric suffering partial damage.

Stage 2: Environmental Enhancement Focused on Micro-renovation (2016—2019)

After years of expropriation, about half of the houses in Puntong Village were designated as public housing and remained vacant, necessitating urgent repairs. Following the implementation of the "Guangzhou Urban Renewal Regulation" in 2016, Puntong Village became the first historical district micro-renovation project led by the government. Through the repair of public housing, improvement of infrastructure, and enhancement of public spaces, the living environment was improved, and intangible cultural heritage was introduced, forming a “micro-renovation + cultural activation” model. In this stage, community planners acted as a bridge to establish the “Co-Creation Committee,” exploring a mechanism for multi-stakeholder participation.

Stage 3: Environmental Enhancement Focused on Cultural Heritage Restoration (2022 to Present)

In this stage, special restoration projects were initiated for immovable cultural relics, historical buildings, and traditional architectural styles that were not covered in the previous stage, reinforcing the protection of historical context. In 2022, restoration work began on buildings listed in the “Protection Directory” and improvements to the surrounding environment, while optimizing the management of public housing. Through the government-led cultural, commercial, and tourism center, new business formats such as bookstores and cafes were introduced, promoting the functional diversification of the space.

Through summarizing the historical value and reviewing the renovation process, it is evident that the historical information layers of Puntong Village are diverse and complex[66].

The renovation history of Puntong Village reflects a policy shift from “large-scale demolition and construction” to “micro-renovation + cultural heritage transmission,” and several specific characteristics can be distilled:1.Complex Interweaving of Spatial Ownership: The coexistence of private property rights and public housing highlights the prominent contradictions between the protection of historical buildings and the demands of modern functionality.2.Resilience of Social Networks: The interplay between traditional clan organizations and modern governance systems creates a multifaceted social network. Significant differences in residents' awareness and capacity for participation affect the effectiveness of community governance and the level of resident engagement.3.Challenges in Cultural Transmission: During the protection process, it is necessary to balance the activation of intangible cultural heritage, the preservation of architectural authenticity, and commercial development.

2. Summary of the Participation Mode of Puntong Village

The participatory design model of Puntong Village consists of four stages: participatory research, participatory design, participatory co-construction, and participatory sharing. Below is a summary of the participatory methods and reflections on the outcomes of these four stages (Fig 3-3).

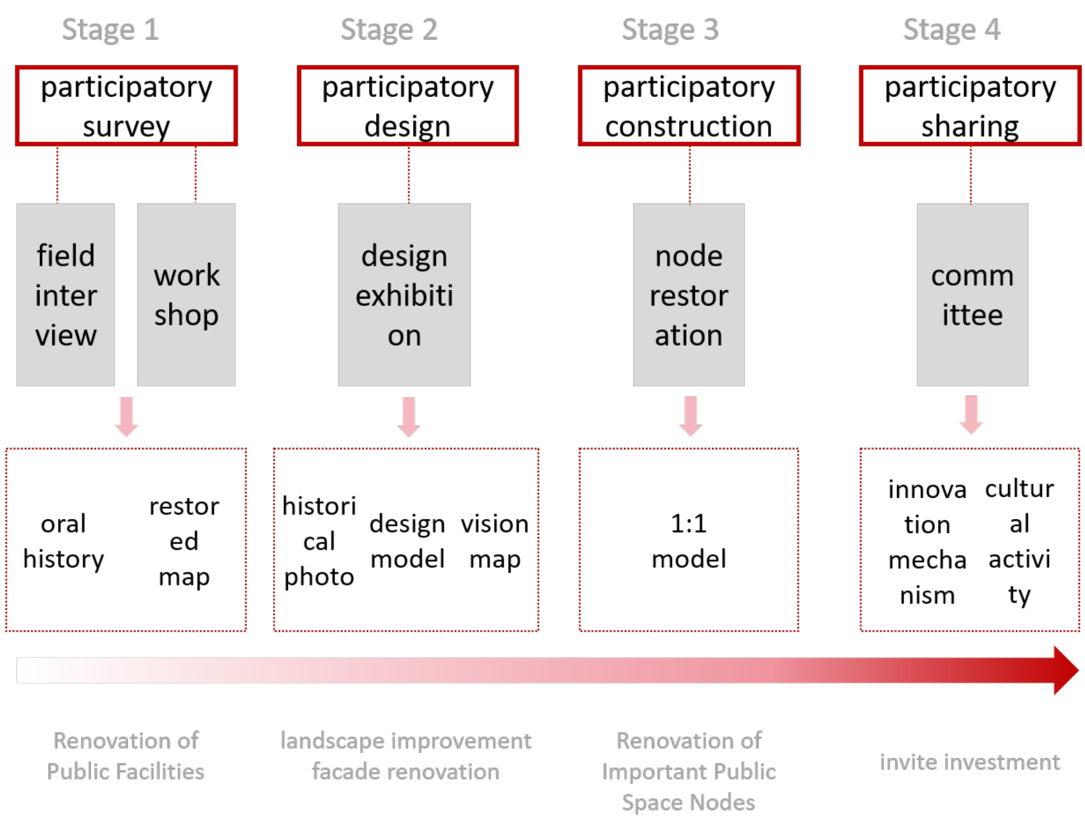


Fig 3-3 Participatory Design Pattern Diagram of Puntong Village(Source: by the author)

Participatory Research: In the participatory research phase, the design team primarily employed on-site interviews and oral history collection to integrate historical information about the site. Due to historical evolution and changes over time, the landscape of the water town and the traditional architectural style of Puntong Village have undergone significant changes.

Additionally, the few existing cultural relics and historical buildings within the scope of protection and renovation, most of which have undergone multiple renovations since liberation, necessitated the collection of firsthand information through the oral histories of local residents to supplement historical data and restore the historical appearance. The team held design workshops themed around the repair of ancestral halls, inviting elders from various clans to share historical anecdotes and folk activities.

Ultimately, the team integrated over thirty oral history accounts and created relevant historical restoration maps (Fig 3-4). They also collected pain points regarding the use of public spaces through in-depth interviews with residents.

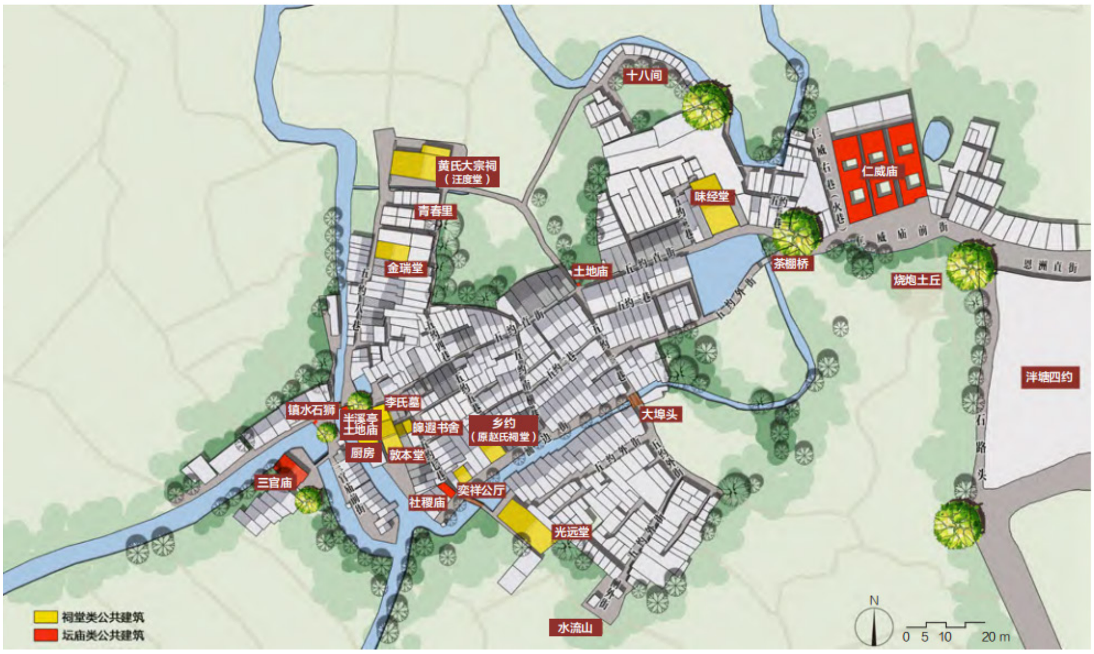


Fig 3-4 Historical Restoration Map of Puntong Village(Source: reference[65])

Participatory Design: In the participatory design phase, the team mainly invited residents to participate through design exhibitions. Three themed activities were organized, showcasing the history, life, and future of Puntong Village, thereby attracting community residents to engage in discussions about the enhancement of public space landscapes.

In the Historical Aspects, the team exhibited historical maps, old photographs of the community, and models of the historical restoration maps created collaboratively during the participatory research phase. Through visualizations, modeling, and engaging quizzes, the team aimed to stimulate community residents' enthusiasm for participation (Fig 3-5).

Fig 3-5 Exhibition of "History, Present and Future of Puntong Village " (Source: reference[65])

In the Life Aspects, the team displayed scenes of public space usage within the Puntong Village site to gather residents' feedback on existing issues and opinions regarding public spaces, guiding them to participate in discussions about community environmental enhancement.

In the Future Aspects, the team created a "Vision Map" based on the renovation suggestions collected during preliminary research visits, hoping to obtain design feedback from residents through intuitive design boards (Fig 3-6).

Fig 3-6 Future Vision Map Display Board of Puntong Village (Source: reference[65])

In the participatory co-construction phase, the team primarily invited residents to participate in model building using a 1:1 construction model approach. Through participatory co-construction, the team and residents collaboratively created three 1:1 scale of physical models (Fig 3-7). By placing these physical models in various locations based on daily activity usage, they simulated the spatial effects after construction. Furthermore, the co-construction activities reinforced residents' cultural identity and sense of community belonging.

Fig 3-7 Model Construction and Placement Simulation (Source: reference[65])

In the participatory sharing phase of Puntong Village, the team primarily focused on establishing new mechanisms and the autonomous transmission of cultural activities. By forming the “Puntong Village Micro-Renovation Co-Creation Committee,” the community began to gradually establish a joint decision-making and two-way communication mechanism suitable for participatory design updates, aimed at actively transmitting and disseminating local culture (Fig 3-8). At the same time, the renovation and upgrading of the community environment introduced external businesses, revitalizing community vitality. Furthermore, the team utilized new media for cultural dissemination and organized residents to spontaneously revive the long-discontinued Choy Li Fut martial arts, thereby forming an autonomous transmission of historical culture.

Fig 3-8 Cultural Heritage Inheritance & Co-creation Committee (Source: reference[65])

3.1.2 Participatory Design in Shenjing Village

1.The Renovation Background of Shenjing Village

Shenjing Village is located in the Changzhou Street of Huangpu District, Guangzhou, at the intersection of the front and back channels of the Pearl River estuary in eastern Guangzhou (Fig 3-9).

Fig 3-9 The Location of Shenjing Village (Source: reference[69])

The village covers an area of approximately 2.54 square kilometers, with a resident population of 13,000 and a registered population of 4,000. Shenjing Village has a history of about 700 years and is rich in historical resources. It is one of the first historical and cultural districts in Guangzhou, one of the first traditional villages in Guangdong Province, and a nationally recognized traditional village.

The village retains historical buildings such as ancestral halls, ancient residences, and gate towers, and it continues to practice traditional crafts like gray sculpture, brick carving, and hand embroidery, as well as folk activities such as the Dragon Boat Festival and the initiation ceremony.

However, due to the influence of the higher-level planning concept of "protective development," Shenjing Village's economic development has been slow, lagging behind other village collectives in Guangzhou. The micro-renovation of Shenjing Village involves multiple stakeholders and complex property rights, necessitating an effective multi-party negotiation platform for the renovation process. In this context, the Shenjing Co-Creation Workshop was established in April 2016. The workshop consists of the Shenjing Village collective, professional institutions, government departments, and enterprises, aiming to address community issues and meet residents' needs while promoting spatial planning and implementation of micro-renovation[68].

2. Summary of the Participation Mode of Shenjing Village

The participatory design model of Shenjing Village mainly consists of three phases: participatory research and design, participatory negotiation, and implementation of guidelines (Fig 3-10). Below is a summary of the participation methods and reflections on outcomes in these three phases.

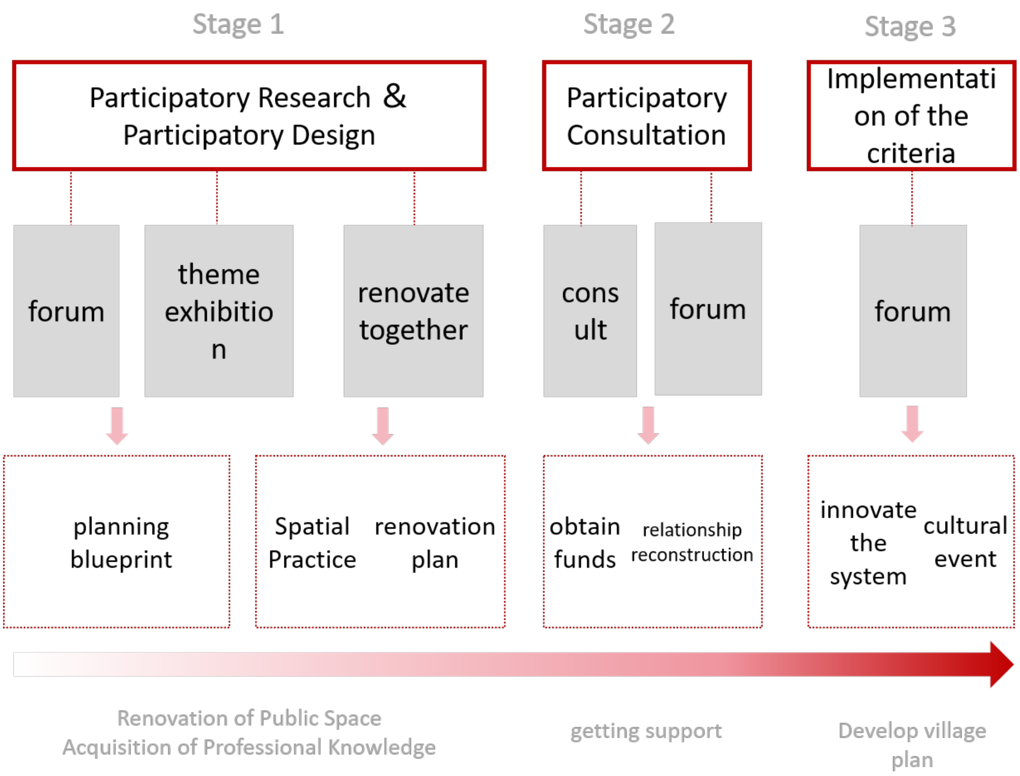


Fig 3-10 Diagram of the Participatory Design Pattern of Shenjing Village (Source: by the author)

Participatory Research and Design: The participatory design in Shenjing Village is primarily led by the "Co-Creation Workshop," which serves as a platform for multi-party participation and collaborative governance, combining both top-down and bottom-up approaches. In the phase of participatory research and design, the workshop primarily relies on discussion meetings and thematic exhibitions to understand residents' needs, identify design issues, and revise design proposals based on residents' feedback, creating a cyclical mechanism of "problem definition—communication and negotiation—collaborative design."

In terms of specific implementation methods, a thematic exhibition on cultural history was held to organize the village's history and genealogy. This was followed by on-site visits and tea gatherings to communicate and integrate design needs, as well as a university student planning exhibition to collect residents' feedback and promote design iteration. Ultimately, a village planning blueprint was created, visually presenting the development vision of "cultivating family traditions and promoting cultural innovation" (Fig 3-11).


a "我们一起聊聊深井" 茶话会
b 大学生规划作品展
c 愿景图

Fig 3-11 The Achievement of a Development Consensus (Source: reference[69])

Additionally, through the collaborative renovation of public spaces, upgrades were made to public space nodes such as the flowerbed in front of No. 9 Conggui West Street, No. 2 Dexingli, and the Xiaolanling Ancestral Hall. These nodes served as renovation examples to guide villagers in transforming vegetable plots and courtyards while introducing greenery and cultural elements.

By discussing design proposals and renovation spaces with planners, villagers gradually recognized the public nature of public spaces, altering their understanding of space and planning, which in turn encouraged further participation (Fig 3-12).

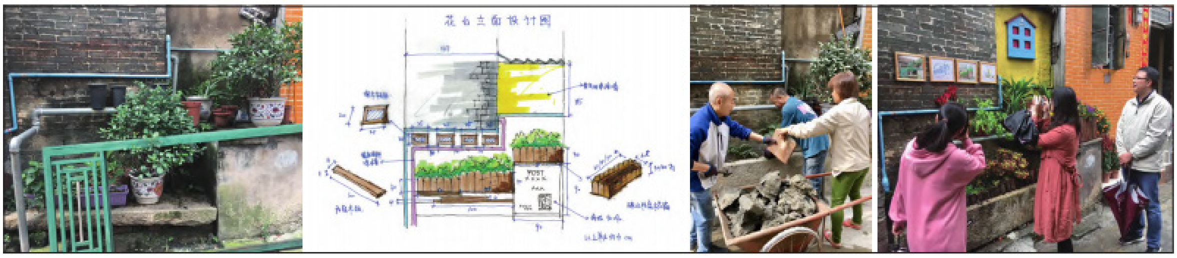


Fig 3-12 The Renovation Process of Public Space (Source: reference[69])

Participatory Negotiation: In this phase, the team primarily engaged in participatory negotiation with the government and local residents regarding issues such as funding and property rights. By explaining the limitations of fiscal funds to residents and relaying property owners' demands to the government, as well as demonstrating the feasibility of repurposing private ancient buildings for public use, a consensus was reached on the activation of multiple public spaces.

Through the process of multi-party discussions on renovation proposals, the social relationships among the government, villagers, and designers underwent reconstruction. The intervention of participatory design altered the traditional dominance of the government in village renovation processes, allowing residents to participate in village development matters through upward feedback and negotiation channels, thus promoting collaborative design among multiple stakeholder groups.

Implementation of Guidelines: This phase primarily addresses renovation spaces that have functional activation disputes. For instance, regarding the Xiaolanling Ancestral Hall, the design team organized discussions on a "content-for-space exchange" system, attracting social organizations to offer public welfare activities and establishing relevant regulations. In response to current issues and multiple demands, participatory community planning encourages collective attention to public affairs, forming new ways of thinking and organizational forms to address shared coexistence issues within public spaces, thereby generating new institutional capacities to adapt to the new environment[70].

3.1.3 Summary and Reflection on Case Models

1. Reflections on the Case of Puntong Village

Based on the summary and induction of the participatory design model of Puntong Village, the following insights can be gained:

Participatory Research Phase: The use of oral history for historical restoration has certain reference value, but for non-historical information, the depth of gathering residents' needs through oral methods is insufficient. This approach relies on residents' memories and cultural levels, leading to differences among individuals and a lack of systematic recording tools. Additionally, the scope of participation is related to residents' engagement, and the integration of oral needs is often limited to a few actively participating residents.

Participatory Design Phase: Although the workshops achieved a high level of public feedback, their exhibition format still leans towards one-way output, lacking deep interaction. Furthermore, the methods of collecting design feedback are relatively singular, resulting in insufficient depth of participation.

Participatory Co-Construction Phase: This phase mainly faces two issues: the shallow depth of residents' participation and the lengthy co-construction cycle. According to Liu Chenyu's post-evaluation survey of the Puntong Village renovation project, most residents feel that their decision-making power is limited, and the most significant problem in the co-construction process is the prolonged duration. Additionally, the costs for the 1:1 physical model restoration are relatively high, and part of these costs is shared by the residents, leading to dissatisfaction (Fig 3-13).

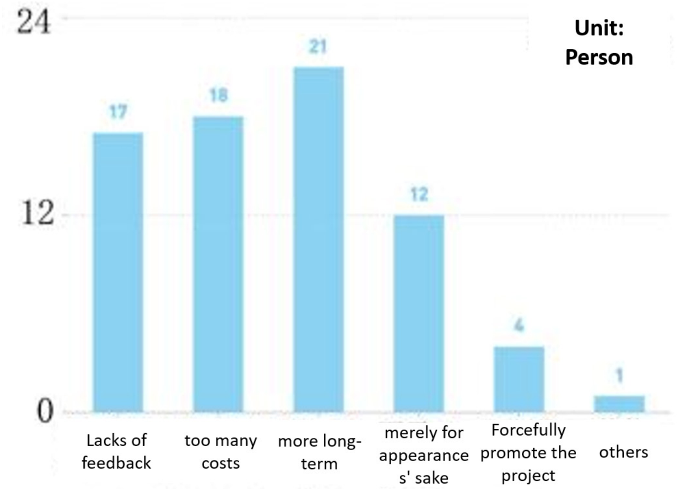


Fig 3-13 The Questionnaire Results Regarding the Renovation Issues (Source: reference[67])

In the participatory sharing phase, the main issues are that the post-renovation situation does not adequately meet the usage needs of residents. Although a co-creation committee has been established, the depth and breadth of public participation among residents remain limited (Fig 3-14).

Additionally, for the renovated public housing, commercial introductions are primarily driven by the local government's cultural and tourism center for investment promotion, resulting in a lack of connection between most introduced merchants and villagers, leading to a low level of community integration.

Fig 3-14 The Current Situation After the Renovation (Source: reference[67])

To address these issues, the introduction of augmented reality technology can provide certain solutions. Particularly in the participatory design process, augmented reality technology can effectively showcase design outcomes and conduct needs assessments. By overlaying virtual environments, augmented reality not only reduces the time and financial costs associated with constructing physical models but also offers interactive, bidirectional communication tools during needs assessments, allowing residents to better express their own needs.

2. Reflections on the Case of Shenjing Village

The case of Shenjing Village primarily emphasizes a participatory design model that combines government leadership with residents. The government provides policy and financial support, while residents participate in decision-making through "co-construction workshops." By adopting differentiated participatory design paths, the model aims to enhance residents' engagement in village renovation and renewal. This problem-oriented, spiral approach has significant implications for the study of design models.

In Shenjing Village's design model, residents hold a dominant position in decision-making. However, the specific participatory methods still rely mainly on tools such as planning drawings and design models for presentation. The mechanisms for collecting and feedbacking opinions are also relatively singular, resulting in residents being relatively passive in the decision-making process. Therefore, introducing augmented reality methods could lower the professional threshold and enhance villagers' understanding and acceptance of the renovation proposals.

3.2 Derivation of Augmented Reality Participation Models

3.2.1 Proposal of Augmented Reality Participation Models

Based on the analysis of the two participatory design cases mentioned above, it can be observed that they generally consist of three main stages: participatory research, participatory design, and participatory negotiation. According to Qian Ying's research on participatory design models for public spaces, the current mainstream participatory design processes for public spaces also include three components: analyzing users' activities and behaviors, clarifying the purposes and tasks of construction, and implementing the design. This design model is an open system[71]. The three components summarized by Qian Ying correspond to the three stages, thus allowing for the derivation of a participatory design model based on traditional participatory methods (Fig 3-15).

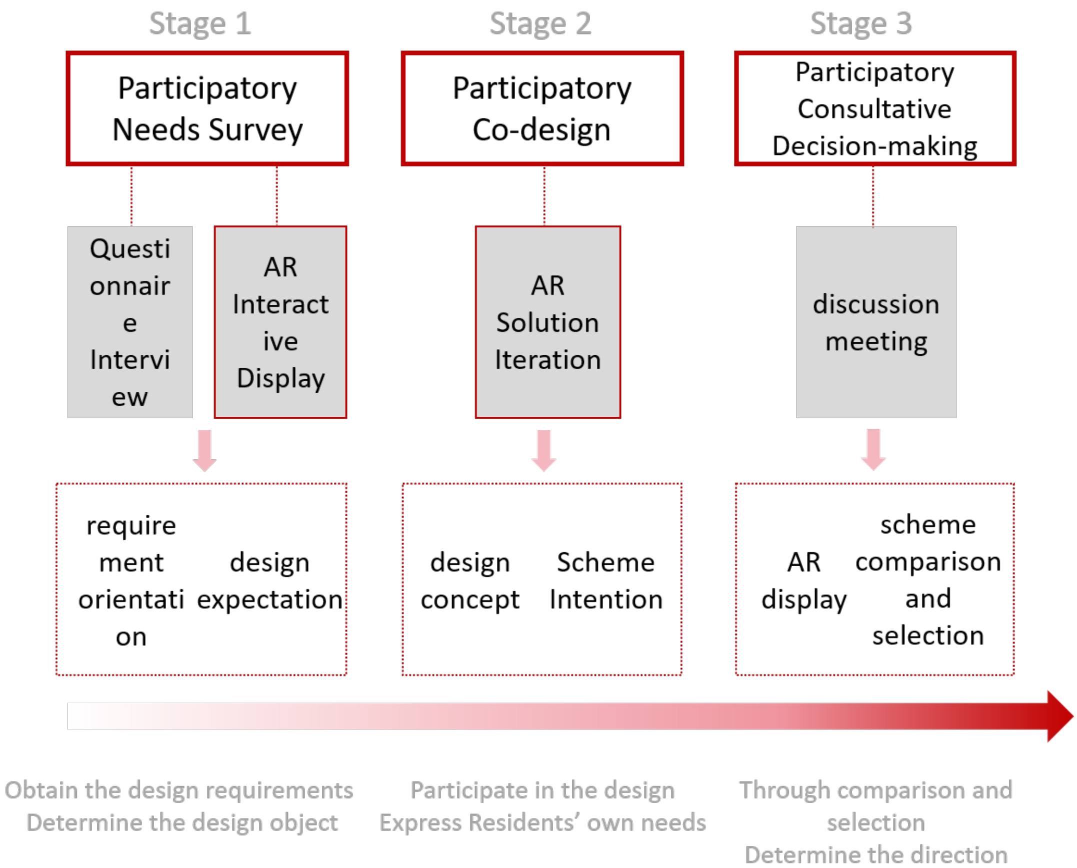


Fig 3-15 Participatory Design Pattern Summarized Based on the Case (Source: by the author)

By summarizing the experiences from the two practical cases, we can identify entry points for integrating augmented reality methods into traditional participatory design models. The analysis of the aforementioned cases reveals that the main issues currently present in participatory design models are: 1. Public feedback methods are relatively singular and tend to be one-way; 2. The level of public participation is shallow, lacking means for deeper engagement; 3. Traditional participatory methods lack advantages in terms of time and financial costs. Therefore, integrating augmented reality methods into the three stages of research, design, and negotiation can effectively address these issues.

In the research stage, in addition to traditional methods such as graphic questionnaires and field interviews, using AR interactive displays allows residents to engage in virtual scene interactions regarding existing problems in their environment. This approach can better express residents' views on the current issues of the site through visual language.

In the co-design stage, the integration of augmented reality technology and the virtual world can reduce the time required for drawing plans and constructing models, while the use of AR software can effectively lower the threshold for residents' participation in design. The integration of augmented reality can shorten the design process, which typically involves a one-way communication of design ideas from designers followed by modifications based on residents' feedback. Additionally, residents can better convey their design ideas through AR software, facilitating deeper participatory design.

In the negotiation and decision-making stage, beyond traditional discussion meetings, AR methods can also be used to display AR proposals. By showcasing the different effects of various proposals once completed, residents can make more informed decisions and advance the design of the proposals.

3.2.2 Design Process of Augmented Reality Participation Methods

Augmented Reality Participation Method — Reality Composer with Tablet Devices

The augmented reality participation method overlays virtual proposals onto real physical environments. Its advantage lies in the ability to conduct design simulations in actual public spaces without the need for prolonged immersion in a virtual environment. This approach not only reduces the physical burden associated with wearing virtual reality devices for extended periods but also provides a more authentic sensory experience.

This design practice primarily employs the 3D modeling software SketchUp in conjunction with the AR design software Reality Composer, utilizing tablet devices.

Due to software limitations in Reality Composer, imported models can only be in USDZ format. Therefore, the 2024 version of SketchUp was chosen, which allows SKP files to be exported as USDZ. This enables the conversion of pre-designed spatial modules and supporting facility components into AR models, which can then be imported into Reality Composer.

Reality Composer is an AR model design software launched by Apple, allowing designers to easily create AR models. Even users without a technical background can efficiently create AR content, making it particularly suitable for scenarios requiring rapid validation of ideas or lightweight AR implementation. The participatory design method using Reality Composer mainly involves constructing horizontal or vertical planes in real scenes to achieve model positioning, ensuring that the model maintains its scale at different distances, thereby allowing it to genuinely exist within the real scene.

Additionally, using the camera, AR models can be displayed on the screen for browsing, with options for scaling and rotating. During the placement of models, participants can continuously compare the design proposals with the real environment, enabling a more accurate assessment of the proposal's feasibility (Fig 3-16). For community renovation projects, this can serve as an innovative tool for public participation and proposal presentation.

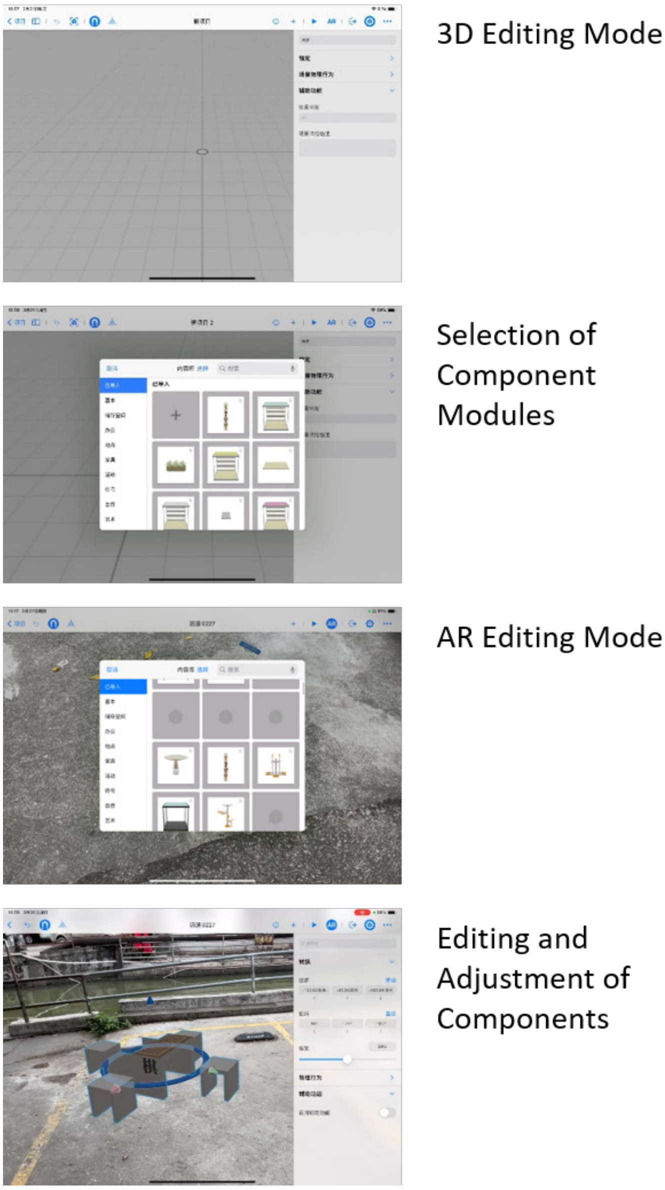


Fig 3-16 operation interface (Source: by the author)

After completing the preliminary preparations, different participants will be invited to conduct augmented reality interactive participatory design experiments in the target real-world site. Participants can freely overlay different design modules and combinations in the physical scene using their smartphones or tablets.

They can switch perspectives by moving around and control the scale and rotation of the modules through their interactions. Finally, the designer will record the participants' design proposals in the form of panoramic photo screenshots and conduct brief interviews. Subsequently, the design results will be compiled and analyzed to gather public design needs (Fig 3-17).

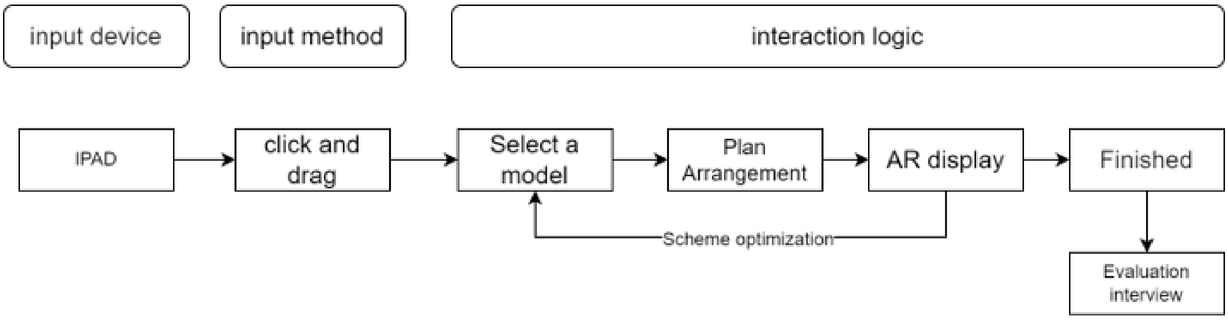


Fig 3-17 The Specific Process of the Participatory Approach via AR (Source: by the author)

3.3 Evaluation Methods of Participatory Design

3.3.1 The Spatial Element Indicators of Participatory Design

In order to conduct research on different elements of urban public spaces and quickly gather public opinions and suggestions regarding these elements, it is essential to distill multiple factors influencing the use of urban public spaces from theory. Furthermore, by leveraging the advantages of augmented reality technology, we can summarize design indicators suitable for participatory design in public spaces. This requires synthesizing various scholars' perspectives to extract design indicators applicable to this participatory design project.

1. Space Element Indicators in Jane Jacobs' Theory

First, based on Jane Jacobs' definition of urban public spaces in "The Death and Life of Great American Cities," urban spaces should "serve people." According to Jacobs' theory, the design elements of urban public spaces can be briefly categorized into four aspects: functional elements, image elements, usage elements, and social elements.

In the image elements, it is noted that "the morphological characteristics of urban space image elements obtained through image analysis reveal the hidden spatial images in people's minds, implying their special feelings and psychological belonging, and expressing their evaluations of the urban spatial environment." Spatial imagery reflects the true image of the urban environment in people's minds.

Thus, users' perceptions of spatial imagery can be used to assess whether the urban spatial forms designed by architects are effective.

If designers can genuinely adopt a human-centered design perspective from the viewpoint of urban residents, fully recognizing the real impact of the urban environment on daily life, and establish a set of design standards to support the formation of image elements, they can create urban forms that are suitable for residents and easily accepted and recognized by the public. Such forms should have high recognition and provide local residents with a strong sense of belonging and familiarity.

In the image elements, it is often possible to distill some spatial design elements that have an intuitive impact on spatial experience, such as interfaces, landscapes, and usage, for the preliminary assessment of participatory design. The following will briefly discuss each spatial element.

Interface: Refers to the morphology, color, materials, and other elements of spatial interfaces that play a crucial role in people's feelings and experiences within urban spaces. The façades of buildings and landscapes provide the most direct experience of interfaces in urban spaces. By using different colors and materials in a reasonable combination, a richer sensory experience can be provided for people within the space. Additionally, factors such as the influence of interface materials, maintainability, and comfort should also be considered.

Landscape: Urban designer Jan Gehl emphasizes the importance of spatial details in "Life Between Buildings." Landscape design within spaces can influence the amount of time people spend in those spaces. As a major component of spatial atmosphere, landscape elements can shape the unique cultural ambiance and spirit of a place, fulfilling people's spiritual needs and fostering their emotional well-being.

Usage: Usage elements primarily refer to the accessibility and functional diversity of public spaces in cities. Accessibility is one of the most important design considerations for urban public spaces. A highly accessible public space, characterized by fairness, openness, and convenience, allows nearby residents to use it freely without being constrained by social status, significantly enhancing the practicality and utilization of the space. Furthermore, the functional diversity of public spaces is also an important factor in their attractiveness. Therefore, in the design of urban public spaces, it is essential to create a unique spirit of place and atmosphere, avoiding formalism and a singular functional tendency to attract more people to enter and use the space.

Today, the variety of composite public spaces is continuously increasing, and urban public spaces must also pay attention to their traffic design, considering the dispersal and guidance of different groups to ensure that public spaces can be conveniently and quickly used by people. Additionally, visual guidance design should ensure that public spaces are maximally visible to people, increasing visual accessibility and usability. Moreover, visual connectivity and continuity within the space play an important role in enhancing space utilization. Thus, in the design of urban public spaces, accessibility, functional diversity, and visual accessibility are all critical considerations.

2. Space Element Indicators in Kevin Lynch's Theory

Second, combining Kevin Lynch's analysis of the five elements of urban imagery in "The Image of the City" regarding people's spatial perception and understanding, along with the principles proposed by Zhou Yiying and Zhang Yi, which focus on regional characteristics, spatial publicness, spatial perceptibility, and ecological safety, we can distill the following design elements from the perspectives of spatial structure and spatial cognition: functional organization, spatial form, physical interface, perceptual experience, greenery arrangement, and traffic circulation[72].

Functional Organization: Corresponding to Lynch's elements of districts, nodes, and paths, this emphasizes the mixing of spatial functions (such as commercial, cultural, and residential) in public space design. By organizing different functional areas, we can enhance the efficiency of urban public space usage, facilitating various activities for residents within the space.

Spatial Form: Corresponding to Lynch's elements of boundaries, districts, and paths, this refers to characteristics such as the scale, enclosure, and continuity of interfaces in public spaces. An appropriate urban public space form should facilitate residents' daily activities while coordinating spatial forms with the surrounding environment.

Physical Interface: Corresponding to Lynch's elements of boundaries and landmarks, this refers to the relationship between the boundaries of public spaces and their surrounding environment, such as building facades and ground paving. The design of boundaries should correspond to the functions of the space while fully considering safety and ease of passage for people.

Perceptual Experience: Corresponding to all five elements of Lynch's theory, this emphasizes people's cognition and perception of public spaces, including recognition, memory, and the construction of mental maps, as well as overall impressions and experiences of the space.

Greenery Arrangement: Corresponding to Lynch's elements of boundaries, districts, and paths, this refers to the layout and design of vegetation and greenery within public spaces.

Greenery not only provides visual aesthetic appeal but also serves functions such as sunshade, cooling, and air purification. The arrangement of greenery should meet Lynch's indicators of "comfort" and "attractiveness."

Traffic Circulation: Corresponding to Lynch's elements of paths and nodes, this primarily refers to the connectivity of paths and accessibility of nodes within urban public spaces, closely related to Lynch's concepts of "path networks" and "node concentration." The traffic design within public spaces should meet various needs for activities, including the setting and design of sidewalks, bike lanes, and vehicle lanes.

3. Space Element Indicators in Jan Gehl's Theory

Third, combining Jan Gehl's theoretical research in "Cities for People," we can organize the elements of urban public spaces based on human needs and behaviors. The significance of human needs and behaviors in urban space design emphasizes that urban design should be people-centered, creating a better urban living experience for residents.

The core of his theory lies in promoting social interaction, supporting diverse activities, and enhancing sensory experiences through the design of urban public spaces—i.e., the relationship between spatial behavior and humanization. Based on these viewpoints, the following public space design elements are proposed:

Support for Activity Diversity: Public spaces should be fully utilized to meet people's activity needs and expectations, providing diverse activities and services for local residents.

Promotion of Social Interaction: As important spaces for social interaction, urban public spaces should create environments conducive to mutual communication and interaction.

Sensory Comfort: Urban public spaces should provide a comfortable environment for users, including climate, lighting, and sound environments, while also meeting the needs for use at different times, weather conditions, and seasons.

Spatial Accessibility and Interactivity: Urban public spaces should be easily accessible and inclusive for vulnerable groups such as the elderly, children, and individuals with disabilities, ensuring their activities. Public spaces should connect with surrounding environments to enhance regional interactivity and accessibility.

Green Spaces: Urban public spaces should provide sufficient green areas.

Aesthetic Value: Urban public spaces should possess artistic qualities, making users feel comfortable and pleasant while being distinctly recognizable, allowing people to easily identify and use them.

Here is a summary of the definitions of spatial elements by three scholars (Table 3-1).

Table 3-1 The Definitions of Spatial Element by Different Scholars (Source: by the author)

	Spatial Element	**Definition**	**Evaluation**
Jane Jacobs	Interface	The spatial forms, colors and materials that affect people's feelings	Idealized indicators proposed with sociality and diversity as the core
	Landscape	Meet the spiritual and social needs	
	Usage	Spatial accessibility and functional diversity	
Kevin Lynch	Functional Organization	The mixture of spatial functions	From the perspective of spatial structure and cognition, turn the abstract concept into a concrete one.
	Spatial Form	The scale of the space and the sense of enclosure	
	Physical Interface	The boundaries of the space	
	Perceptual Experience	The experience and feeling of the space	
	Greenery Arrangement	Spatial greening	
	Traffic Circulation	The layout of the driveway and the accessibility of the nodes	
Jan Gehl	Support for Activity Diversity	Diverse activities and services	From a humanistic angle, stress the importance of space in boosting social interaction, enabling diverse activities, and enriching sensory experiences.
	Promotion of Social Interaction	Promote social interaction	
	Sensory Comfort	Spatial comfort level	
	Spatial Accessibility and Interactivity	Emphasize the care for vulnerable groups.	
	Green Spaces	Spatial greening	
	Aesthetic Value	Space provides emotional value.	

4. Extraction of Spatial Element Indicators

The core of participatory design lies in its "human-centered" design philosophy. Therefore, designers need to closely focus on spatial elements that are more closely related to the daily lives of community residents when conducting participatory design experiments. Based on a comprehensive theoretical study, and considering that spatial elements should possess a certain level of controllability for public feedback and maintain objectivity as evaluation criteria, some indicators that are subjectively difficult to quantify have been omitted. This has led to the extraction of design elements suitable for participatory design.

Based on the selection, the following indicators suitable for participatory design in urban public spaces have been established:

Public Space Function: Includes types of functions, quantity, and layout location.

Public Space Layout: Includes spatial form and accessibility.

Public Space Scale: Includes sense of scale and comfort.

Public Space Color: Includes color and material.

Public Space Interface: Includes boundary form and architectural facade style.

Public Space Greenery: Includes types of vegetation, density of greenery, and location of greenery.

The above indicators for urban public spaces are proposed based on theoretical research.

3.3.2 Subjective Evaluation Indicators of Participatory Design

As the most direct way for participants to acquire subjective information, a subjective evaluation method is used to assess the interactive experience of participation methods. According to Fang Yuling's summary of the subjective evaluation system, indicators can be constructed from four dimensions: attractiveness, level of participation, innovation, and expressiveness[73].

Additionally, as a form of digital media interaction, the augmented reality participation method is an important evaluation factor. Therefore, the following will combine literature on human-computer interaction experience evaluation and public space participatory design evaluation to construct subjective evaluation indicators for participation methods.

Based on relevant theoretical studies of human-computer interaction experience, and drawing on Wang Xiwei et al.'s evaluation indicator system which focuses on VR reading user interaction experience, indicators can be constructed from five aspects: interaction subjects, interaction functions, interaction systems, interaction content, and interaction interfaces[74].

Combining the characteristics of augmented reality interaction with experiential indicators from human-computer interaction theory, five dimensions of evaluation indicators are distilled:

Interaction Subject: Participants' overall subjective evaluation of different participation methods.

Interaction Function: Evaluation of the richness and complexity of interaction forms during the use of different participation methods.

Interaction System: Evaluation of the convenience of interaction forms in different participation methods.

Interaction Content: Evaluation of the depth and richness of information acquisition by both parties during the interaction process.

Interaction Interface: Subjective evaluation of the interface forms during the interaction process; however, since graphic questionnaires do not possess independent interaction interfaces, this will not be discussed.

According to Liu Bing et al.'s theoretical study on the comprehensive evaluation system of information quality in user experience, information interaction should aim to meet the applicability and satisfaction of information for information consumers.

By dividing user experience into three levels—functional experience, emotional experience, and utility experience—and using clarity, independence, comprehensibility, and operability as basic principles for the indicators, a subjective evaluation system for participation methods based on user experience is distilled, mainly including five indicators: convenience, comprehensibility, learnability, information accuracy, and information completeness[75].

Since participants' cognitive and emotional needs during augmented reality interaction can affect their actual experience, and most evaluations of information quality in the interaction process set users as overly rational, neglecting the impact of user emotions on the overall subjective evaluation process. Based on Jin Yan et al.'s study on the information quality evaluation indicator system for user experience, their evaluation indicator system consists of three levels[76].

Combining the characteristics of augmented reality participation models, the following four dimensions of evaluation indicators are distilled:

Content Information Affecting Cognition: including utility, comprehensibility, simplicity, applicability, accuracy, completeness, and objectivity.

Interaction Information Affecting Cognition: including learnability, fluency, and operability.

Content Information Affecting Emotion: including satisfaction, diversity of expression, low interference, and whether it stimulates curiosity.

Interaction Information Affecting Emotion: including aesthetics, personalization, fun, and universality.

From the perspective of participatory design in urban planning, Vindasius evaluates participation methods from the technical characteristics dimension, including participation scope, participation characteristics, degree of two-way communication, and the necessity of public activities[77].

Combining Vindasius's research with the basic principles of public participatory design, the following four indicators are distilled:

Participation Effectiveness: mainly refers to the public's understanding of the design scheme and feedback.

Participation Breadth: the breadth of participants and their enthusiasm for participation.

Participation Convenience: mainly includes prerequisites for participation methods, applicability of participation methods, and the cost of method application.

Participation Fairness: mainly refers to the need for participation methods to include various stakeholder groups, as well as the opinions and needs of some vulnerable groups in society.

The following are the subjective evaluation indicators of interactive experience proposed according to the above different scholars (Table 3-2).

Table 3-2 Different subjective evaluation indicators(Source: by the author)

	Indicators	**Definition**	**Evaluation**
Subjective Evaluation System	Attractiveness	The degree of attraction to the public and the stimulation of their interest	Focus on the attractiveness and innovativeness of participation. AR technology meets these needs through immersive interaction.
	level of participation	The depth of engagement and sustainability during the participation process	
	innovation	The novelty and uniqueness in technology	
	expressiveness	The clarity and integrity of the transmission of needs and design intentions	
human-computer interaction theory	Subject	The overall subjective feeling of the participation mode	Emphasize the design of functions and interfaces. AR enhances the experience through multimodal interaction and intuitive interfaces.
	Function	The richness and complexity of interaction forms	
	System	The convenience degree of interaction forms in the participation mode	
	Content	The depth and richness of information acquisition	
	Interface	The subjective evaluation of the interface form during the interaction process	

Table 3-3 Different subjective evaluation indicators(continued)

User Experience Theory	Functional Experience	Convenience, comprehensibility, ease of learning, information accuracy, integrity	Balancing functionality and emotion, AR enhances satisfaction through data accuracy and engagement
	Emotional Experience	Sense of fulfillment, diversity of expression, stimulation of curiosity, aesthetic beauty, fun	
	Utility Experience	The actual contribution of the participation mode to the design result	
	Cognitive Influence	Utility, comprehensibility, simplicity, applicability, accuracy, integrity, objectivity	
	Emotional Influence	Personalization, universality, smoothness, operability, stimulation of curiosity	
Participatory design theory	Effectiveness	The depth of the public's cognition and feedback on the design plan	Focusing on fairness and efficacy, AR drives democratic decision-making via technological inclusiveness and instant feedback.
	Breadth	The coverage of participants and their enthusiasm	
	Convenience	Prerequisites for application, scope of application, cost	
	Fairness	The inclusiveness of vulnerable groups and diverse stakeholders	

Based on a comprehensive evaluation system from multiple perspectives, and in conjunction with spatial element indicators and specific application methods of augmented reality experiments, the following subjective evaluation indicators for participatory design methods have been constructed. These evaluation indicators are primarily divided into six dimensions, as detailed below:

Universality: This refers to participants' understanding of the participation method and the breadth of its audience. This indicator also affects the ease of applying new technologies.

Learnability and Comprehensibility: This pertains to the difficulty participants experience in mastering different interaction methods within the participation framework, including understanding and operation. Understanding refers to the degree to which participants accept the operation, processes, and precautions of the participation method after the designer's introduction. Operation refers to the ease of executing interaction methods during the specific participation process, closely related to the complexity of the participation process.

Expressiveness Accuracy: In participatory design, the visualization of design proposals and the two-way communication between designers and participants are crucial. Therefore, the ability of participation methods and tools to help participants accurately express their ideas is an important evaluation factor.

Fun Factor: This measures the attractiveness of the participation method to participants, as well as whether it can stimulate their enthusiasm for participation, thereby enhancing engagement and design efficiency. The fun factor directly impacts the audience range and completion rate of the participation method.

Satisfaction: This primarily refers to the impact of participants' emotions on the outcomes of the participation method, as well as their satisfaction with the participation process, which directly influences the results of the participation method. Unlike the fun factor, satisfaction is affected not only by personal factors but also by external factors such as equipment, age, and cultural context.

Utility: This refers to the usefulness or value contribution of the participation method. Utility reflects the value judgment of the outcomes of the participation method, quantifying the extent to which the results meet demands, and is directly related to factors such as efficiency and cost of the participation method.

3.3.3 Subjective Evaluation Methods of Participatory Design

The subjective evaluation of participation methods primarily revolves around participants' assessments of the universality, learnability, expressiveness accuracy, fun factor, satisfaction, and utility of both traditional and augmented reality participation methods. Additionally, evaluations will be made on six dimensions of spatial elements. Each subjective evaluation indicator will use a five-point Likert scale, assigning scores from 2 to -2. During the questionnaire process, in-depth insights into each participant's views and evaluations of the current participation methods will also be gathered through interviews.

Universality: Participants' understanding of the participation method, categorized into the following five levels: Very well understood, Fairly well understood, Generally understood, Not well understood, Not understood at all.

Learnability and Comprehensibility: The subjective ease of understanding and operating the participation method, categorized as: Very easy, Fairly easy, Generally easy, Not very easy, Difficult.

Expressiveness Accuracy: The accuracy of different participation methods in expressing design needs, categorized as: Very accurate, Fairly accurate, Generally accurate, Not very accurate, Completely inaccurate.

Fun Factor: Participants' level of interest in different participation methods, categorized as: Very interested, Fairly interested, Generally interested, Not interested, Very uninterested.

Satisfaction: The degree of satisfaction with the outcomes and processes of the participation methods, categorized as: Very satisfied, Fairly satisfied, Generally satisfied, Not very satisfied, Not satisfied at all.

Utility: The subjective contribution of the outcomes of the participation method, categorized as: Very valuable, Fairly valuable, Generally valuable, Not very valuable, Not valuable at all.

Furthermore, subjective evaluations of the expressiveness of spatial elements in different participation methods will be assessed using five levels: Very helpful, Somewhat helpful, Generally helpful, Not very helpful, Not helpful at all.

Each level will also be assigned scores from 2 to -2. Specific evaluations of spatial elements are as follows:

Spatial Function: Whether the participation method can help participants better express their spatial function needs, including function types and distribution locations.

Spatial Layout: Whether the participation method can help participants better express their spatial layout needs, including floor plan forms and layout accessibility.

Spatial Scale: Whether the participation method can help participants better express their spatial scale needs, including scale size and comfort.

Spatial Color: Whether the participation method can help participants better express their spatial color needs, including space colors and materials.

Spatial Interface: Whether the participation method can help participants better express their spatial interface needs, including different forms of spatial interfaces.

Spatial Greenery: Whether the participation method can help participants better express their spatial greening needs, including greening density and locations.

3.4 Summary

This chapter delves into the application modes and evaluation methods of augmented reality in participatory design, with a focus on case studies from Puntong Village and Shenjing Village. It reflects on the shortcomings of traditional participatory design and proposes innovative ideas for the integration of AR technology.

Firstly, the case of Puntong Village demonstrates its policy shift from "large-scale demolition and construction" to "micro-renovation + cultural heritage." This shift emphasizes the complexity of spatial ownership, the resilience of social networks, and the challenges of cultural inheritance. Through four stages of participatory research, design, co-construction, and sharing, the design team collaborated with residents to explore a multi-stakeholder participation mechanism. While certain achievements were made, there are still shortcomings in the depth of participation and feedback mechanisms.

Secondly, the case of Shenjing Village highlights a participatory design model that combines government leadership with community engagement, forming a "co-creation workshop." This model promotes spatial planning and implementation through a multi-party negotiation platform, enhancing residents' awareness and capacity for participation. However, the singularity of participation methods and the inadequacy of feedback mechanisms still require improvement.

Based on reflections from these two cases, this chapter proposes a simulation of the AR participation model, leveraging the advantages of AR technology to suggest specific application methods in the research, design, and negotiation stages. The integration of AR technology can enhance the depth and breadth of public participation, lower participation barriers, and improve the visualization and interactivity of design proposals.

Finally, regarding evaluation methods for participatory design, this chapter summarizes spatial element indicators and subjective evaluation indicators. By assessing elements such as spatial function, layout, scale, color, interface, and greenery, combined with participants' subjective experiences, a more comprehensive understanding and optimization of the effects of participatory design can be achieved.

In summary, this chapter not only provides a theoretical foundation and practical pathways for the application of AR technology in participatory design but also offers new ideas and methods for future urban public space design.

Chapter 4 Experimental Analysis of the Effectiveness of AR Participation Models

4.1 Experimental Framework and Specific Procedures

The experimental site selected is the Huanxiufang community in Lijiao Village. This experiment primarily conducts a comparative study between the demand survey methods of traditional graphic questionnaires and those of augmented reality, focusing on participants' specific spatial needs regarding the functionality, scale, interface, color and material, and greenery of public spaces within their residential community.

The experiment consists of two phases (Fig 4-1).The first phase invites residents in the area to provide feedback on their desired modifications to public spaces through graphic questionnaires. The second phase invites residents to use augmented reality methods to design specific proposals for the public spaces they wish to modify. Subsequently, the differences in public space demand feedback between the traditional graphic questionnaire participation method and the interactive augmented reality participation method will be compared, and subjective evaluations of both participatory design methods will be conducted.

The content of the graphic questionnaire is mainly divided into two parts: participants' basic information and their expectations for public space design needs. The collection of participants' basic information primarily includes age and gender. In the design demand survey, willingness to express and collect data regarding the functionality, scale, interface, color and material, and greenery needs of public spaces will be gathered and statistically analyzed based on spatial element indicators.

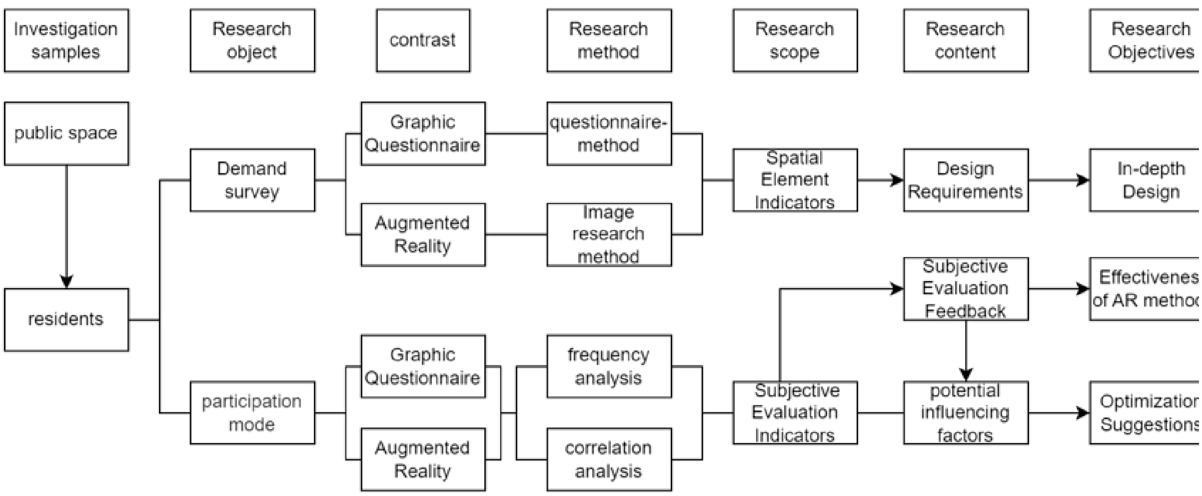


Fig 4-1 The process of the experiment(Source: by the author)

The augmented reality participation method will invite participants to select spaces they believe need renovation and upgrades, conveying their design needs through the insertion of spatial modules. After completing the design, the proposals will be recorded by taking screenshots of the images presented on the devices, documenting the specific styles, locations, and types and quantities of components used in each participant's design. The results will ultimately be presented in chart form to illustrate public demand for design elements and compared with the results from graphic questionnaires and interviews.

In terms of data analysis, image analysis will be primarily used to statistically evaluate the positions and layouts of various functional spaces and facilities within the site, integrating public demands for spatial layout forms. Additionally, frequency analysis will be employed to count the usage of different functional facilities and components, consolidating public needs for spatial functionality. The frequency of different colors used for components will be analyzed to investigate public preferences for spatial color and material. The frequency of different enclosure methods will be analyzed to assess public needs for spatial interfaces. Furthermore, the combination forms of modules will be statistically evaluated to gain insights into public demands for spatial scale. Finally, the usage and layout forms of different greenery will be examined to understand public preferences for greenery arrangements.

For the analysis of subjective evaluation results, correlation analysis will be primarily employed to compare participants' satisfaction with the two design methods, along with a comparison of the improvements in subjective evaluation indicators for different design methods.

4.2 Specific Procedures of the Experiment

4.2.1 Design of Spatial Modules

To simplify the operational difficulty for residents and obtain more generalized demand data, while allowing the design results to provide some experience related to spatial element indicators, different components suitable for augmented reality participatory design will undergo modular design. Each module scheme has the following characteristics:

1.Simple and Clear Design Elements: In the preliminary questionnaire interviews, participants mainly conveyed their spatial needs to designers through text descriptions. However, in a virtual environment, participants can only use pre-designed modules to express their design ideas based on visual digital content. Therefore, concise design elements and simple forms help improve the recognizability of digital information in the modules. Additionally, as carriers of information transmission in participatory design, a key principle for spatial modules is to simplify spatial forms and structures while experiencing the characteristics of different spatial elements.

2.Diverse Functions: By selecting a rectangular frame as the basic structure, users can insert various functional facilities within the frame, thereby increasing the freedom of public participation in design. Therefore, in participatory design, representative functional facilities will be included in a list, allowing users to decide the functional attributes of the modular space based on their needs, such as seating facilities in rest spaces, reading facilities in cultural spaces, and play facilities in activity spaces.

3.Replaceable Elements: The modular space design with a rectangular frame structure has plasticity in spatial form, allowing the frames to be interconnected to meet different spatial scale and size requirements. Simultaneously, the frame structure ensures that we can select various enclosure forms to meet participants' needs for privacy and openness. Materials and colors, as more intuitive elements of spatial factors, play a key role in public space cognition. Two types of color choices should be provided: colors found within the community and colors not typically found in the community, allowing participants to choose familiar colors from the site environment or bright colors that are less common in their living environment.

4.Flexible Greenery Arrangement: In the rectangular frame modules, greenery can serve as both a landscape element and a means of enclosure. A variety of greenery options should be provided for participants of different age groups, while varying heights of greenery can offer a richer planting experience and visual effect.

In summary, the preliminary proposal envisions a modular device with a rectangular frame as the main structural element. The modular device features interchangeable interface elements, color elements, and enclosure elements. Additionally, the rectangular modules have combinable characteristics, allowing for high recognizability in virtual reality environments while facilitating control over the variety and quantity of modules and their combinations to adjust spatial scale and form elements. Furthermore, the internal components of the rectangular modules can also facilitate the selection of spatial functional elements.

Moreover, for similar types of modules and components, the number should be reduced, providing only one or two scheme options. This approach not only minimizes the negative impact of prolonged digital device use on the human body but also facilitates better statistical analysis of public demand data. This study has initially constructed five types of public space module schemes for participatory scene design (Fig 4-2).

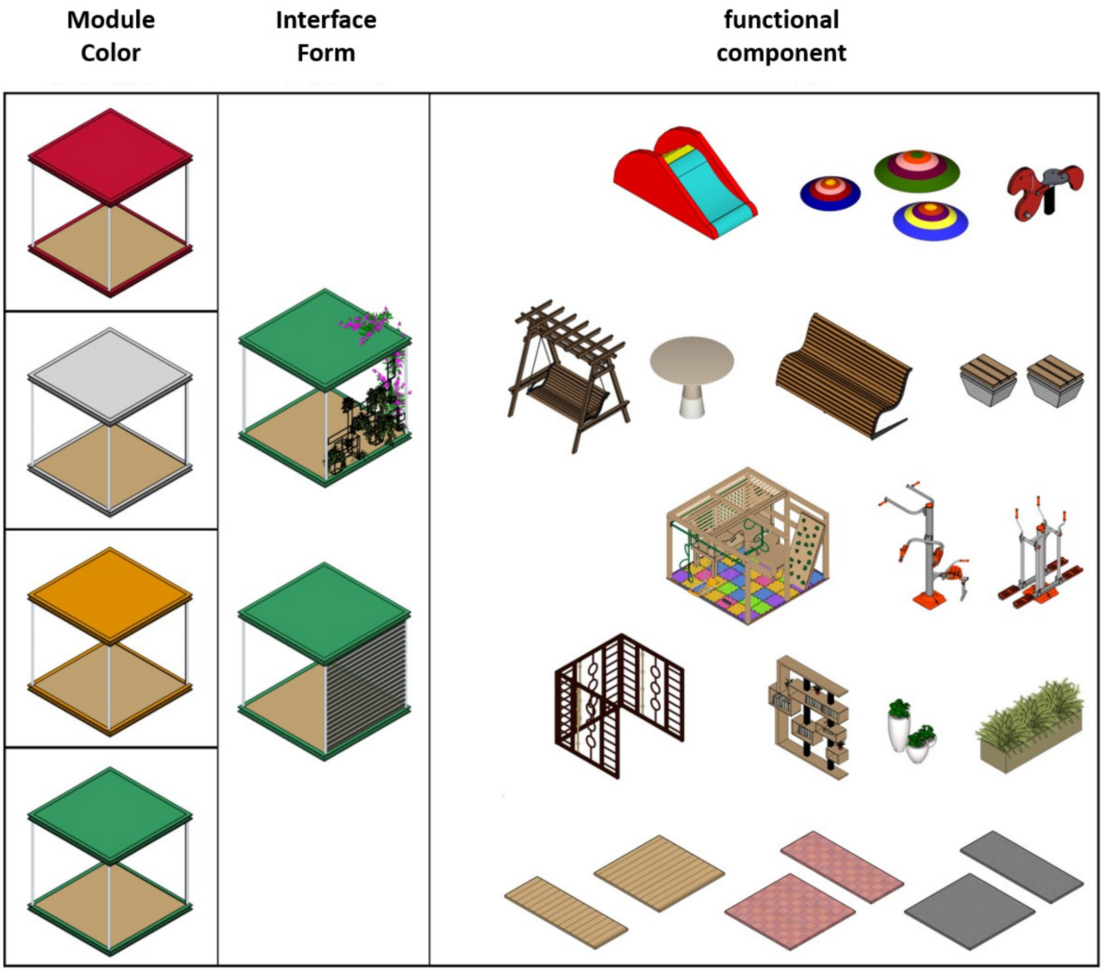


Fig 4-2 five types of public space module schemes(Source: by the author)

4.2.2 Graphic questionnaire in Participatory Design

During the demand survey phase of the graphic questionnaire, a total of 31 residents were invited to fill out the questionnaire and participate in interviews. This experiment collected opinions and needs for the renovation of the waterfront public space in the Huaxiufang community through on-site invitations.

Among the 31 participants, the majority were middle-aged individuals aged 45-69, accounting for 48.39%. The second largest group was young people aged 18-45, making up 38.71%. The proportion of minors was 9.68%, while those over 69 years old accounted for 3.23%. This indicates that the primary users of the public space in this community are young people and older adults with a certain degree of mobility.

According to the questionnaire results, 75% of participants indicated that they have responsibilities for caring for children. The specific results from the on-site interviews also revealed that most families indeed have children to care for. Therefore, in the subsequent design renovation, it is essential to fully consider the establishment of playgrounds for children to meet the needs of community residents.

4.2.3 Augmented Reality Participatory Design

During the demand survey phase of augmented reality, in addition to the previously involved 31 residents, other interested residents also participated in related operations, resulting in a total of 41 residents contributing to the participatory design outcomes.

In the design process, the augmented reality program Reality Composer locates models by constructing horizontal or vertical planes in real-world scenes. Therefore, when participants place models, a sudden change in perspective can lead to model repositioning, causing loss of design outcomes, which poses challenges for residents unfamiliar with the operation.

Additionally, in AR mode, residents find it difficult to control the movement of models in a single coordinate direction, especially for larger existing functional modules. Participants are unable to judge whether the model's position and scale are correct during movement, leading to design difficulties.

Furthermore, holding the device for an extended period to aim at the site does not accommodate the physical condition of older adults (Fig 4-3).

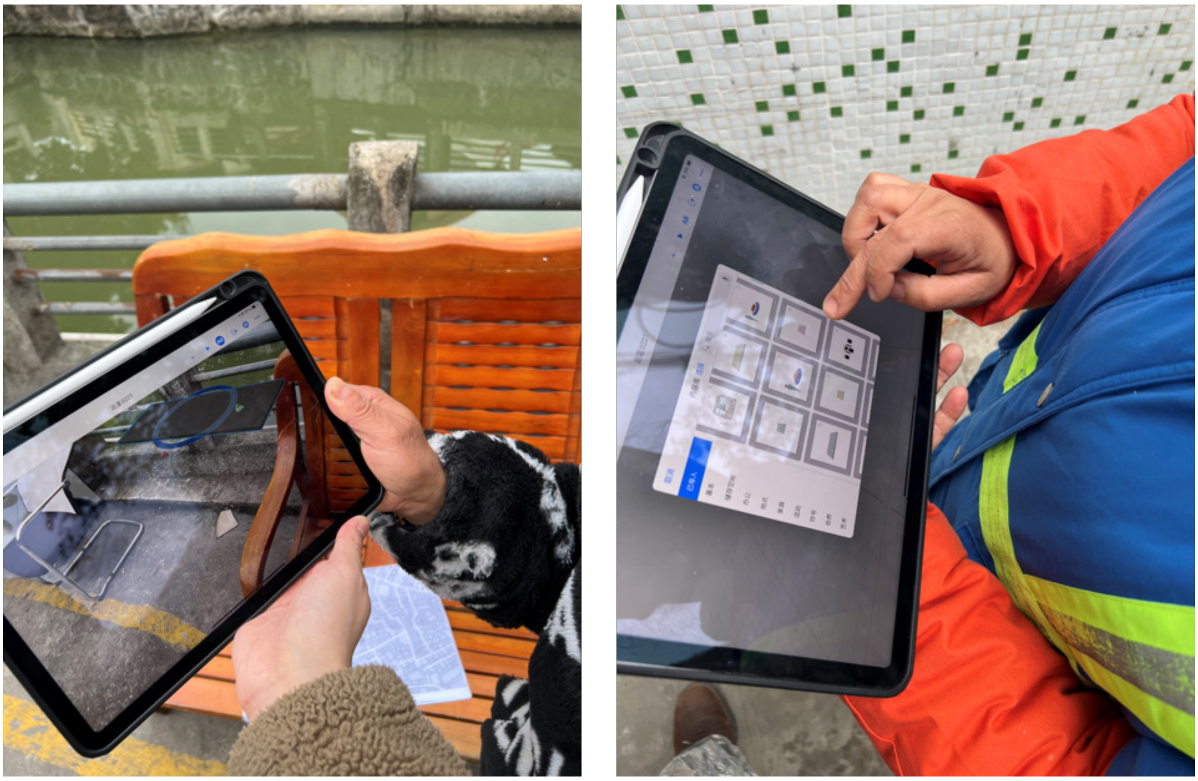


Fig 4-3 The residents carry out learning and component selection(Source: by the author)

Therefore, in the actual operation process, pre-design is primarily conducted in an editing mode without real-world overlays. After arranging large components in a clearly defined virtual environment, they are then presented in the real scene using AR mode for comparison and refinement.

Additionally, for older adults who have difficulty with operations, assistance from designers is provided. They can express their needs verbally, allowing the designer to execute the operations and provide real-time feedback for the demand survey (Fig 4-4).

Fig 4-4 The process of residents' participatory design(Source: by the author)

During the experiment, it was observed that although residents were actively invited to participate in the design of the Huanxiufang waterfront public space, most residents still chose to provide feedback and design proposals primarily based on their current location or the nearest open space available to them. This tendency highlights the importance of proximity in their decision-making process. Additionally, some existing waterfront spaces that already host public activities significantly influenced residents' choices for design locations, with space size being a major factor.

Additionally, some existing waterfront spaces that already host public activities significantly influenced residents' choices for design locations, with the size of the space being a major factor in their considerations. This suggests that familiarity and existing usage patterns play a crucial role in shaping their preferences.

While most residents indicated in the survey that an appropriate scale of public space was sufficient, under the augmented reality approach, the majority still preferred to select larger spaces for their design proposals (Fig 4-5).

Fig 4-5 The results of the residents' participatory design(Source: by the author)

Ultimately, the various participatory design proposals from residents were organized into a demand map format to analyze the distribution of needs and integrate data for different requirements (Fig 4-6).

Fig 4-6 demand map(Source: by the author)

4.2.4 Subjective Evaluation of Participation Methods

After completing the demand surveys using both the graphic questionnaire and augmented reality methods, 31 participants were invited to provide subjective evaluations of the two participation methods. The evaluation focused on various indicators, including universality, ease of learning and understanding, accuracy of expression, fun factor, satisfaction, utility, as well as elements of public space such as spatial function and layout. Participants rated these indicators using a matrix scale.

4.3 Analysis of Experimental Results

4.3.1 Analysis of Public Needs

1.Activity type

Before conducting the demand analysis, a statistical overview of the types of activities that participants primarily engage in within the community was compiled based on the questionnaire results. The statistics indicate that the two most common activities among participants are running (28.13%) and walking (25%), which correspond to the demographics of the crowd in the area. Other activities include chatting (15.63%), walking dogs or birds (12.5%), as well as resting and fishing. Due to the current constraints of public space in the area, activities that require designated zones, such as ball sports, gym equipment use, and reading, accounted for 0%.

Additionally, data was organized regarding the time participants choose to use public spaces. According to the statistics, over half of the participants indicated that they primarily engage in activities in the community's public spaces in the afternoon (37.5%) and evening (28.13%), with only a small portion of participants primarily active in the early morning. The proportion of those engaging in activities in the morning and at noon is relatively low.

2. Analysis of Demand Orientation in the Picture-and-Text Questionnaire

According to the survey results, the current public space in the area primarily faces the following functional issues:

Insufficient Public Space: This is the most significant concern, accounting for 37.5%.

Lack of Rest Benches: This issue accounts for 34.38%. Given that a considerable portion of the public space users are elderly, there is a clear shortage of resting benches.

Inconvenient for Walking: This concern accounts for 12.5%. The mixed traffic of pedestrians and vehicles, along with the absence of dedicated non-motorized lanes, presents challenges for creating a pedestrian-friendly environment.

Some young and elderly participants feel that the current space meets their daily needs but still has areas for improvement. A small number of participants expressed specific needs regarding the greenery and aesthetics of the public space.

Regarding the design requirements for spatial elements, the need for more space, more accessible paths, and increased greenery are the primary concerns for most participants, with proportions of 34.38%, 28.13%, and 21.88%, respectively. In terms of spatial scale, over half (62.5%) of the participants believe that the current scale is appropriate, while a portion (34.38%) indicated that a larger scale would be preferable.

On the issue of spatial privacy, 90.63% of participants expressed a desire for an open space to facilitate better social interactions. For boundary elements of the space, over half (62.5%) chose vegetation as the enclosing feature, while a small number believed that boundaries should remain completely open. No participants selected walls as boundaries for the space.

Finally, regarding color choices for the space, 50% of participants selected green as the primary color for the public space, followed by orange at 46.88%. No participants chose gray as the primary color (Fig 4-7).

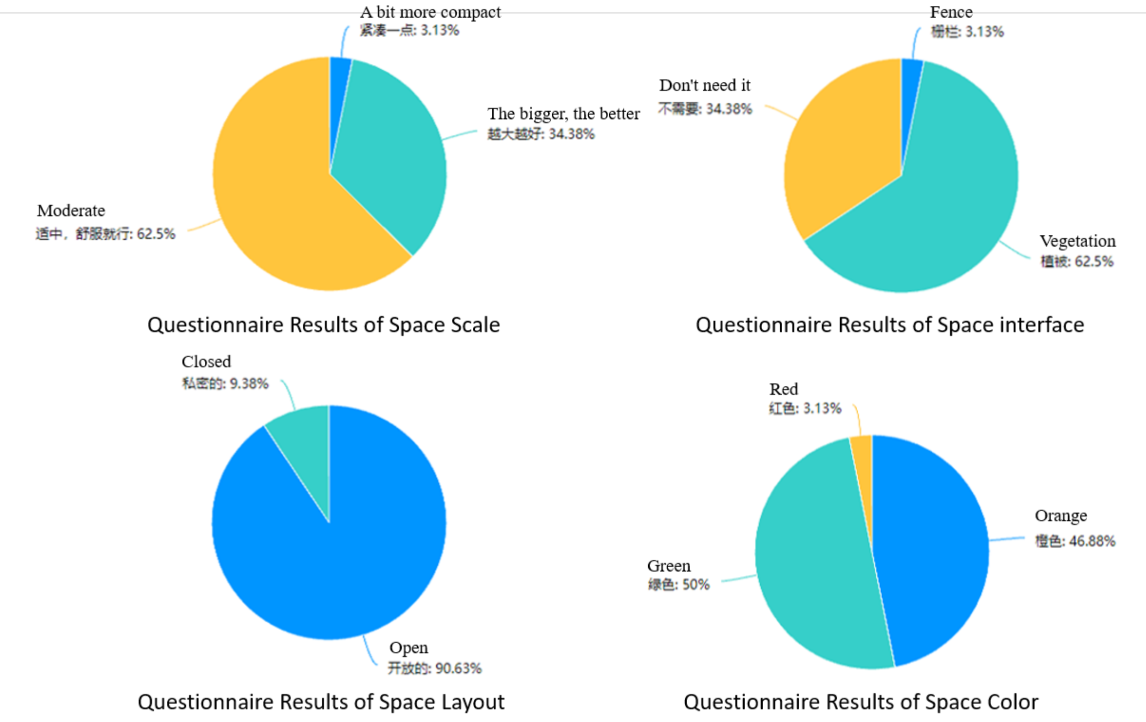


Fig 4-7 The questionnaire survey results of the spatial element indicators(Source: by the author)

The following are the frequency results of different needs of residents under the participation mode of the traditional picture-and-text questionnaire (Table 4-1).

Table 4-1 the frequency results of different needs(Source: by the author)

questions	option	frequency	percentage (%)
What kind of activities do you usually engage in within the community?	Running, taking a walk	8	25.81
	Playing cards and chess	8	25.81
	Chatting	5	16.13
	Walking the dog	4	12.9
	Resting	3	9.68
	Fishing	3	9.68
What time periods do you usually carry out activities in the community's public spaces?	Afternoon	11	35.48
	Evening	9	29.03
	Early morning	6	19.35
	Noon	3	9.68
	Morning	2	6.45
What problems do you think exist in the public spaces of the community where you live?	Insufficient public space	11	35.48
	Lack of resting seats	11	35.48
	Inconvenient for walking	4	12.9
	Lack of children's facilities	3	9.68
	Lack of fitness facilities	1	3.23
	Lack of cultural space	1	3.23
Which of the following aspects do you value most regarding public spaces?	More space	10	32.26
	More convenient to reach	9	29.03
	More greenery	7	22.58
	More beautiful	3	9.68
	More functions	2	6.45
How large a public space do you think is suitable for activities?	Moderate	20	62.5
	The bigger, the better	11	34.38
	A bit more compact	1	3.13
A more open space or a more private one?	Open	29	90.63
	Private	3	9.38
What do you hope the public space will be enclosed by?	Vegetation	20	62.5
	Don't need it	11	34.38
	Fence	1	3.13
What color would you prefer for the public space?	Green	16	50
	Orange	15	46.88
	Red	1	3.13

Based on the usage of functional components in the design, we can obtain the distribution of residents' functional needs for different public spaces (Fig 4-8). By combining the usage rates of various functional components, we can gain a rough understanding of residents' spatial needs. The component usage rates are derived from the average proportion of functional component elements in the design proposals.

Fig 4-8 The distribution situation of different components in the site(Source: by the author)

Similar to the survey results, the majority of participants selected the layout for resting areas, accounting for 41.9%. The second most chosen feature was children's activity spaces, which accounted for 32.3%. The remaining features included greenery, fitness, culture, and others.

From the participatory results, we extracted the usage rates of different component facilities in the design proposals.

The most frequently appearing functional component was seating arrangements, totaling 41.9%, which includes various individual chair facilities, tables and chairs in resting spaces, shared tables and chairs, and various individual table facilities.

The second most common was children's activity facilities, accounting for 22.6%.

The third was various paving facilities, making up 19.4%, which includes paving for children's activity areas, paving under tables and chairs, and paving choices for water-friendly walkways. Lastly, fitness equipment, greenery, and bookshelf components were laid out more randomly (Table 4-2).

According to the survey results on boundary forms, most participants chose semi-open boundary forms such as fences and greenery, while a small number opted for completely open boundaries. No participants selected solid walls as boundaries, which aligns with the survey results indicating a preference for open boundary forms.

Table 4-2 Spatial demands in the augmented reality participation mode(Source: by the author)

Spatial Element Indicators	**Category**		**appearance frequency （%）**
Space Function	function type	rest	41.9
		children's activities	32.3
		landscaping	12.8
		fitness	6.5
		culture	6.5
	component	chair	37.1
		children's facilities	22.6
		pavement	19.4
		green plants	6.4
		fitness equipment	6.4
		table	4.8
		bookshelf	3.3
Space Interface	fence boundary		46.1
	green plants boundary		38.5
	without boundary		15.4
Space Layout	Open		100
	closed		0
Space Color	Color	Green	46.7
		Orange	33.3
		Grey	13.4
		Red	6.6
	pavement material	Wooden	69.6
		Brick	17.4
		Concrete	8.7
		Rock	4.3

In terms of color elements, the most frequently chosen colors remain bright shades like orange and green, with green being the highest proportion, consistent with the survey results. Additionally, in the augmented reality participation method, a small number of participants selected gray components, while no participants chose gray in the graphic survey, indicating the limitations of textual descriptions.

Regarding paving materials, the majority of participants chose wooden flooring, accounting for 69.6%, followed by stone paving, concrete paving, and stone block paving.

4. The demand comparison between the two participation methods

Through the comparison in the table below (Table 4-3), we can derive preliminary resident needs:

Increase the Resting Function of Public Spaces: Residents wish to add more resting areas in public spaces to meet their daily relaxation needs.

Moderate Spatial Scale and Open Boundaries: Residents prefer public spaces with a moderate scale and open boundaries to facilitate social interactions.

Color Arrangement of Spaces: In terms of color choices, residents lean towards using green to create a natural and comfortable environment.

Table 4-3 The demand comparison between the two participation methods(Source: by the author)

category of demand	**Graphic Questionnaire**	**Augment Reality**
activity time	afternoon and evening	unable to acquire
activity category	stroll chess and cards	unable to acquire
Space Function	relax	relax and children's activities
Space Layout	moderate	moderate
Space Scale	unable to acquire	can be obtained by screenshot
Space Color	green	green
Space Interface	boundary of green plants	fence boundary
Space Greenery	unable to acquire	can be obtained by screenshot

4.3.2 Evaluation of Participation Methods

1. Reliability analysis

Reliability analysis is a statistical method used to assess the reliability of measurement tools such as questionnaires and scales. It aims to evaluate the stability and consistency of measurement results. The core objectives are to answer the following questions: When measuring the same subject repeatedly, are the results similar? Are the measurement results consistent across different assessors or at different time points?

The stability of results is generally verified using the quantitative indicator Cronbach's α coefficient. This indicator is primarily used to measure the internal consistency of scales or questionnaires, with values typically ranging from 0 to 1; higher values indicate better internal consistency. Generally, a Cronbach's α coefficient above 0.7 is considered indicative of good internal consistency.

Based on the reliability analysis of a questionnaire with 27 items and 31 samples, the Cronbach's α coefficient is 0.783, indicating relatively good internal consistency (Table 4-4).

Table 4-4 Reliability analysis(Source: by the author)

sample size	number of projects	Cronbach α
31	27	0. 783

2.针对参与方式指标的评价分析

The following figure shows the results of the subjective evaluation analysis by residents of the two participation modes (Fig 4-9).

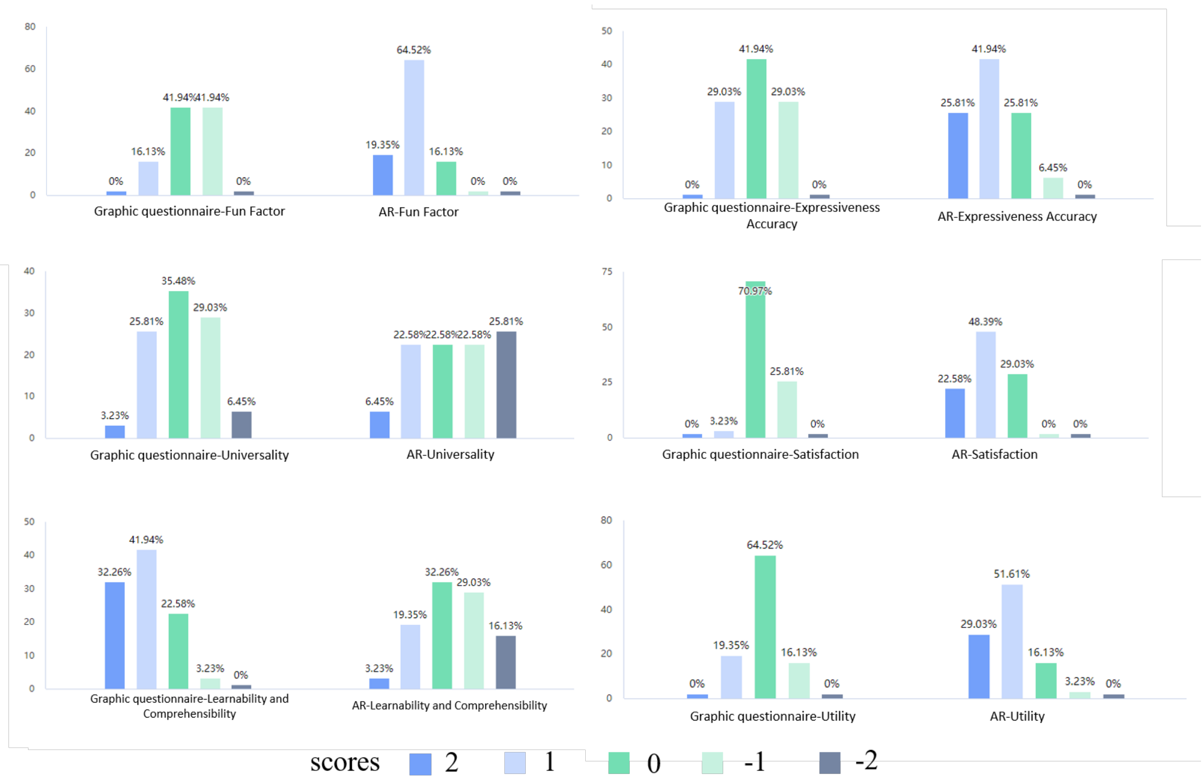


Fig 4-9 The questionnaire results of the subjective evaluation of the participation methods(Source: by the author)

Universality Indicators: Most residents at the site have a low level of understanding of both participation methods. However, relatively speaking, a larger number of residents are more familiar with the graphic questionnaire method, while most are completely unaware of the augmented reality participation method.

Learnability and Comprehensibility Indicators: Over half of the participants indicated that the graphic questionnaire method is easier to use. Most participants felt that the augmented reality method is not particularly user-friendly. This may be attributed to the relatively high proportion of middle-aged participants, who find it slightly challenging to use digital devices. However, the relatively simple operation of the iPad allows most people to complete the design independently. For some older participants who find it difficult to operate independently, a method of verbal guidance combined with designer assistance allows them to complete the task smoothly.

Expressiveness Accuracy Indicators: Most participants believe that the augmented reality mode allows them to express their design intentions and ideas more clearly. At the same time, more than half of the participants feel that the graphic questionnaire can roughly meet their expression needs, but there are still certain shortcomings. Overall, the feedback of augmented reality in terms of expression has been recognized by most residents.

Fun Factor Indicators: Most participants find the graphic questionnaire method to be less engaging and the filling process somewhat tedious. In contrast, the augmented reality participation mode significantly enhances fun due to its high interactivity, making it more appealing for residents. However, in conjunction with the ease of learning and understanding indicators, the graphic questionnaire's inherent simplicity and high popularity remain reasons for its common use in participatory design. Meanwhile, the augmented reality mode has a certain threshold due to its operational difficulty, resulting in lower universality.

Satisfaction Indicators: Participants using the augmented reality mode can visually see the approximate effects of their design intentions, thus providing a higher level of design satisfaction and emotional value. This leads to significantly higher completion rates and participation enthusiasm. In contrast, traditional graphic questionnaires, due to their textual limitations and abstract expressions, fail to meet residents' emotional values in design participation.

Utility Indicators: Most people maintain a neutral attitude regarding the value of the final results from the graphic questionnaire method, as it cannot rely solely on text and images to abstract concepts. However, due to real-time feedback on design outcomes, most residents indicate that their participation results have certain value and represent their intentions. From the perspective of time cost, although the augmented reality participation mode requires more time for design, its ability to quickly iterate design outcomes makes it relatively more efficient in obtaining final demand directions.

In summary, through the survey results of the subjective evaluation indicators of the two participation methods, we have compiled the positive evaluations from participants regarding the six subjective evaluation indicators of both methods to derive the residents' satisfaction with the two participation methods, summarized in the following chart (Fig 4-10).

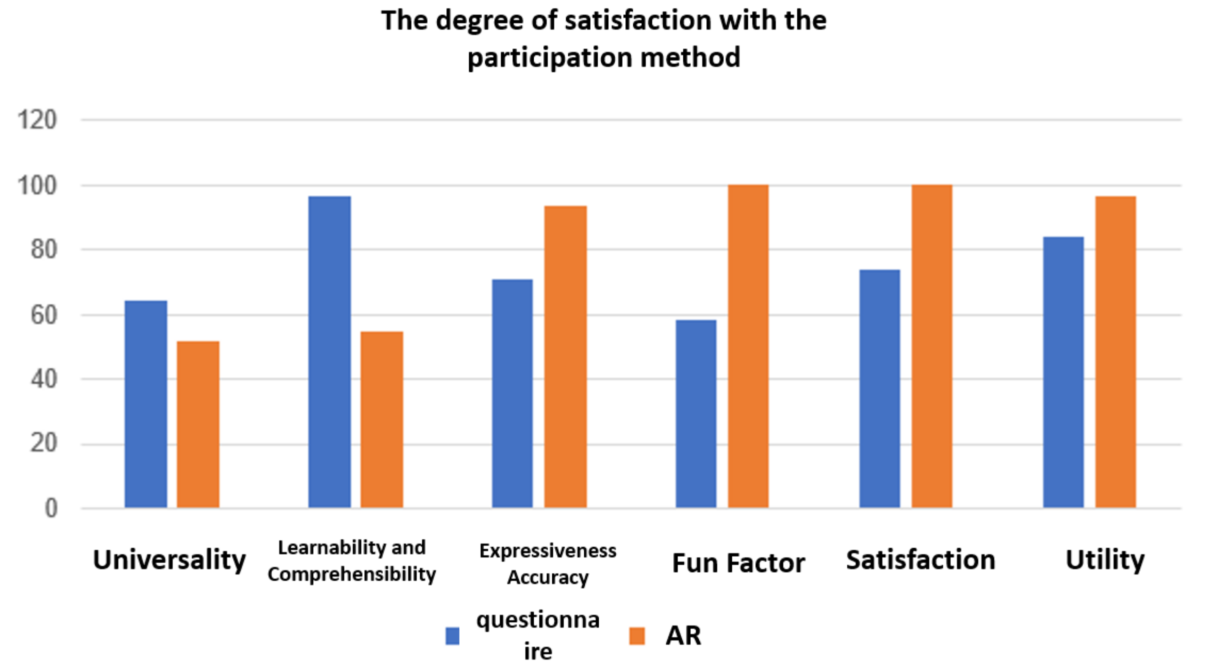


Fig 4-10 The satisfaction degrees of the two participation methods(Source: by the author)

It can be observed that, aside from the Universality indicator and Learnability and Comprehensibility indicator, the augmented reality participation method significantly outperforms the graphic questionnaire method in terms of expression accuracy, fun factor, satisfaction, and utility. Notably, in the fun factor and satisfaction indicators, the augmented reality method received 100% positive feedback, with the fun factor improving by 41.93% compared to the graphic questionnaire method.

Conversely, the graphic questionnaire method achieved higher satisfaction in terms of Universality and Learnability and Comprehensibility, particularly showing a decrease of 41.94% in the Learnability and Comprehensibility indicator for the augmented reality method.

3. The evaluation and analysis of the spatial element indicators

In terms of evaluating spatial design elements, overall, the augmented reality participation method received higher ratings across all elements compared to the traditional graphic questionnaire method (Fig 4-11). Although both participation modes received high ratings in spatial functionality indicators, data and on-site interviews indicate that the traditional graphic questionnaire method can adequately meet feedback on spatial functional needs.

Therefore, the functional components provided by the augmented reality method can help residents select functions more quickly, serving as an enhancement.

Regarding the evaluation of spatial layout elements, the graphic questionnaire method, due to the limitations of text, fails to provide visual expressions for layout and accessibility choices, resulting in many residents being unable to visualize the design outcomes. This leads to lower ratings. In contrast, augmented reality can present the spatial layout results intuitively on the screen, receiving more positive feedback.

In the evaluation of spatial scale, although most participants rated the augmented reality method highly, a small number of participants expressed concerns that component arrangement through zooming might lead to scale issues. Additionally, screenshots from participants showed some components distorted in spatial scale, which is an area needing optimization in the future.

For the evaluations of spatial color, spatial interface, and spatial greening layout, the augmented reality participation method also received higher ratings. Furthermore, in terms of greening layout, some participants reported that the models of plants were too fragmented and difficult to manipulate, leading to certain performance issues.

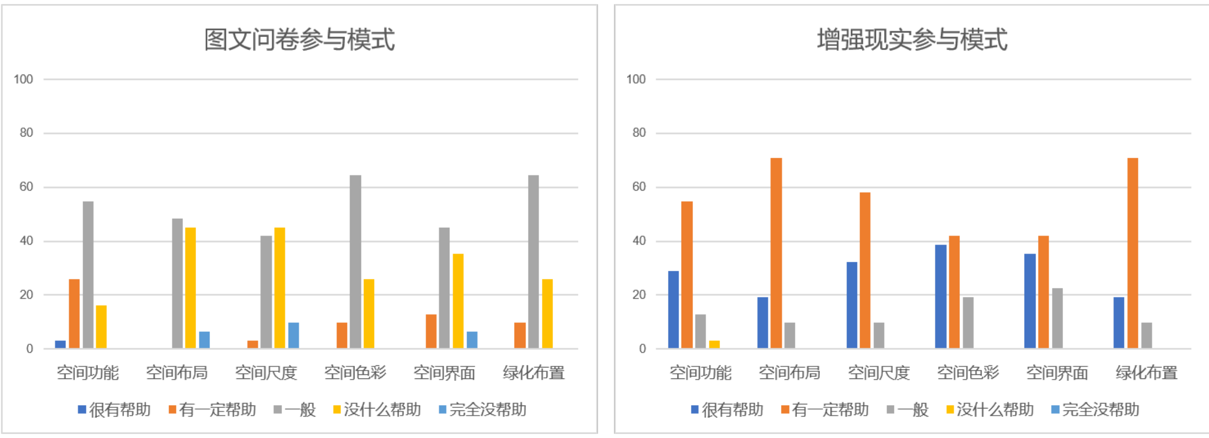


Fig 4-11 The questionnaire results regarding the spatial element indicators(Source: by the author)

In summary, by comparing the positive evaluations of the augmented reality participation method and the graphic questionnaire method in terms of spatial element indicators, we have organized residents' satisfaction with the two participation methods, as shown in the table below.

Overall, the augmented reality participation method received higher satisfaction ratings across all six indicators compared to the graphic questionnaire method. Notably, in terms of spatial scale and spatial layout, the intuitive expression of augmented reality led to satisfaction increases exceeding 50%.

However, the improvement in satisfaction for the spatial functionality indicator was not significant, indicating that the graphic questionnaire method essentially meets residents' usage needs (Fig 4-12).

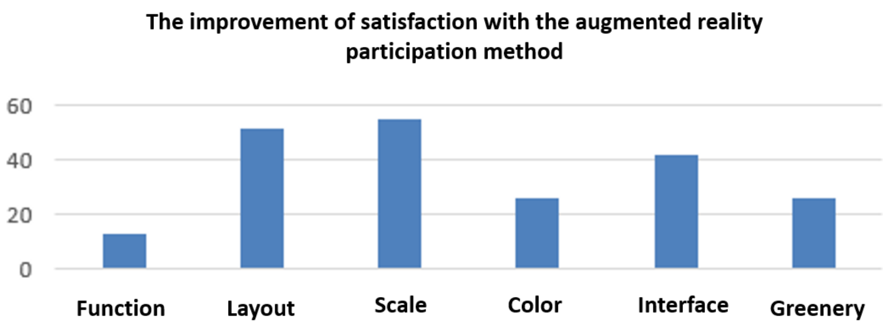


Fig 4-12 The improvement of the AR participation method with spatial elements(Source: by the author)

4.3.3 Analysis of Intrinsic Factors

Correlation analysis is a statistical method used to study the degree of association between two or more variables, quantifying the linear or nonlinear relationships among them. Its goal is to measure the strength and direction of the linear relationships between these variables, indicating how they are interconnected. This paper employs the Pearson correlation coefficient for correlation analysis. The Pearson correlation coefficient is primarily used to measure the linear correlation between two continuous variables, with a value range from -1 to 1. A coefficient closer to 1 or -1 indicates a stronger relationship between the variables, with positive and negative values representing positive and negative correlations, respectively. A coefficient closer to 0 indicates a weaker relationship or the absence of a linear relationship. Generally, a coefficient above 0.7 indicates a very strong relationship; between 0.4 and 0.7 indicates a strong relationship; and between 0.2 and 0.4 indicates a moderate relationship.

1. Correlation Analysis between Age and Participation Methods

Based on the correlation between age and different indicators (Fig 4-13), we can derive the following insights:

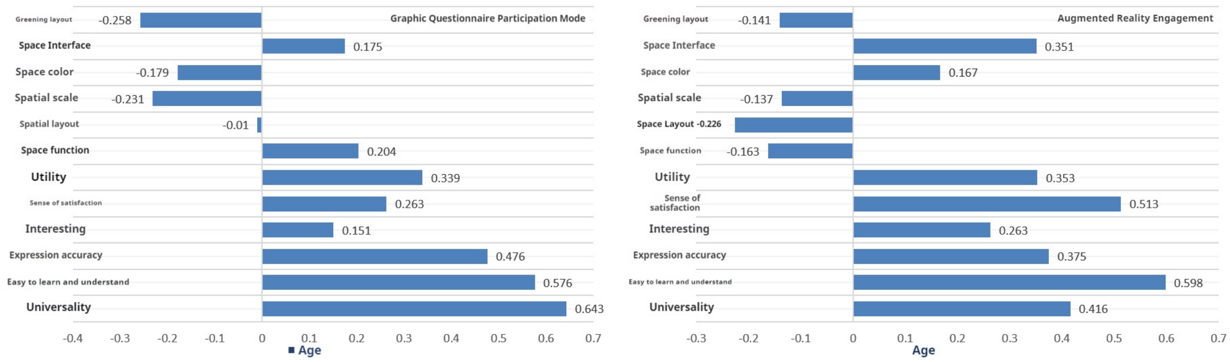


Fig 4-13 The correlation between age and the two participation methods(Source: by the author)

The graphic questionnaire participation method is more user-friendly for the elderly. It shows a positive correlation with age in terms of Universality, Learnability and

Comprehensibility, spatial functionality, and spatial interface, indicating its suitability for collecting basic needs from older adults. Conversely, the graphic questionnaire method shows a negative correlation with age in terms of expression accuracy, spatial scale, and greening layout, suggesting that these areas require supplementary explanation through diagrams or verbal descriptions.

The augmented reality participation method, due to its visualization advantages, shows a positive correlation with age in terms of spatial interface and spatial color, indicating that intuitive expression helps address challenges in interface forms and color selection. However, it shows a negative correlation with age in terms of spatial functionality, spatial scale, and greening layout, suggesting operational challenges that need simplification to meet the needs of older users.

Conclusion: For the elderly population, it is preferable to use graphic questionnaires to collect functional needs. For interface and color aspects, augmented reality is more suitable for assisting in needs collection.

2. The correlation analysis among the indicators of participation methods

First, let's examine the correlation between indicators of the graphic questionnaire participation method. The correlation coefficient between Universality and Learnability and Comprehensibility is 0.452, indicating a positive correlation between the two. This effectively explains the widespread applicability of the graphic questionnaire format, which is also more straightforward and comprehensible for older residents (Table 4-5).

Table 4-5 The correlation analysis of the questionnaire participation method(Source: by the author)

	Universality	Learnability and Comprehensibility	Expressiveness Accuracy	Fun Factor	Satisfaction	Utility
Universality	1					
Learnability and Comprehensibility	0.452*	1				
Expressiveness Accuracy	0.352	0.669**	1			
Fun Factor	0.198	0.014	0.177	1		
Satisfaction	0.159	0.339	0.433*	0.202	1	
Utility	0.118	0.196	0.142	0.095	0.136	1

Additionally, there is no significant correlation between Universality and Expression

Accuracy, Fun Factor, Satisfaction, and Utility, with correlation coefficients close to 0.

Moreover, Learnability and Comprehensibility indicator shows a positive correlation with Expression Accuracy, and the correlation is notably high, indicating that participants who better understand the graphic questionnaire are more capable of clearly articulating their needs. Furthermore, the positive correlation between Expression Accuracy and Satisfaction suggests that clearly expressing one’s needs can provide participants with greater emotional value.

In analyzing the correlations between indicators of the augmented reality participation method, the main indicators with high correlations include Fun Factor with Universality, Learnability and Comprehensibility with Satisfaction, and Learnability and Comprehensibility with Utility. Although there is a slight negative correlation between Expression Accuracy and Satisfaction, the correlation coefficient is close to 0, making it negligible (Table 4-6).

The analysis indicates that improving Learnability and Comprehensibility can lead to higher fun, thereby attracting more participants to engage in participatory design. Additionally, due to its simplicity, participants' satisfaction is also likely to be higher. This suggests that selecting participation methods that are easy to operate, such as mobile phones and tablets, is reasonable. Furthermore, enhancing Learnability and Comprehensibility can also increase the Utility of the results, indicating that user-friendly participation formats are significant for improving the efficiency of participatory design and reducing design iteration costs.

Table 4-6 The correlation analysis of the augmented reality participation method(Source: by the author)

	Universality	Learnability and Comprehensibility	Expressiveness Accuracy	Fun Factor	Satisfaction	Utility
Universality	1					
Learnability and Comprehensibility	0.282	1				
Expressiveness Accuracy	0.278	0.194	1			
Fun Factor	0.403*	0.477**	0.195	1		
Satisfaction	0.115	0.521**	-0.065	0.308	1	
Utility	0.228	0.507**	0.159	0.21	0.126	1

4.3.4 Experimental Conclusions and Optimization Suggestions

1. Conclusion

Through statistical analysis of the two participation methods—graphic questionnaires and interactive augmented reality—across six evaluation indicators and six spatial element indicators, it can be preliminarily concluded that the augmented reality method is an effective tool for participatory design. Additionally, the data analysis results provide certain optimization suggestions for the participatory design model.

2. Optimization Suggestions

The graphic questionnaire method, as a mainstream tool for urban design demand surveys in China, is characterized by its high convenience, dissemination, and tolerance for error, making it more suitable for the fast-paced lifestyle and efficient information dissemination of the current internet era. Moreover, the limitations of augmented reality technology regarding equipment, operation, and application software prevent it from achieving large-scale popularity like graphic questionnaires.

From the perspective of enhancing participant engagement, the augmented reality method can indeed better leverage participants' subjective initiative. Its high interactivity and immersive experience can spark public curiosity and provide participants with higher emotional value, effectively increasing participation levels. However, considering the individual differences among various participant groups, a highly engaging method does not necessarily lead to a higher audience reach, as most participants prioritize practicality.

Additionally, considering the age of participants, the graphic questionnaire format is more suitable for the elderly population. This format has certain advantages in expressing spatial functional elements, aligning better with the understanding and operational needs of older adults. In terms of expressing spatial elements, participants place more emphasis on the expression of spatial functions in graphic questionnaires, demonstrating that text and image displays can clearly convey their needs to designers.

In terms of spatial layout, since graphic questionnaires struggle to show real-time demands such as "how to arrange and what it will look like after arrangement," it is more reasonable to adopt augmented reality participation methods in this aspect of design. Similarly, in surveys requiring interface and color representation, the augmented reality participation model is also more appropriate.

Moreover, in interactive augmented reality, participants express spatial scale more strongly. The immersive expression of virtual models overlaid on real scenes provides participants with a more authentic spatial scale experience. Participants who can quickly understand and operate augmented reality technology can achieve a more comprehensive participatory experience and solution outcomes, making the augmented reality participation model more suitable for younger individuals with higher learning capabilities.

In summary, although the augmented reality participation method is more suitable for participatory design in public spaces regarding the expression of spatial elements, considering the actual conditions of local residents and the specific needs of participants, combining traditional graphic questionnaire methods can better capture the diverse needs of multiple stakeholders and help improve design efficiency.

4.4 Summary

This chapter presents a detailed analysis of the effectiveness of two participatory modes—traditional graphic questionnaires and augmented reality—through an experiment conducted in the Huanxiufang community of Lijiao Village, Guangzhou. The experiment was divided into two phases: first, a graphic questionnaire was used to collect residents' needs for public space renovation, followed by feedback on spatial design proposals using AR technology. The research focused on aspects such as the functionality, scale, interface, color materials, and greenery requirements of public spaces, aiming to compare the differences in public space demand feedback between the two participatory methods.

Subjective evaluation results indicate that while the AR participation mode received high recognition from participants in terms of Fun Factor and Satisfaction, the traditional graphic questionnaire still holds advantages in terms of Learnability and Comprehensibility and Universality. This suggests that traditional graphic questionnaires are more suitable for elderly populations, as they better meet their needs, while the AR participation mode is more appropriate for younger individuals due to its higher operational complexity. There is a significant correlation between participants' ages and their evaluations of the participation methods, highlighting the need to consider user experience across different age groups in design.

In summary, the AR participation mode, as an emerging participatory design tool, demonstrates good feasibility and can effectively enhance residents' sense of involvement and satisfaction with the design. However, leveraging the advantages of traditional graphic questionnaires, it is recommended to combine both methods in practical applications to more comprehensively meet the needs of different groups and improve design efficiency. Additionally, future research should focus on simplifying interaction methods to promote broader adoption and application of AR technology.

Chapter 5 Design Practice Based on Augmented Reality Participation Model

Based on the research on augmented reality participatory models in previous chapters, we have summarized and refined participatory design strategies suitable for the renovation of old villages. Next, we will apply these design strategies in a specific site to validate their usability.

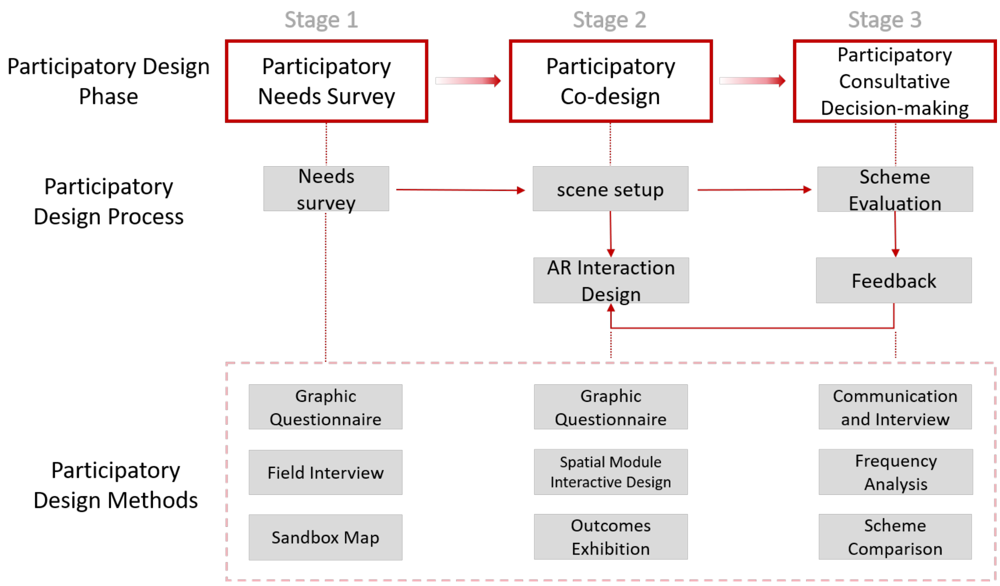


Fig 5-1 The AR Participation Model Applied to Huanxiufang Community(Source: by the author)

The practical strategies for participatory design in Huanxiufang Community in this chapter are refined based on the AR participation model established in Chapter 3, incorporating considerations of site characteristics and operational convenience (Fig 5-1). Building on the three stages of participatory design with AR technology outlined in Chapter 3, the corresponding participatory design process is divided into sections including needs survey, scene setup, interactive design, scheme iteration, and outcome feedback. Augmented reality tools are applied to the design process during the participatory co-design stage.

This chapter will focus on the public space of the Huanxiufang community in Guangzhou, using the previously established design methodology to demonstrate the participatory design approach supported by augmented reality. First, we will conduct a site analysis and current situation survey to identify the issues that require renovation from the designer's perspective. Then, through participatory research, we will gather residents' priorities and willingness for the renovation of different areas within the site to determine the design objects. Finally, based on the selected design objects, we will conduct the design process using participatory design methods (Fig 5-2), proposing optimization suggestions for the public space of the Huanxiufang community, and summarizing experiences from the design process and outcomes to refine the augmented reality participatory design model.

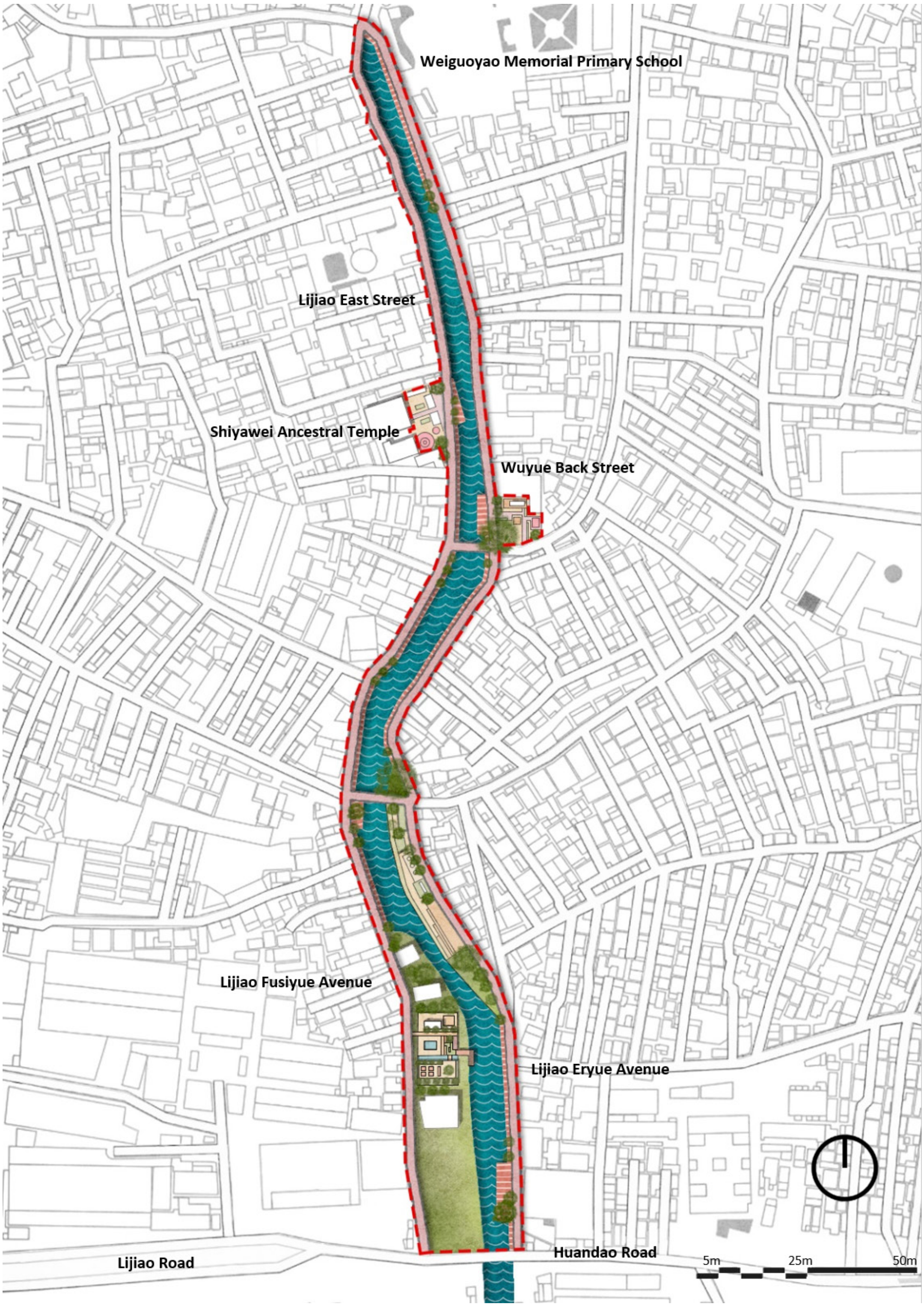


Fig 5-2 The plan view of the renovation achievements of Huanxiufang Community(Source: by the author)

5.1 Site Information

5.1.1 Site Overview

The Lijiao Water Town is located in the southern suburbs of Guangzhou, spanning both banks of the southern navigation channel of the Pearl River. It encompasses the southern part of Henan Island (now the main island of Haizhu District) and 11 settlements on Shajiaodao (now Luopu Street Luoxi Island in Panyu District), forming a water town lifestyle circle connected by waterways. As the core area, Lijiao Village is situated at the southern end of the new urban axis of Haizhu District, in a waterfront area bordered by Haizhu Lake to the north, the southern navigation channel of the Pearl River to the south, and the South China Expressway to the east, making its geographical location extremely important.

Lijiao Village was founded in the Southern Song Dynasty and has a history of over 800 years, making it one of the oldest ancient villages in Guangzhou. The total planned land area is 1.5142 million square meters, with a total construction volume of 4.36 million square meters, making it the largest urban village renovation project in Haizhu District. This project not only carries the legacy of historical culture but also faces the challenges of modernization, necessitating a balance between preservation and development to meet residents' living needs and urban development goals.

The selected site is located in the Huanxiu Fang community, which is situated in the Nanzhou Street of Haizhu District, Guangzhou, Guangdong Province. This community lies in the core area of Lijiao Village, bordered by Lijiao River to the east and the main village road to the west. It is one of the better-preserved areas in terms of historical appearance, retaining the comb-like layout of "alley—urban river—ancestral hall." As a representative area of the ancient streets of Lijiao Village, Huanshi Fang features historical relics such as the stone-paved road from the Ming Dynasty, the ear-wall residential group from the Qing Dynasty, and wooden ancestral halls from the Ming and Qing periods.

According to the population structure statistics from the "Seventh National Population Census Bulletin of Guangzhou (2020)," the Huanshi Fang community has a permanent population of 12,000, with tenants accounting for 61%. The density of private housing ownership is 76%, and 35% of historical buildings have issues with unauthorized additions. Additionally, due to the narrowness of the historical streets, the internal roads in the community are quite narrow, with the narrowest section being only 1.2 meters wide. The mixed presence of motor and non-motor vehicles has resulted in a motor vehicle passage rate of less than 40%, leading to a traffic contradiction characterized by "external efficiency and internal congestion."

In the "Urban Renewal Plan for Lijiao Village," this area is designated as a "Demonstration Zone for the Revival of Lingnan Water Town Culture," and efforts should be made to maintain most of the original street widths. However, many of the existing buildings and facilities no longer meet the daily living needs of residents and are in urgent need of renewal (Fig 5-3). Therefore, it is essential to reconcile the conflict between historical appearance preservation and the improvement of residents' living quality.

Fig 5-3 Aerial view of the current situation of Huanxiufang Community(Source: by the author)

At the same time, the dense clusters of historical buildings, complex property rights structures, and differences in spatial cognition among residents (such as the significant disparity in support for the protection of ear-walled buildings between indigenous residents and tenants) greatly increase the difficulty of design and renovation. These issues are typical pain points that participatory design aims to address. Furthermore, the current state of the urban river has led to the disappearance of waterfront activities due to pollution interception projects, and the original ancestral hall spaces have become empty shells with very low utilization rates. This situation further emphasizes the urgency of involving multiple stakeholders in spatial optimization.

5.1.2 Historical Development

Commonly known as "Before there was Haizhu, there was Lijiao," the history of this village dates back to the Tang Dynasty, initially inhabited by clans such as Liang, Yan, Bai, Cai, Luo, and Tan. The eastern street of the village once had a "Fengtian Chengyun" gate tower, built in recognition of imperial favor, which witnessed the political status of the early settlement. During the Ming and Qing dynasties, the village produced many distinguished scholars and became famous in Lingnan for its reputation of "Five hundred years of ancestral virtue and thirteen generations of scholarly tradition"[78]. In the Qing Dynasty alone, Lijiao village produced three Jinshi (top scholars) and over twenty Juren (provincial scholars). A local saying goes, "Nine dragons go to sea, six cranes return," vividly depicting the flourishing of the imperial examination system, meaning that if nine Lijiao students went to take the exam, six would return triumphant. This reflects the strong atmosphere of literary education, with more than ten private schools and academies established in the village.

According to the Wei clan genealogy, the Wei clan members arrived in this area during the Jianyan period of the Southern Song Dynasty (early 12th century), marking over 900 years of history. The development of Lijiao village has primarily been guided by two influential clans: the Wei and the Luo.

The Wei clan is situated in the southern part of the village, while the Luo clan resides in the northeast. Through the construction of ancestral halls and the compilation of genealogies, these two clans have formed significant clan powers (Fig 5-4). They have also dominated the development and reclamation of the surrounding areas, including Luoxi, Dasha, Shangjiao, Xiaojiao, and Houjiao[79]. The unique dendritic water system of Lijiao village naturally delineates the layout of the settlement, with the waterways dividing the two clans into different regions. The Wei clan primarily occupies the areas of Yiyue, Eryue, Sanyue, Siyue, Wuyue, as well as Zhongqufang and Huanshiufang, while the Luo clan is mainly distributed in the slightly northern area of Zhoujinli.

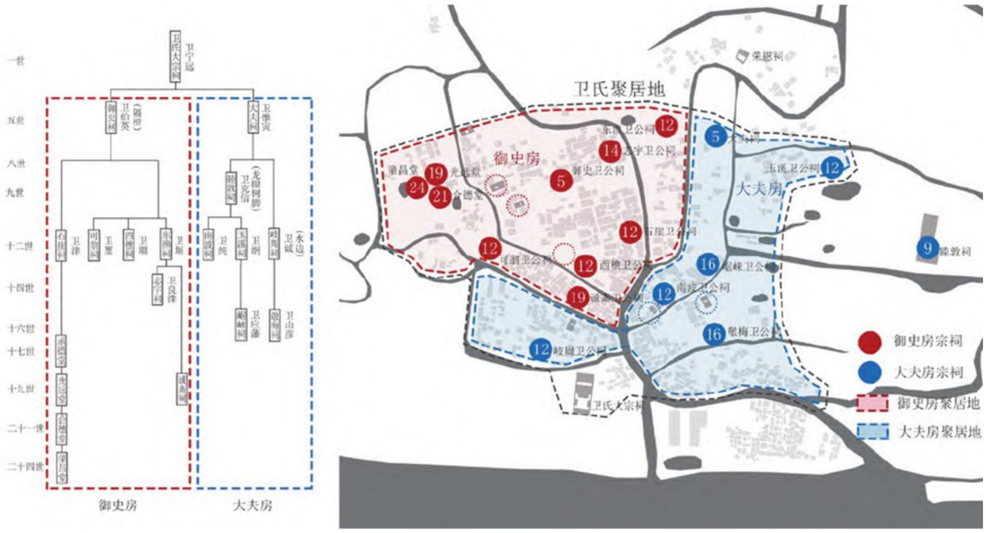


Fig 5-4 The mapping of the clan branch relationships of the Wei family in space(Source: reference[73])

In an era when waterways served as roads, the confluence of these creeks naturally formed core spaces for clan activities, leading to the emergence of functional areas such as ancestral halls, temples, and marketplaces. Thus, the waterways serve not only as boundaries separating different clans, families, and streets but also as vital nodes connecting various regions.

The "Wei He De Tang Map" is a master plan of Lijiao village drawn over 20 years ago, currently preserved in the Wei Zhaochang Hall. It was hand-drawn by Wei Benli, a descendant of the Wei clan. This map (Fig 5-5) illustrates the historical evolution of the clan composition and structural relationships within Lijiao village.

Fig 5-5 A hand-drawn plan map of Lijiao Village(Source: reference[74])

According to the "Wei He De Tang Map," there were a total of 14 altars in Lijiao village at that time. The South Temple, also known as the Tianhou Palace, is located at the southernmost part of Zhongqufang and served as a communal altar for the entire village, significantly influencing the overall layout. The North Temple is situated on the northern side of Zhongqufang, near the waterway, facing south; the North Emperor Temple is located at the confluence of the Er Yue waterway. The Hua Tuo Temple, Hu Xuan Temple, and Wu Di Temple are respectively located at the eastern water entrance, the northeastern water entrance, and the southern water entrance of the village. The Earth God Temple is positioned at the boundary between the Wei and Cao clans. Additionally, altars were also established in areas close to the waterways, such as Nanan Fang, the northern side of Er Yue, and the northeastern side of Luo Di. The distribution of these altars reflects the local belief centered around water deity worship, with deities surrounding the village[79].

As a typical Lingnan water village, Lijiao features numerous ancestral hall buildings along its waterways. Among them, the Wei clan's grand ancestral hall was built during the

Ming Dynasty's Wanli period and is recognized as a cultural heritage site in Guangzhou. The 34 ancestral hall buildings in Lijiao village constitute the largest and most complete group of ancestral halls in the Guangfu region (Fig 5-6).

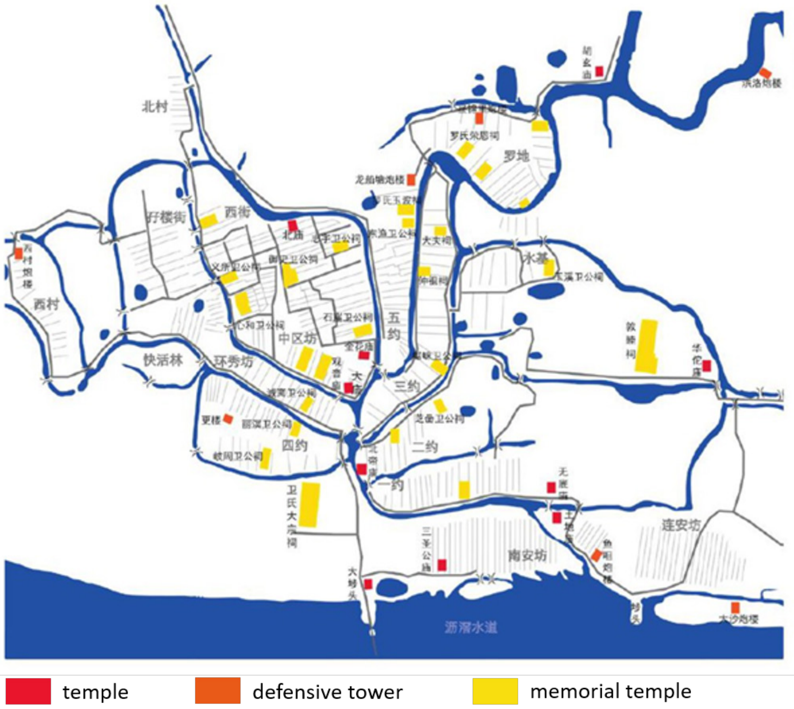


Fig 5-6 The Distribution and Morphological Texture of Ancestral Temples and Shrines(Source: reference[74])

Among the 12 existing ancestral halls, various styles of wooden architecture from the Song, Ming, Qing, and Republic of China periods can be observed. The Wei clan's grand ancestral hall was initiated in the 22nd year of the Ming Dynasty's Wanli period and was completed in 1615. Due to the Wei clan's prominence in the imperial examination during the mid to late Ming Dynasty, they needed to showcase their clan status through the ancestral hall. According to the "Wei Clan Genealogy," its location follows the feng shui principle of "backing the mountain and facing the water," with its axis directly aligned with the main river of Lijiao, symbolizing "wealth flowing in and cultural lineage enduring." Inside the hall, there are 12 giant screen doors, each 3.7 meters high, which are the largest of their kind in the Guangfu region. During the Opium War, British forces mistakenly believed it to be the governor's office in Guangzhou and fired upon it, leaving visible bullet marks.

Since the reform and opening up, the rural economy has developed vigorously, leading to the filling of waterways in the village and the construction of rows of rental houses on the vacant land beside them. The original appearance of the water village has been lost. Once there were 34 ancestral hall buildings, but now only 13 remain, and those that are left have not been well-preserved.

Today, Lijiao village has become a stagnant urban village. Due to the long-term lack of updates to basic infrastructure such as water supply and drainage, the planning of the streets is chaotic. Compared to other ancient villages with orderly architectural layouts, the current state of the village is uncomfortable and no longer meets the daily living needs of the residents.

Among the preserved ancestral halls in the village, those listed as district-level cultural heritage buildings include the Xinhe Wei Ancestral Hall (Qing Dynasty, Qianlong period), the Yushi Wei Ancestral Hall (Ming Dynasty, Jiajing period), the Shiya Wei Ancestral Hall (Qing Dynasty, Daoguang period), and the Zhiyu Wei Ancestral Hall (Republic of China), forming a ritual space network of "one main and four secondary." The Shiya Wei Ancestral Hall has been converted into the Lijiao Library, the Zhiyu Wei Ancestral Hall has started summer training classes, and the Cuicui Wei Ancestral Hall has fallen into a paper cup manufacturing factory. The Yushi Wei Ancestral Hall, hidden in an alley in the central area, has been transformed into dormitories for migrant workers; the "Red Ancestral Hall" and Wei Ancestral Hall on Xijie are dilapidated and abandoned; the Zhiyu Wei Ancestral Hall has undergone various alterations (Fig 5-7). At the same time, many historically valuable old houses and residences in the village have been demolished or renovated, with fewer than 30 of the original Ming and Qing residences still standing.

Fig 5-7 The Current Situation of Zhiyu Wei Ancestral Hall(Source: by the author)

Buildings constructed after 1950, such as schools, shops, and residences, have not been well-preserved and are not included in the cultural heritage protection list of Haizhu District. Although these buildings are not considered dangerous or illegal structures, they are all awaiting demolition. Many culturally significant sites have already begun construction, leaving only ruins and overgrown weeds. In recent years, the development of residential buildings near the village has also severely impacted the village's landscape and urban scenery.

5.1.3 Policy Drivers

As an important node in Guangzhou's historical context, the renovation of Lijiao Village has long been on the agenda. Since the proposal of the "Optimization and Enhancement of One River, Two Banks, and Three Belts" strategy by Guangzhou in 2016, the northern area of Lijiao Water Town has been included in the planning of the Haizhu Innovation Bay at the southernmost end of Guangzhou's new central axis, marking its significant geographical position. According to the "Guangzhou Urban Master Plan (2017-2035 Draft Publicity)," the renovation project of Lijiao Village is positioned as a demonstration project driven by the dual cores of "cultural heritage protection and urban function enhancement" (Fig 5-8).

The project aims to protect and inherit the historical and cultural heritage of Lijiao Village while enhancing its urban functions and improving the living environment for residents. By integrating modern urban planning with traditional cultural preservation, Lijiao Village is expected to achieve a dual revival of culture and economy in the future, injecting new vitality into the overall development of Guangzhou.

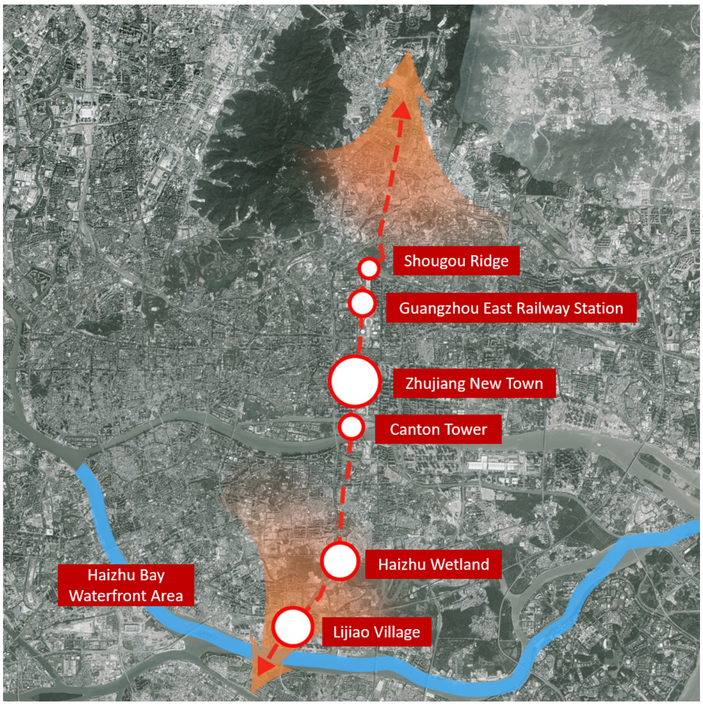


Fig 5-8 The relationship between Lijiao Village and the New Central Axis of Guangzhou(Source: by the author)

At the same time, from the 2019 "Haizhu Innovation Bay (Lijiao Area) Urban Design and Regulatory Detailed Planning Announcement," it can be seen that under the new plan, Lijiao Village primarily focuses on residential and commercial land use. Large commercial areas are concentrated in the southern part of the area near the waterfront, while the main historical heritage in the northern part is preserved. The planning not only aims to open up the new urban axis but also emphasizes maintaining the original appearance of the historical districts and their cultural landscapes (Fig 5-9).

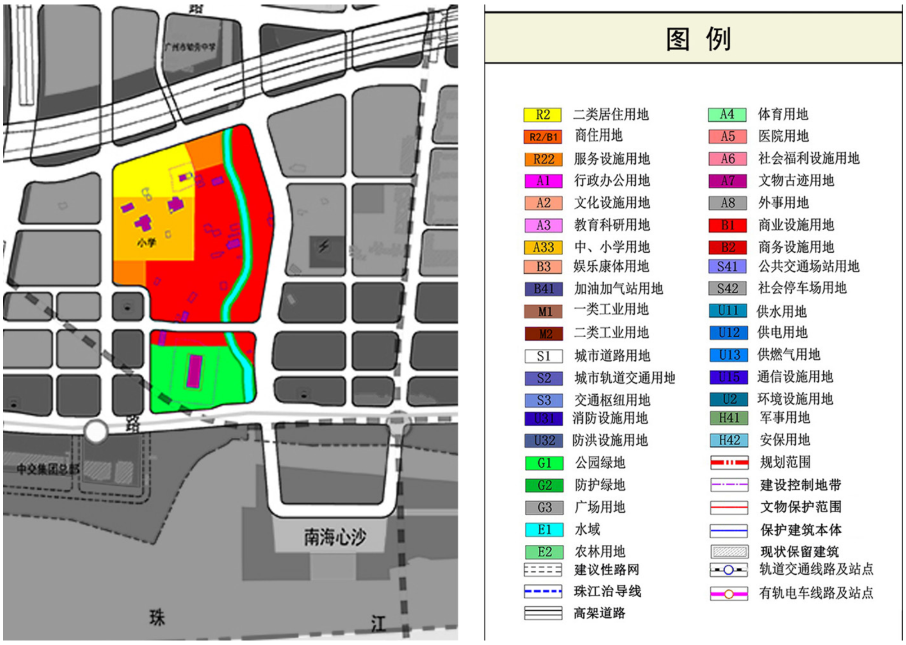


Fig 5-9 The Regulatory Detailed Plan of Huanxiufang Community(Source: http://ghzyj.gz.gov.cn/ywpd/slgsnew/content/post_7458490.html)

5.2 Current Status Survey of the Site

5.2.1 Distribution of Architectural Functions

During the on-site survey, it was evident that most of the old buildings along the street were in disrepair, with a high vacancy rate. Many buildings showed signs of damage, and some had only partial walls remaining, with weeds overgrowing in the courtyards. Additionally, the facades along the street lacked harmony and were severely damaged.

Most of the buildings in the area are low-rise residential structures, primarily 1-4 stories high. While most have maintained their original historical appearance and texture, there are also some instances of haphazard constructions. Furthermore, there are numerous modern residential or office buildings exceeding seven stories, which somewhat disrupts the original architectural style of the district in terms of height.

In terms of the functions of the buildings within the area, most have continued the workshop functions of small garment factories established after the reform and opening-up. The remaining buildings along the street primarily serve as individual commercial businesses and mixed-use developments. The commercial buildings on the west side of the river channel have a higher proportion of commercial functions, while the east side, which does not directly connect to the roadway, has not formed a distinct commercial entity. Instead, it mainly serves residential and public service functions, with a few scattered shops. To the north of the site, there is an educational building, the Wei Guoyao Memorial Primary School in Haizhu District, Guangzhou (Fig 5-10).

According to the "Haizhu Innovation Bay (Lijiao Area) Urban Design and Regulatory Detailed Planning Announcement," the future positioning of this area will also focus on commercial and residential uses, aiming for harmonious development while preserving the original architectural style.

Fig 5-10 The distribution of the functions of the buildings around the site(Source: by the author)

5.2.2 Street Texture and Architectural Facades

Most of the residences in Lijiao Village still follow the typical three-room, two-hall layout of the Cantonese region. Some have added courtyards and auxiliary buildings, resulting in the formation of quadrangle courtyards or multi-layered compound residences (Fig 5-11). The houses generally face the nearby river channel, with their main entrances oriented toward the streets. Historically, the village was home to wealthy families or merchants, so the building materials used in the residences were relatively expensive, primarily consisting of blue bricks and featuring beautifully decorated and ornate gable walls.

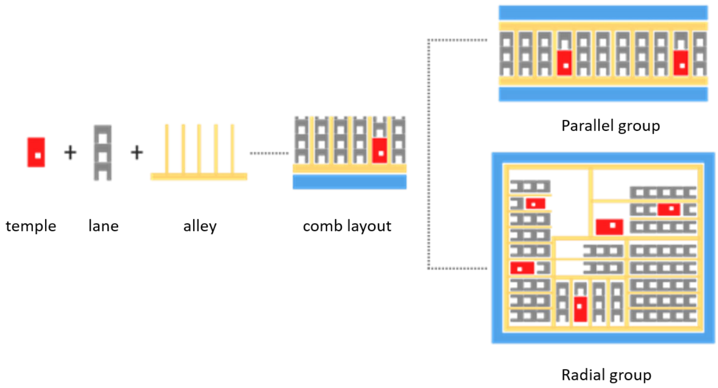


Fig 5-11 "Three Rooms and Two Corridors" in Guangfu region(Source: by the author)

With the gradual decline of the village and the rise of small workshops after the reform and opening-up, most residences underwent transformations into workshops, leading to various additions. As a result, it is common to see modernist structures made of concrete or brick walls added to the sides or tops of the original brick houses. Excessive additions have disrupted the traditional comb-like layout of the village, breaking the texture of the streets and alleys in the area (Fig 5-12), resulting in a dense and chaotic urban village where the scale of the streets has become uncontrolled.

Fig 5-12 The current architectural texture of Lijiao Village (Source: by the author)

On the building facades, the phenomenon of haphazard construction is particularly severe due to the self-built houses in Lijiao Village. Numerous illegal constructions have made the facades along the street appear very disordered, with awnings and protruding components everywhere, and the overall building quality is poor. Additionally, the materials and colors of the streets and alleys are not uniform, resulting in a facade for the main community street that does not provide a pleasing aesthetic (Fig 5-13).

Fig 5-13 The phenomenon of additional construction in the village(Source: by the author)

5.2.3 Traffic Flow Lines

Due to the small scale of the streets and the predominant mixed-use commercial and residential functions of the buildings along them, the roads are often crowded with a large number of motor vehicles, non-motorized hand trucks, bicycles, and pedestrians. Additionally, the presence of many small workshop-style individual businesses in the area leads to goods being piled up at shop entrances, with some even placed directly in the middle of the streets (Fig 5-14). This significantly increases the likelihood of traffic congestion and poses a considerable safety hazard for local residents, especially children and the elderly.

Fig 5-14 The sundries and garbage piled up on the street(Source: by the author)

In terms of the walking experience on the roads, the current pedestrian experience is not pleasant due to the intersection and parallel flow of various traffic streams (Fig 5-15). Furthermore, the old roads have not been renovated, resulting in uneven surfaces in the alleys, while illegal constructions on both sides of the roads have led to the accumulation of building materials on the street, greatly reducing the efficiency of road traffic and squeezing the already limited public space.

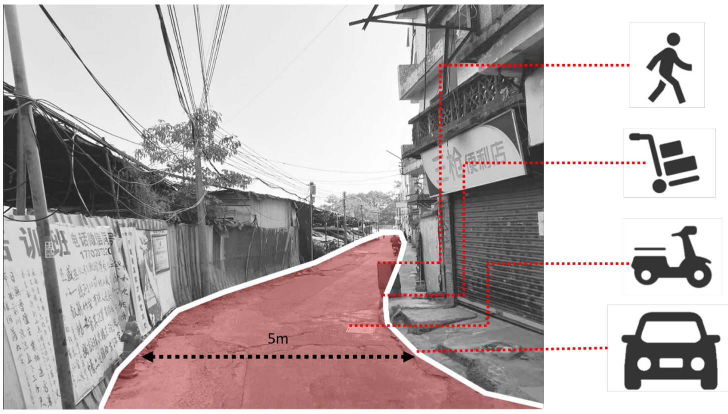


Fig 5-15 The situation of the mixed traffic of pedestrians and vehicles on the street(Source: by the author)

Moreover, the high density of vehicle and pedestrian traffic, combined with narrow streets, means that the main roads in the community cannot meet basic fire safety requirements. The average width of the main streets is about 5 meters, but due to the external storage of goods by some shops, the display of advertising boards, and the haphazard parking of hand trucks, the actual width is far less than 5 meters. Some secondary alleys are even narrower than 4 meters, failing to meet the requirements for fire lanes (Fig 5-16).

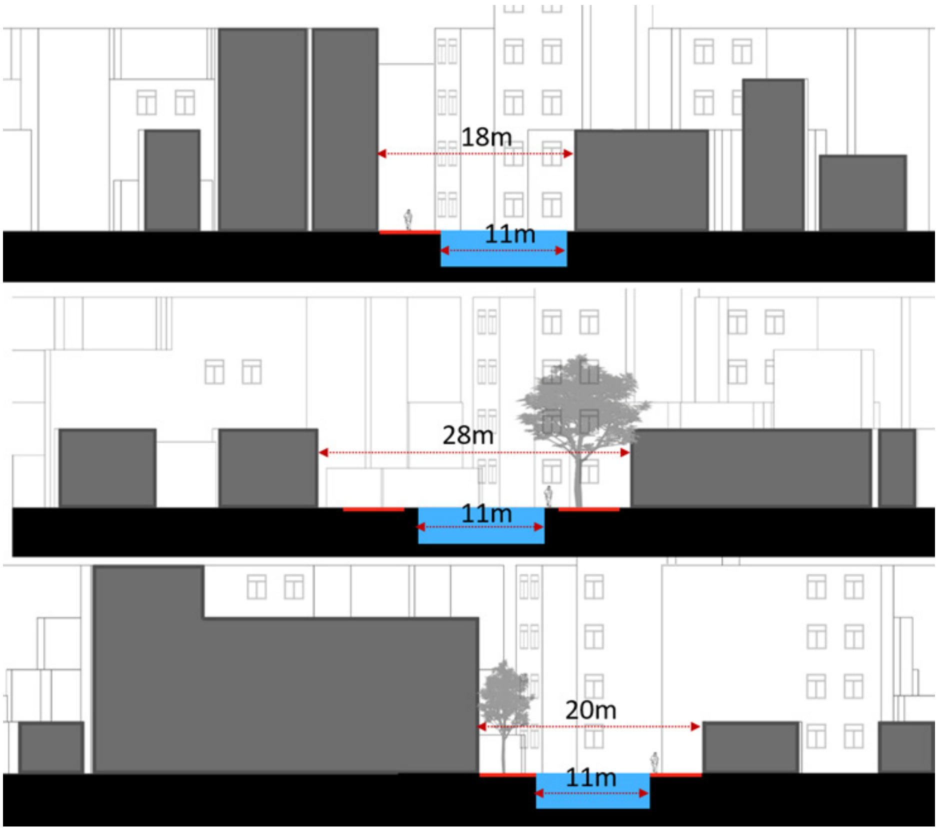


Fig 5-16 Analysis of Street Scale(Source: by the author)

5.2.4 Current Status of Public Spaces

According to preliminary research results, the public space within the site is in a state of scarcity. Observations of the distribution of public spaces in the community reveal a scattered arrangement. Most public spaces are located near river channel bridges, around ancient trees, and in areas with lower building density, such as the square in front of the Shiyawei Temple (Fig 5-17).

Fig 5-17 The Current Situation of the Public Space (Source: by the author)

Most public spaces are elongated along the river channel. Preliminary research indicates that residents primarily use these public spaces for resting and playing mahjong, often setting up their own tables and chairs along the river for daily social activities.

Another reason for the current scarcity of public space in the community is the arbitrary occupation by other activities (Fig 5-18). Small workshops along the streets, due to their limited space, often pile up large quantities of goods, foam boxes, and discarded packaging in the already scarce public spaces, further compressing the daily activity space available to local residents. In addition to the occupation by businesses, the lack of parking spaces combined with heavy traffic has led many motor vehicles to park haphazardly along the streets, occupying public space.

Fig 5-18 Vehicles' arbitrary occupation of public space(Source: by the author)

5.2.5 Problem Examination

Based on the analysis of the current situation of the site, the main contradictions can be summarized into three points:

1. Scarcity of Public Space. As a community primarily functioning for residential and small-scale commercial purposes, public space is very limited. Although there are many idle lands along the river channel, arbitrary occupation is prevalent, with many areas that should serve as activity spaces being used for parking, storing goods, and dumping garbage.

2.Insufficient Vitality of Public Space. As an old village, the public spaces within the community can no longer meet the daily needs of residents. There is a lack of spaces for daily activities for the elderly and children.

3.Chaotic Street Space. The streets in this old village are relatively narrow, and the mixed traffic flow means that the 5-meter-wide roads must accommodate motor vehicles, non-motorized vehicles, pedestrians, and freight needs simultaneously, resulting in a chaotic street environment that affects residents' daily use.

Therefore, a participatory survey will be conducted to assess the community's needs for public space and to gather residents' design intentions for spatial renovations.

5.3 Demand research and design object determination

Based on the results of the graphic and textual questionnaire survey in Chapter 4, as well as the demand map obtained through augmented reality, we can preliminarily understand the needs of the residents in the area. The public space within the site is severely lacking and needs to increase the area designated for resident activities. Additionally, more seating should be provided to facilitate daily activities. It is also important to enrich the facilities for children's activities and to create spaces suitable for recreational activities such as playing mahjong.

In terms of spatial design elements, the vegetation coverage should be increased to create an open and transparent public space, using bright colors as the main color scheme.

Based on the survey results, local residents will be invited to participate in further demand investigations using a combination of a sand table map and AR software to identify the areas they believe need renovation and upgrades, thus determining the design objects and scope (Fig 5-19).

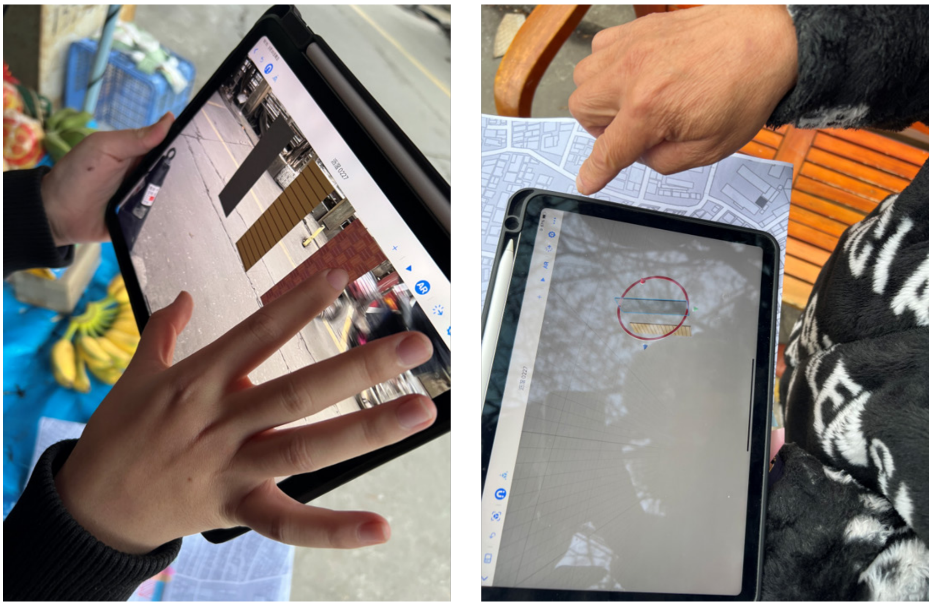


Fig 5-19 The residents use AR software to convey their needs(Source: by the author)

5.3.1 Participatory demand research

During the demand survey process, two main aspects need to be confirmed: first, to identify the public space nodes for renovation and upgrading; second, to understand residents' preliminary expectations for the renovation of each node.

In addition to using AR software for the design of different node spaces, this study also employs a sand table map approach, inviting residents to express their needs on a two-dimensional flat map using various methods. During the participation process, different colored pins are used to indicate the priority of the participants' demands for upgrading that area; different colored stickers represent the functional expectations for the renovation of that plot. The participatory design results are obtained through the collage of participants on the map (Fig 5-20).

Fig 5-20 The residents use stickers to express their design expectations(Source: by the author)

First, regarding the demand priority for the renovation design of different areas within the site, the colors of the pins range from red, yellow, green to blue, representing priority from high to low, with red being the highest and blue the lowest. According to the design feedback from residents shown in the figure below, it can be seen that residents have a high design willingness for five areas within the site (Fig 5-21).

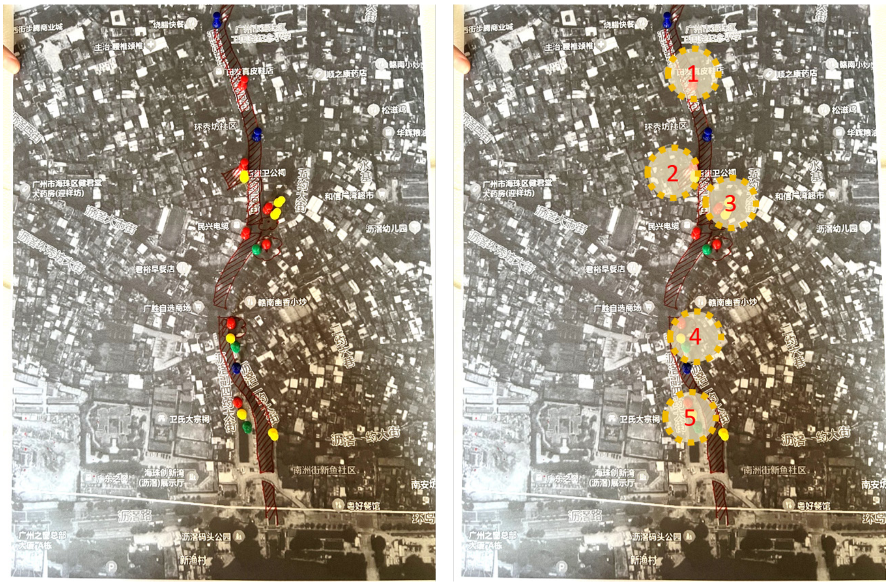


Fig 5-21 The results of the priority of residents' renovation needs (Source: by the author)

Second, regarding the functional expectations for the renovation of different areas within the site, the colors of the stickers range from orange, green, pink to blue, representing the desired functions to be increased: resting space, green space, activity space, and waterside space. The participatory design results shown in the figure below indicate that the most desired functions are resting and activity functions (Fig 5-22).

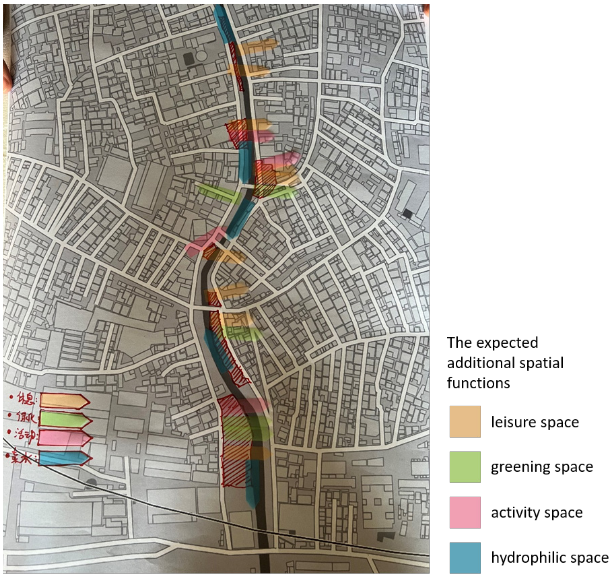


Fig 5-22 Residents' expectations of spatial functions(Source: by the author)

5.3.2 Design Object Determination

Based on the frequency analysis of the design results for various public spaces within the site from the previous public demand-oriented experiment, four spatial nodes have been preliminarily identified for the renovation and upgrading of public spaces. The goal is to enhance community vitality through improvements to these public space nodes (Fig 5-23). Additionally, in conjunction with the current state of the site's roads and resident interviews, a pedestrian-friendly transformation of the main roadway along Lijiao Creek will be implemented to meet residents' daily activity needs.

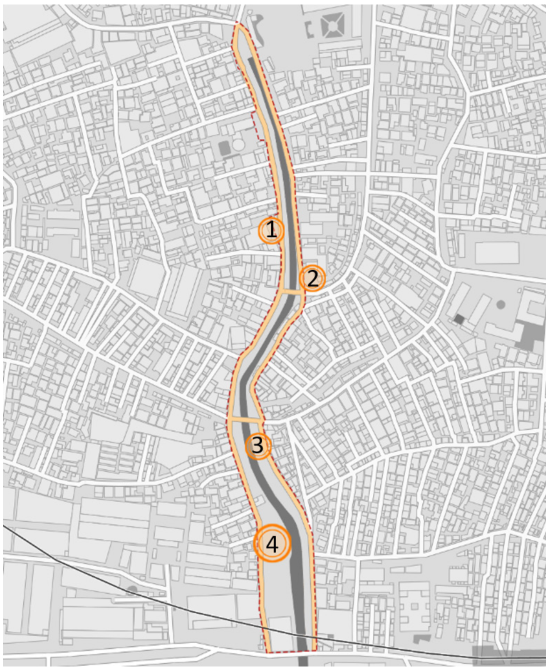


Fig 5-23 Determination of the Design Object(Source: by the author)

5.4 Participatory Design of Node 1

5.4.1 Current Situation Analysis

Currently, Node One serves as an activity square in front of the ancestral hall and is expected to have strong spatial vitality. However, the space has lost its vitality due to random occupation by clutter and vehicles. On-site research revealed that a few benches placed near the riverside area of the square are often used by residents for resting activities.

Additionally, the Shiyawei Ancestral Hall within this node, which serves as a historical exhibition hall and activity room for the community, has not fully realized its functional characteristics, resulting in a lack of public vitality (Fig 5-24).

Fig 5-24 The Current Situation of Node 1(Source: by the author)

Based on the preliminary findings from the current status survey, it is believed that this node has the potential to be transformed into a pocket park.

In the future, residents will be invited to participate in the design process, focusing on the square in front of the Shiyawei Ancestral Hall and the riverside resting area.

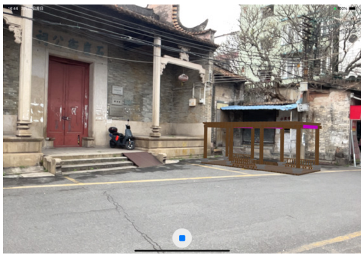
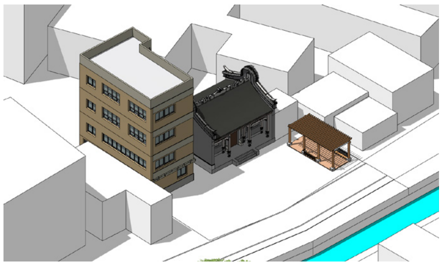
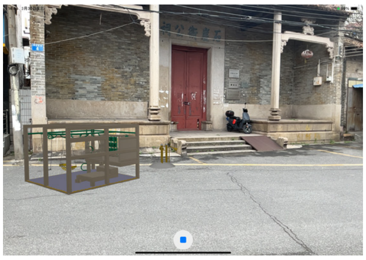
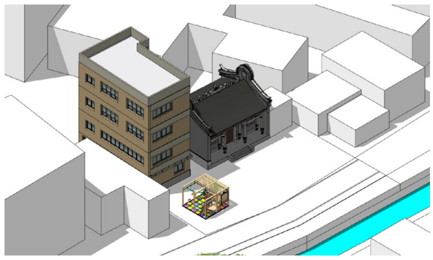
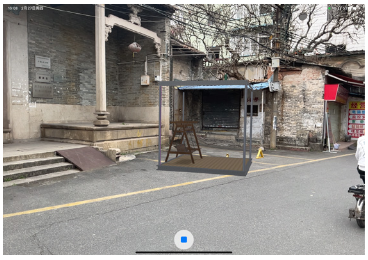
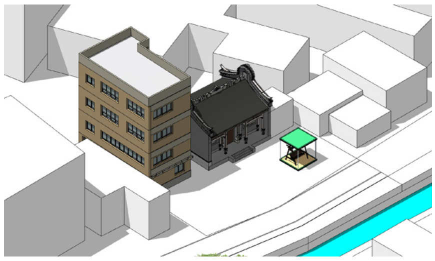
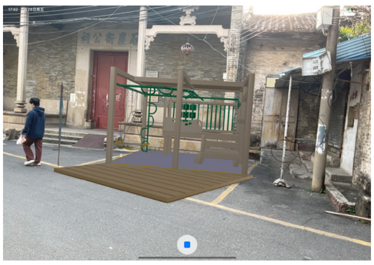
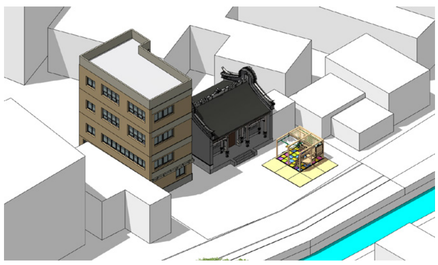
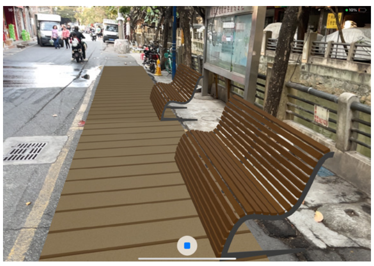
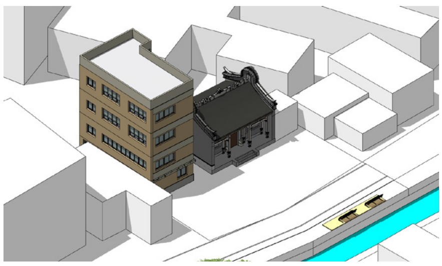
5.4.2 Participatory Design

Based on the participatory design results from residents regarding Node One (Table 5-1), the majority of residents believe that increasing resting facilities, like benches and chairs, would help activate the vitality of the space. Additionally, two participants specifically mentioned the strong desire for a children's activity area.

Therefore, it has been preliminarily decided to add a well-equipped children's activity area and a comfortable resting area at this node. To ensure that the space is not disturbed by the roadway and to enhance safety, obvious distinctions in materials and green separations will be implemented.

Furthermore, the waterfront area will be extended to include more comfortable seating for relaxation.

Table 5-1 The results of the participatory design by the residents at Node 1(Source: by the author)

	Public Demand	**Results of participatory design**	**Extraction of the design concept**
Participant 1	It is hoped that the resting function of the square can be enhanced.		
Participant 2	The open space can be transformed into an activity venue.		
Participant 3	If the square is to be renovated, sunshade pavilions can be added.		
Participant 4	It will be safer to demarcate the driveway and the square.		
Participant 5	Add resting seats by the riverside.		

5.4.3 In-depth Design and Design Outcomes

Based on the above design concept, the public space of Node One is primarily divided into two parts:

1.Community Activity Center in Front of Shiyawei Temple: This area will retain its community activity function, providing resting places and children's play areas for local residents through spatial division. The resting area will feature comfortable seating and greenery to create a tranquil environment suitable for gatherings and relaxation. The children's play area will be equipped with safe play facilities, such as slides and swings, to meet children's activity needs while ensuring safety.

2.Waterfront Platform and Extension of Square Space: The section along the river will undergo an open design to create a waterfront platform, providing residents with opportunities to engage closely with the water. The waterfront platform will include resting seats and a viewing area for residents to enjoy the river view and engage in social activities. This platform will also serve as an extension of the square space towards the river, enhancing the overall connectivity and vitality of the space (Fig 5-25).

In summary, the design renovation of Node One mainly includes the following aspects:

Spatial Vitality: Enhance the spatial vitality of Node One through functional division and facility setup, encouraging resident participation and interaction.

Safety: Ensure a safe distance between the children's play area and other areas through material differentiation and green separation, reducing potential safety hazards.

Waterfront Experience: The design of the waterfront platform will provide residents with a new recreational spot, strengthening the community's connection with the natural environment.

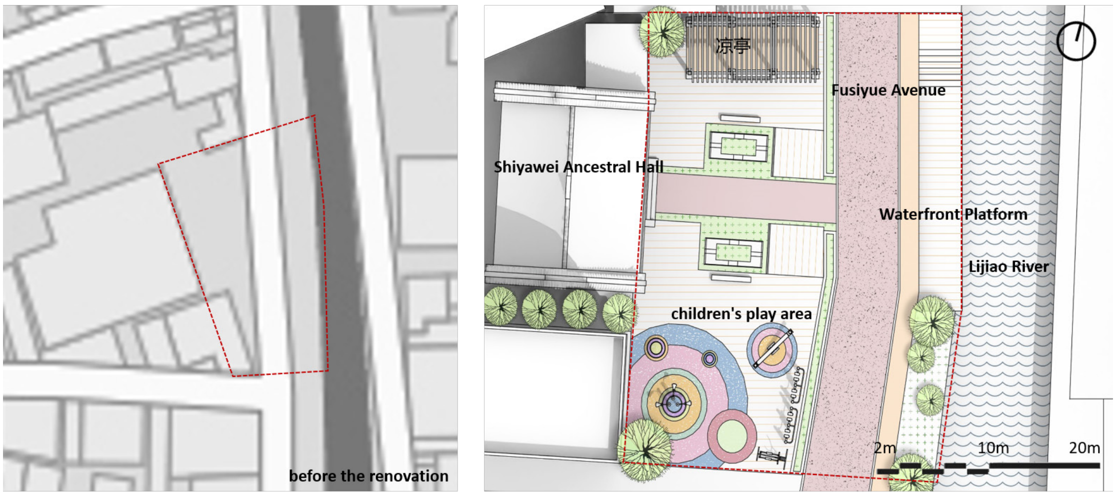


Fig 5-25 Comparison of Node 1 before and after renovation(Source: by the author)

The view from the perspective of people after the renovation of Node 1 is shown in the following picture (Fig 5-26).

Fig 5-26 the perspective of people after the renovation of Node 1(Source: by the author)

The rendered effect picture of Node 1 after the renovation is shown in the following picture (Fig 5-27).

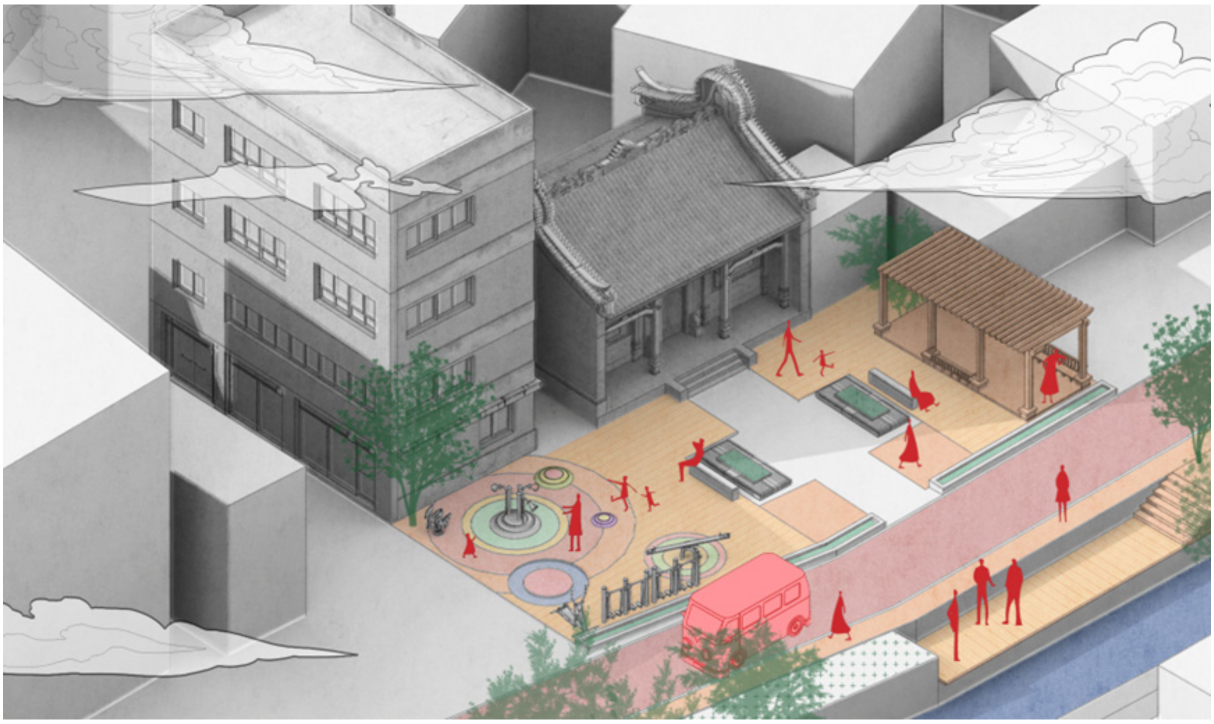


Fig 5-27 the rendered effect picture of Node 1 after the renovation(Source: by the author)

5.5 Participatory Design of Node 2

5.5.1 Current Situation Analysis

Analysis of the current situation of public space at Node 2: The most significant feature of the public space at Node 2 is the presence of an ancient banyan tree, which is located near Lianqiao, an important traffic node connecting the east and west sides. Originally, a large area of seating was arranged around the ancient tree to provide resting space for nearby residents. However, due to the outdated layout and improper placement of the seating, along with the accumulation of clutter, the utilization rate of the seating is low. According to the survey, only the sanitation workers in the vicinity frequently use these seats, and they have currently become a storage place for cleaning tools. Interviews with nearby residents indicate that most residents believe the resting seats by the banyan tree are very valuable and hope to restore their resting function while increasing greenery and activity areas (Fig 5-28).

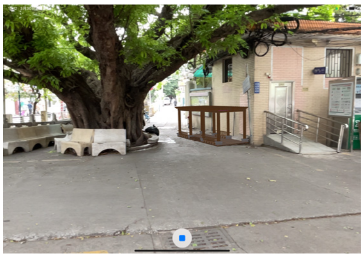
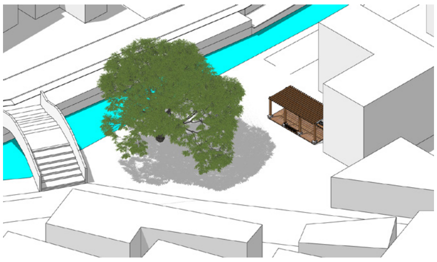
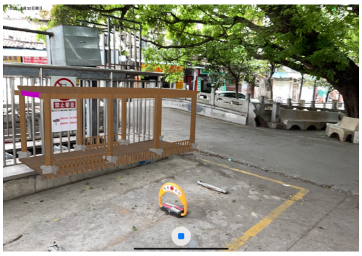
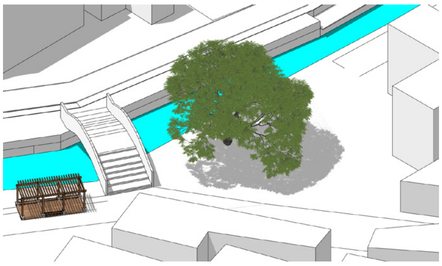
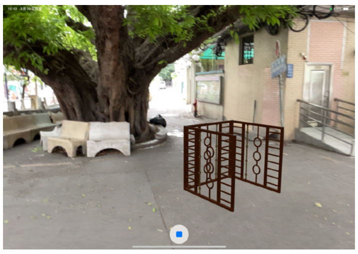
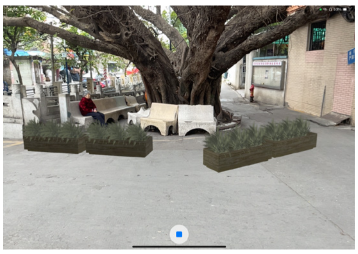
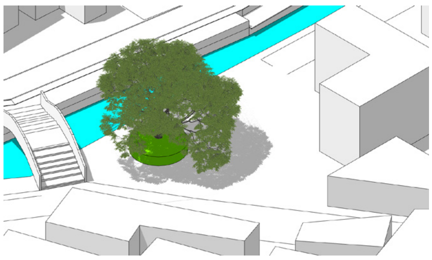
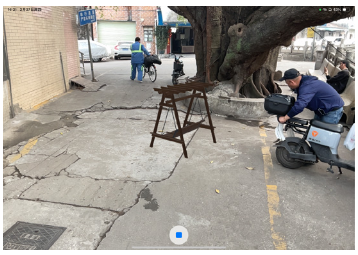
Fig 5-28 The Current Situation of Node 2(Source: by the author)

Based on preliminary research, it is believed that the focus of the renovation at this node should be on creating a pocket park centered around the ancient tree, while paying attention to the connection with the surrounding bridges and roads during the renovation.

5.5.2 Participatory Design

Analysis of the results from the participatory design by residents (Table 5-2) reveals that the majority of residents agree on the rationale for transforming this node into a pocket park. A small number of residents believe that since there is already Lijiao Park nearby, a new park is unnecessary; however, they support the renovation and upgrade of the space next to the banyan tree. The more contentious points concern the layout of the resting areas, with one option being next to the public restroom and the other near the parking spaces by the bridge. Given that the area by the bridge needs to consider its relationship with water management facilities, it is initially deemed more appropriate to utilize the vacant space near the public restroom. Additionally, participants highlighted the need to increase greenery and activity facilities.

Table 5-2 The results of the participatory design by the residents at Node 2(Source: by the author)

	Public Demand	**Results of participatory design**	**Extraction of the design concept**
Participant 1	Resting pavilions can be added next to the public restrooms.		
Participant 2	Transform the parking spaces beside the bridge into pavilions or rest stops.		
Participant 3	Add fitness equipment to the open space beside the trees.		
Participant 4	Carry out greening renovation and upgrading of the seats beside the trees.		
Participant 5	Since there were a lack of seats, a swing was placed.		

5.5.3 In-depth Design and Design Outcomes

Based on the above design concept, the specific design plan for Node 2 focuses on maintaining its traffic flow functionality while arranging resting areas around the ancient banyan tree. Additionally, multiple fitness activity spaces will be added to accommodate the daily activities of residents. A resting pavilion can be placed in the vacant space near the north side for the use of nearby sanitation workers (Fig 5-29).

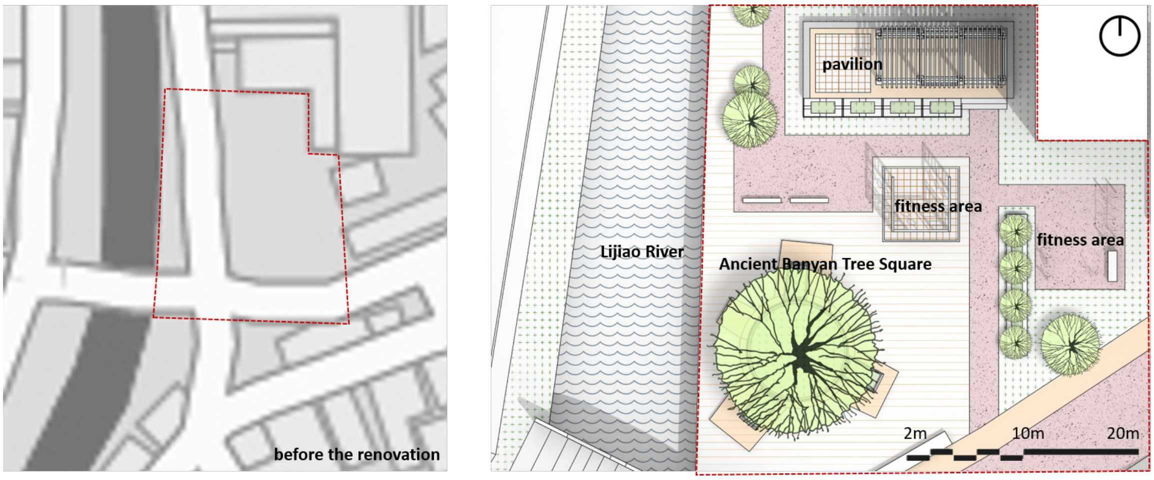


Fig 5-29 Comparison of Node 2 before and after renovation(Source: by the author)

The view from the perspective of people after the renovation of Node 2 is shown in the following picture (Fig 5-30).

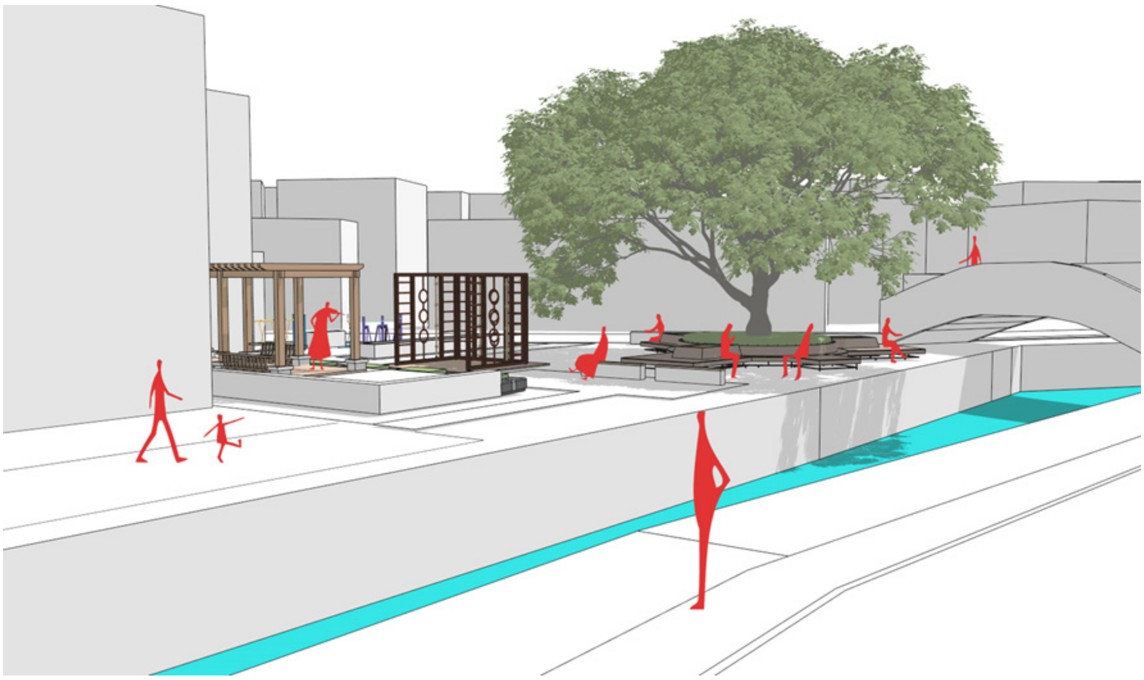


Fig 5-30 the perspective of people after the renovation of Node 2(Source: by the author)

The rendered effect picture of Node 2 after the renovation is shown in the following picture (Fig 5-31).

Fig 5-31 the rendered effect picture of Node 2 after the renovation(Source: by the author)

5.6 Participatory Design of Node 3

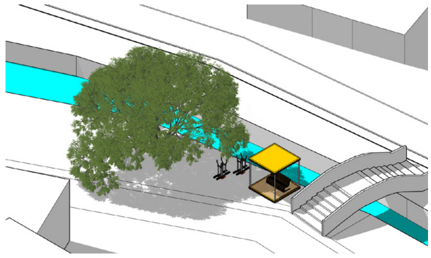
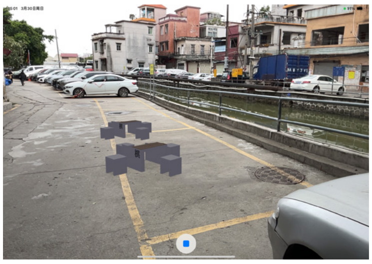
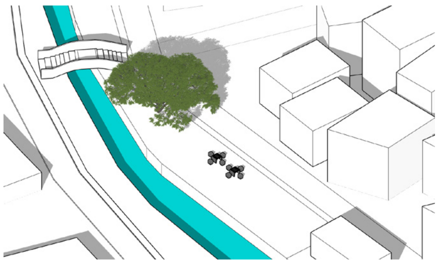
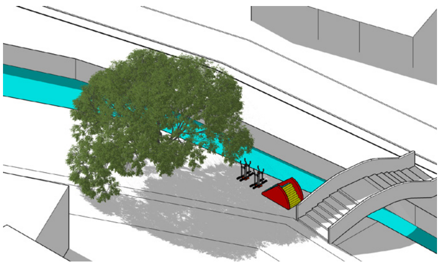
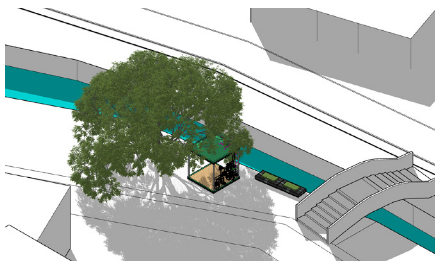
5.6.1 Current Situation Analysis

Analysis of the current situation of the public space at Node 3 reveals that its main characteristic is that it is a relatively elongated area, featuring an ancient banyan tree. Currently, this area is primarily used as a parking lot, while many residents set up tables and chairs in the remaining space for playing chess and card games. As a result, this public space is quite vibrant, attracting a large number of residents for socializing and various activities on a daily basis. Given that this area is adjacent to a bridge, it sees a significant flow of residents, making it suitable as an open and transparent public space. The initial concept is to develop it into a waterfront green park. In the subsequent participatory design phase, relevant designs will focus on the existing leisure activities within the space (Fig 5-32).

Fig 5-32 The Current Situation of Node 3(Source: by the author)

5.6.2 Participatory Design

Table 5-3 The results of the participatory design by the residents at Node 3(Source: by the author)

	Public Demand	**Results of participatory design**	**Extraction of the design concept**
Participant 1	Add some activity facilities for children to use.		
Participant 2	The arrangement of the fitness equipment and seats.		
Participant 3	The parking spaces can be removed and replaced with tables and chairs facilities.		
Participant 4	Arrange fitness equipment and children's facilities along the river.		
Participant 5	The current cement ground lacks beauty and more greenery can be added.		

According to the analysis of the participatory design results from residents (Table 5-3), the majority of residents agree with the intention to add resting and activity facilities in this area. They believe that the vacant space at this node is quite vibrant, but the existing facilities are outdated and lack aesthetic appeal.

The different participatory design outcomes mainly vary in the distribution of seating and the analysis of activity facilities.

Additionally, some participants pointed out that the area lacks greenery, as there is currently only one banyan tree, and the surrounding area is occupied by parking spaces. It is suggested to increase greenery and reduce the parking area to support the daily activities of residents in this node.

5.6.3 In-depth Design and Design Outcomes

Based on the aforementioned design concept, the specific scheme design for Node 3 will focus on enhancing the residents' connection with the natural environment. As a park green space, this node utilizes a sunken slope treatment that allows residents to more easily access the riverbank and enjoy the natural scenery.

Based on the aforementioned design concept, the specific scheme design for Node 3 will focus on significantly enhancing the residents' close connection with the natural environment. As a park green space, this node skillfully utilizes a sunken slope treatment that enables residents to more effortlessly access the riverbank and fully enjoy the beautiful natural scenery.

Near the ancient banyan tree, a well-planned and dedicated chess and card space will be carefully arranged to offer a tranquil and comfortable environment for residents who are fond of these leisurely activities (Fig 5-33).

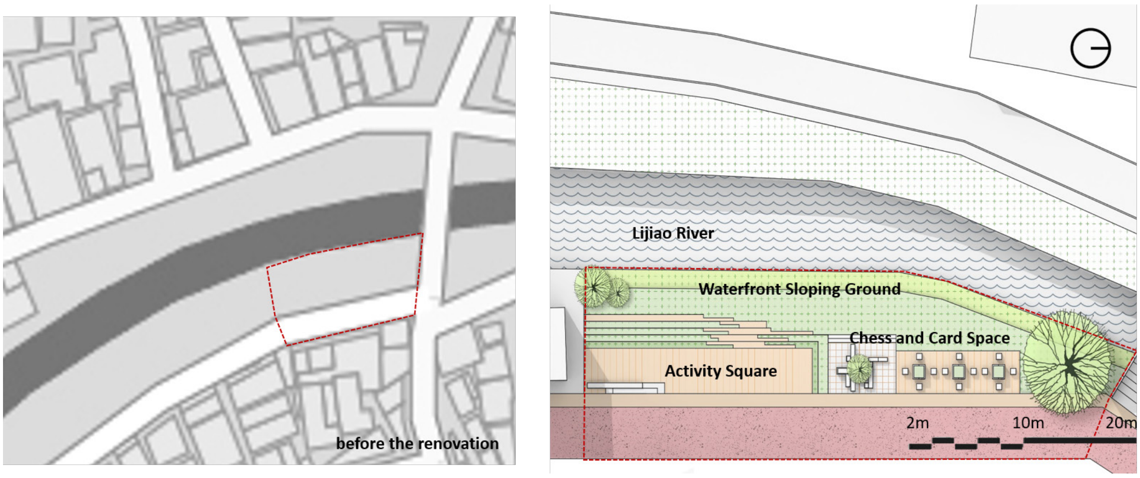


Fig 5-33 Comparison of Node 2 before and after renovation(Source: by the author)

The view from the perspective of people after the renovation of Node 3 is shown in the following picture (Fig 5-34).

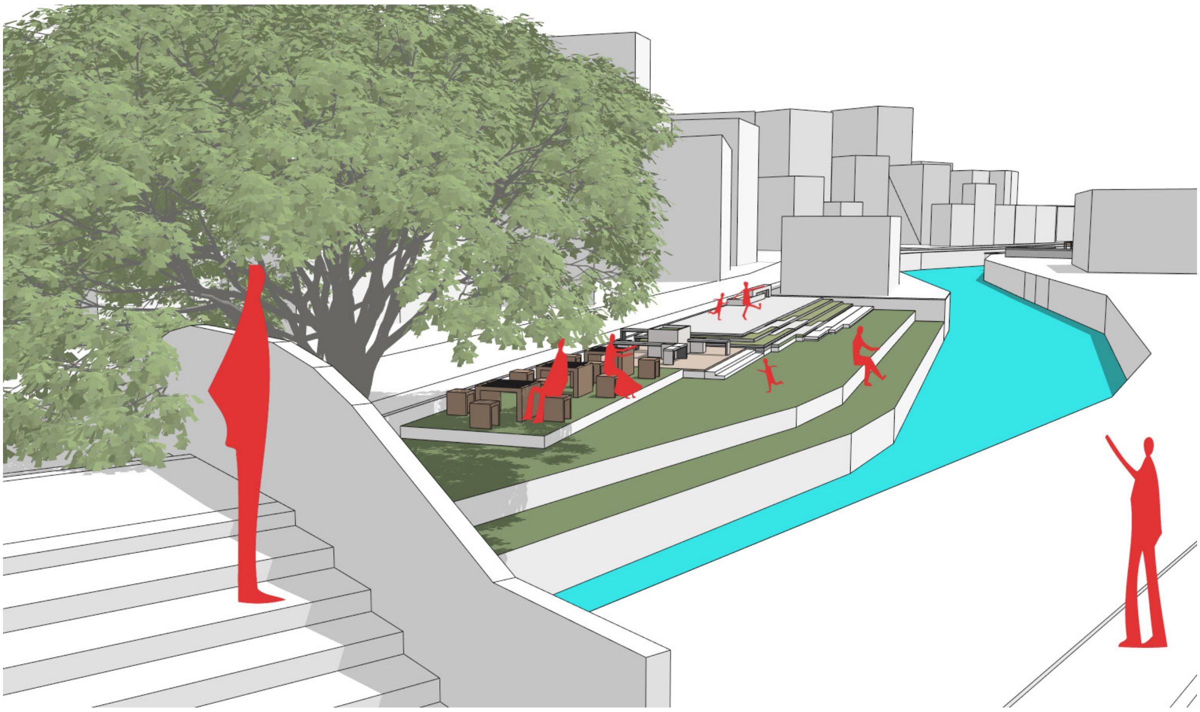


Fig 5-34 the perspective of people after the renovation of Node 3(Source: by the author)

The rendered effect picture of Node 3 after the renovation is shown in the following picture (Fig 5-35).

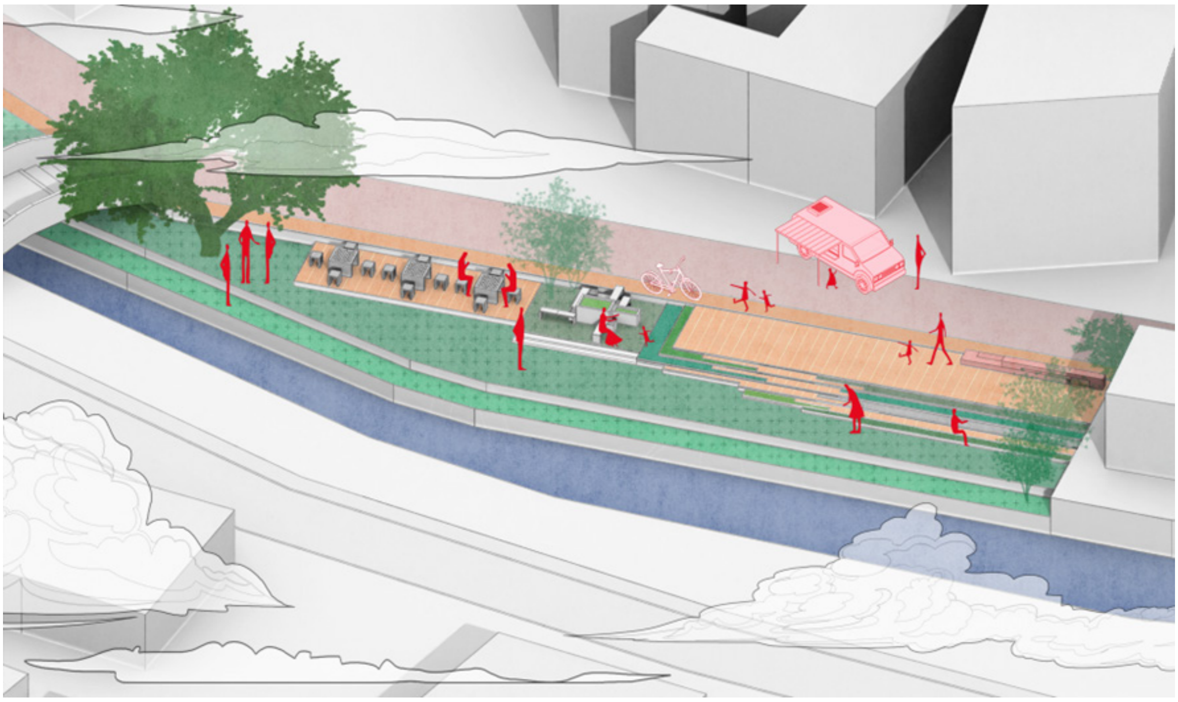


Fig 5-35 the rendered effect picture of Node 3 after the renovation(Source: by the author)

5.7 Participatory Design of Node 4

5.7.1 Current Situation Analysis

Node 4 is characterized by having the largest public space area within the community. Currently, this area is primarily used as a parking lot at the community entrance, while the northern part is designated for storing construction waste. This usage not only affects the aesthetic of the space but also limits residents' opportunities for activities and leisure.

According to the on-site survey results, residents generally hope that this area can be enhanced with more spaces suitable for relaxation and activities. They desire more green areas, seating, and facilities suitable for community events. Given the large area, it has the potential to accommodate large community activities, so it is tentatively proposed to transform this area into a community waterfront park (Fig 5-36).

Fig 5-36 The Current Situation of Node 4(Source: by the author)

5.7.2 Participatory Design

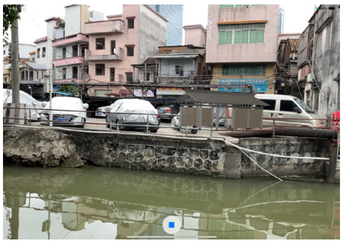
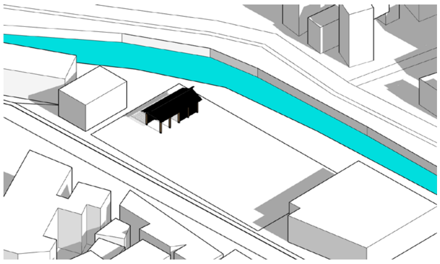
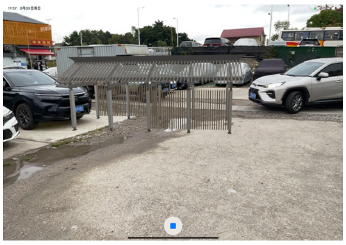
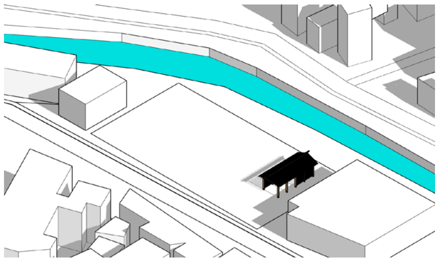
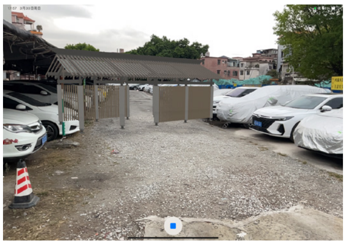
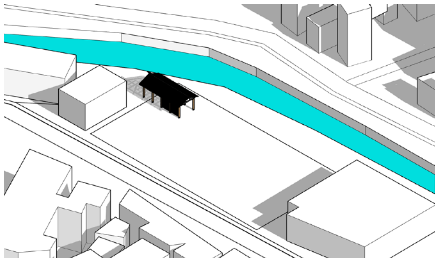
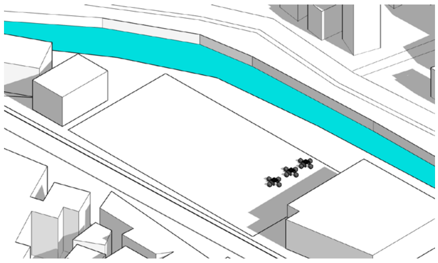
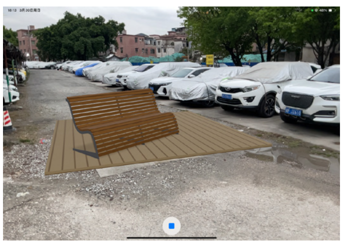
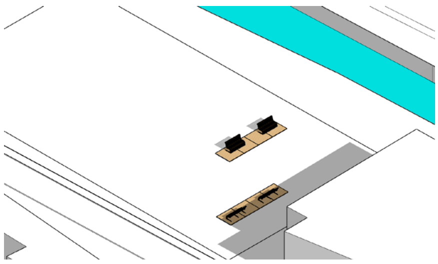
Based on the results of the participatory design involving residents (Table 5-4), the preliminary conclusion is that the majority of residents support some level of public space transformation for the parking area.

Residents generally believe that the large size of the parking area allows for potential modifications. At the same time, most residents do not agree with completely eliminating the parking area, as the current number of parking spaces adequately meets their needs.

Considering these crucial factors such as the limited existing outdoor areas and the community's need for more engaging spaces, it is strongly recommended to comprehensively transform the area near the riverbank into a dynamic public space. This will not only significantly enhance the vibrancy of the area but also effectively compensate for the long-standing lack of sufficient outdoor activity space.

This thoughtful transformation will undoubtedly help improve residents' quality of life substantially by providing them with an abundance of more diverse opportunities for leisure pursuits and meaningful social interaction.

Table 5-4 The results of the participatory design by the residents at Node 4(Source: by the author)

	Public Demand	**Results of participatory design**	**Extraction of the design concept**
Participant 1	There are too many parking spaces. Pavilions can be added to facilitate management.		
Participant 2	Add a resting area at the entrance of the parking lot.		
Participant 3	Add a resting area facing the riverbank.		
Participant 4	Add tables and chairs facilities for activities.		
Participant 5	Set aside a section of the parking lot for daily activities and add resting facilities.		

5.7.3 In-depth Design and Design Outcomes

Based on the above design concept, the public space transformation for Node 4 is mainly divided into three parts: Viewing Area, Activity Square and Sports Park.

Viewing Area (Northernmost Part): A pavilion is set up for residents to cool off and engage in indoor activities, providing a comfortable leisure environment.

Activity Square (in the center): It can hold large community events, with seats for relaxation, enabling residents to gather and interact.

Sports Park (Southern Part): Designed specifically for community fitness activities, it offers a variety of sports facilities to encourage residents to participate in exercise.

Additionally, this node will integrate with the road system by extending a waterfront walkway towards the Lijiao River, enhancing the relationship with the river and encouraging residents to engage in activities in the waterfront green space (Fig 5-37).

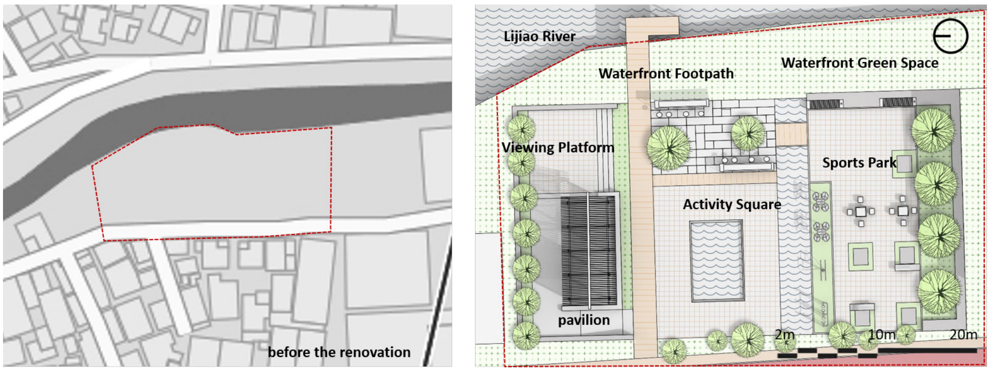


Fig 5-37 Comparison of Node 4 before and after renovation(Source: by the author)

The view from the perspective of people after the renovation of Node 4 is shown in the following picture (Fig 5-38).

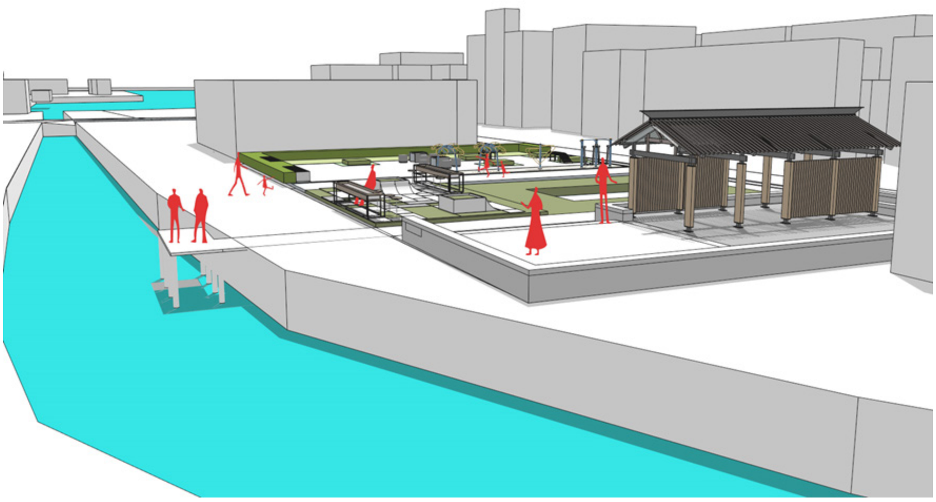


Fig 5-38 the perspective of people after the renovation of Node 4(Source: by the author)

The rendered effect picture of Node 4 after the renovation is shown in the following picture (Fig 5-39).

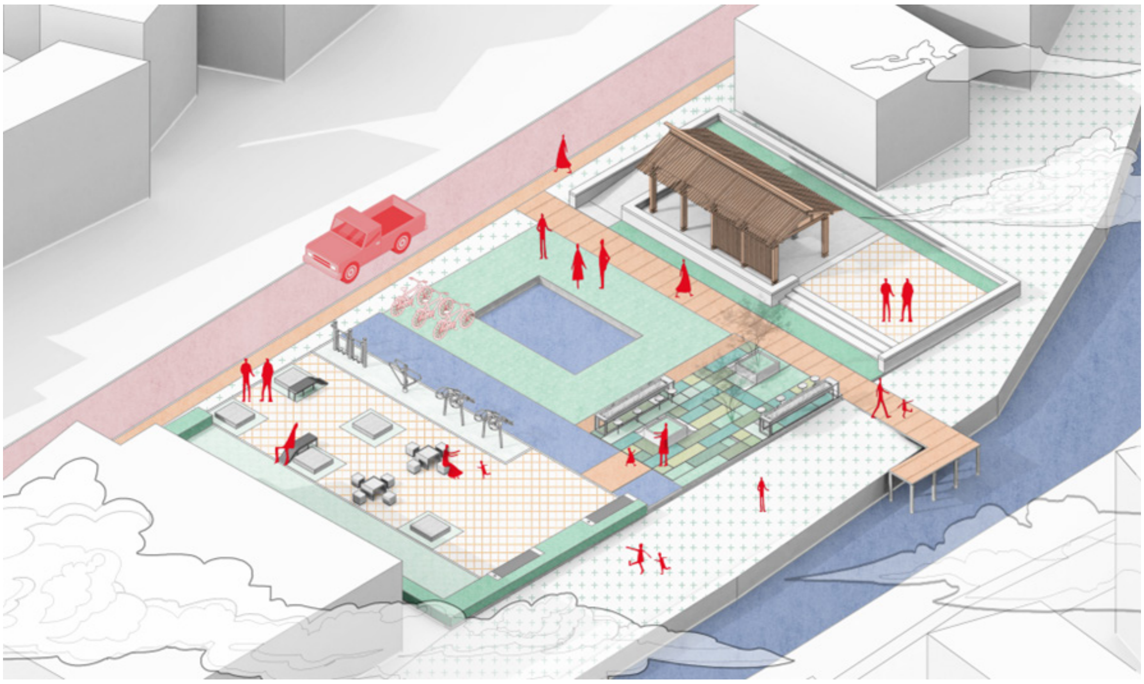


Fig 5-39 the rendered effect picture of Node 4 after the renovation(Source: by the author)

5.8 Participatory Design of Road

5.8.1 Current Situation Analysis

The current road system in the area is a mixed-use space for both vehicles and pedestrians. Additionally, there are some remnants of the original waterfront pathways near the Lijiao River, but they have fallen into disrepair, posing safety hazards and not meeting the needs of large crowds (Fig 5-40).

Fig 5-40 The Current Situation of the Road(Source: by the author)

Based on interviews conducted on-site, most residents express dissatisfaction with the current state of the roads. The reasons for their dissatisfaction can be summarized in three main points:

The roads are too narrow, making the one-way lanes overcrowded, leading to frequent congestion during peak commuting hours (Fig 5-41).

The condition of the roads is poor and requires leveling and resurfacing.

Residents feel that the mixed-use nature of the roads compromises safety.

Therefore, the subsequent participatory design will primarily focus on addressing the chaotic flow within the area and implementing pedestrian-friendly improvements.

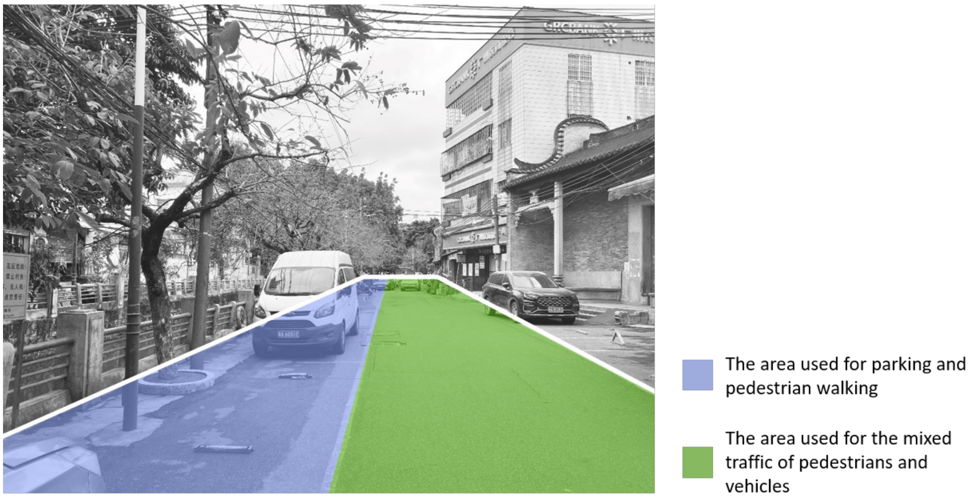


Fig 5-41 The situation of the mixed traffic of pedestrians and vehicles(Source: by the author)

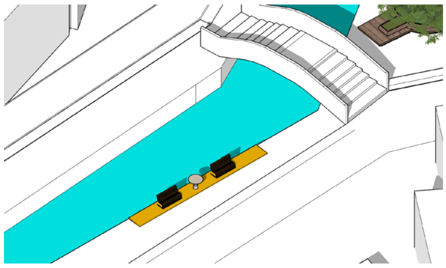
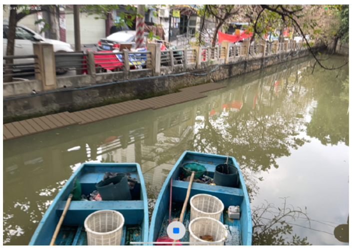
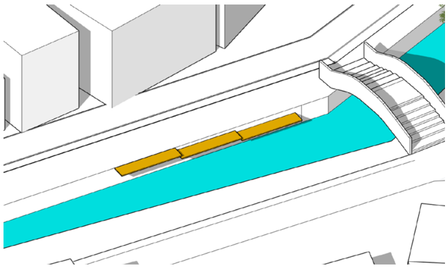
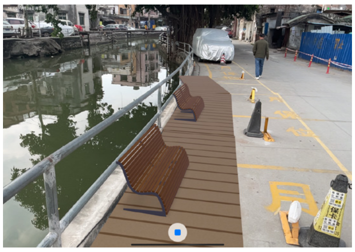
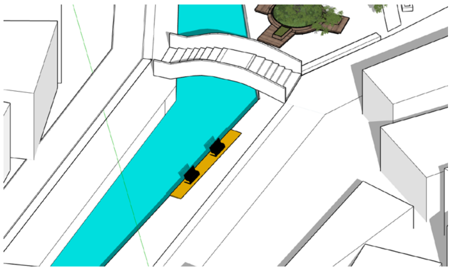
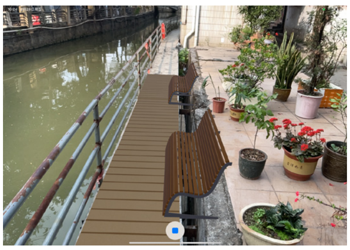
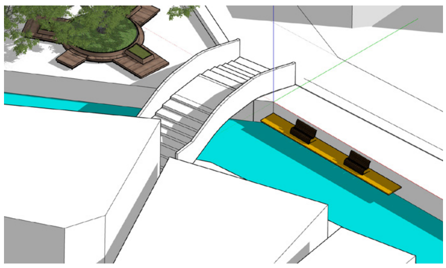
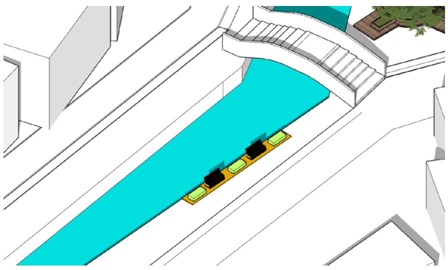
5.8.2 Participatory Design

Almost all residents agree that the road optimization should widen the pathways in the area while adding sidewalks to ensure pedestrian safety. The design results also show that residents have used different materials to distinguish between vehicle lanes and pedestrian paths (Table 5-5).

Residents expressed a mix of support and concern regarding the proposal to remove parking spaces in favor of sidewalks. Supporters believe this would benefit elderly residents by creating a more walkable environment, while those with concerns argue that reducing parking spaces could lead to difficulties for some residents if their parking spots are too far from their homes.

To address this, a waterfront approach can be adopted. In areas with ample parking, sidewalks can be developed towards the river, allowing for an increase in pedestrian pathways without reducing existing parking spaces. Meanwhile, in areas where residents engage in frequent activities, parking zones can be reduced to create sidewalks and add resting seats.

Table 5-5 The results of the participatory design by the residents of Road(Source: by the author)

	Public Demand	**Results of participatory design**	**Extraction of the design concept**
Particip ant 1	agree with the road optimization, and tables and chairs can be added to the sidewalk section.		
Particip ant 2	It will be more convenient to go fishing through the stepped waterfront walking paths.		
Particip ant 3	Removing the parking spaces and converting them into sidewalks is safer for children.		
Particip ant 4	In some open spaces, the walking paths can be restored to the original waterfront walking paths.		
Particip ant 5	Distinguish the materials and greening of the sidewalk.		

5.8.3 In-depth Design and Design Outcomes

According to the design concept mentioned above, the originally 5-meter-wide road will be divided into flow lines using different materials, with 4 meters allocated for vehicle passage and 1 meter specifically designated for pedestrian pathways. This design not only ensures smooth traffic for vehicles but also provides a safe passage for pedestrians.

Additionally, by introducing a waterfront walkway along the river, the pedestrian flow along the riverbank has been increased. This transformation not only enriches waterfront activities but also invigorates the road, making this public space more attractive and valuable (Fig 5-42). This design approach effectively balances traffic needs with the walking experience of residents, enhancing the overall community environment.

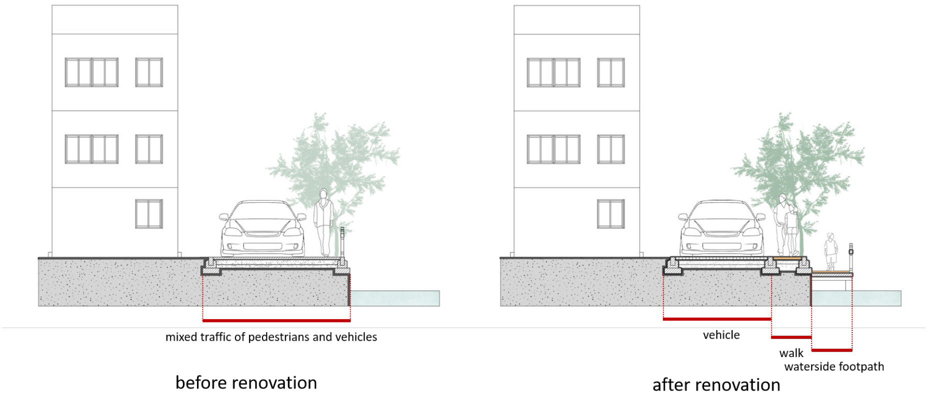


Fig 5-42 Comparison of the road before and after renovation(Source: by the author)

In terms of material selection, based on previous user feedback, there is a preference for durable materials such as concrete and bricks for the renovation of sidewalks(Fig 5-43).

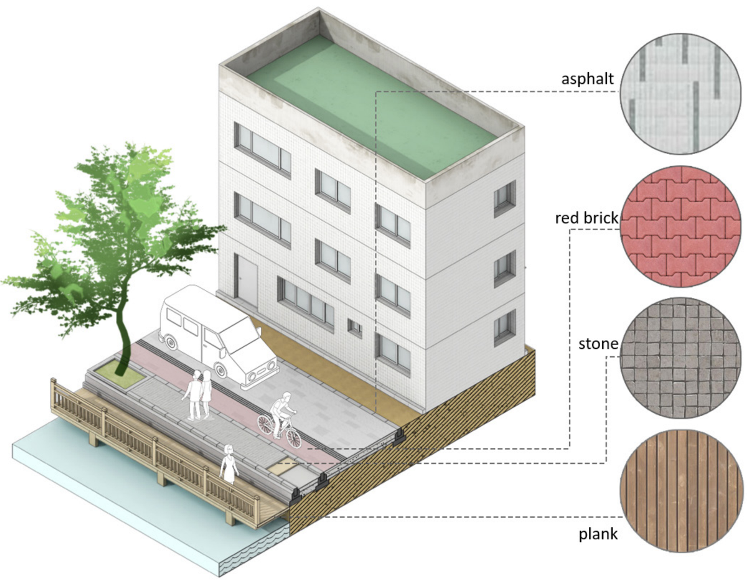


Fig 5-43 The Selection of Road Materials(Source: by the author)

Considering the flow line division, the final material choice includes asphalt for the vehicle lane, with red bricks used to separate the vehicle lane from the pedestrian path. The pedestrian pathway will utilize stone materials, while wooden waterfront walkways will be incorporated to widen the road.

5.9 Design Conclusions and Evaluation

This chapter builds on the theoretical analyses and experimental results from previous chapters, applying the augmented reality participation model to the design practice of public spaces in the Huanxiufang community of Guangzhou, aiming to validate the effectiveness of participatory design strategies. Through site analysis, current situation surveys, and resident participation surveys, four key renovation nodes were identified, along with corresponding optimization suggestions.

During the needs assessment phase, a combination of graphic questionnaires and AR technology was used to gather residents' expectations for public spaces, clearly identifying the need to increase public space area, add seating, and provide children's activity facilities. Based on resident feedback, the community activity center, pocket parks, waterfront green spaces, and road systems were selected as key renovation focuses. Subsequently, residents were invited to engage in participatory design for different nodes using AR technology, and optimization designs were developed based on their input.

In the design of each node, first, a children's play area and a rest area were added in front of the ancestral hall at Node 1, along with the creation of a waterfront platform to enhance the space's vitality. Next, Node 2 was designed as a pocket park around an ancient banyan tree, increasing greenery and activity facilities to restore its resting function. Node 3 transformed the area into an open green park with chess spaces and waterfront areas to enhance social activities. Finally, Node 4 converted a parking lot into a waterfront park, establishing a viewing area, activity square, and sports park to boost the community's overall vitality.

These designs significantly enhanced the usability of public spaces and improved residents' quality of life. Each node's renovation was centered around the actual needs of residents, ensuring the designs were targeted and practical.

The design approach using augmented reality participation has clear advantages over traditional methods. Firstly, AR technology enhances residents' sense of involvement, allowing them to intuitively participate in the design process. Secondly, the real-time feedback mechanism enables residents to express their opinions instantly, allowing designers to rapidly adjust proposals to better align with actual needs. Additionally, AR technology provides visual effects, helping residents understand design proposals more clearly, reducing communication barriers, and enhancing design transparency. Finally, the AR model promotes interaction between designers and residents, facilitating a more effective co-creation process.

Conclusion and Prospects

1. Conclusion

Through theoretical research and case analysis, this paper has preliminarily constructed an augmented reality participatory model suitable for the renovation of old villages. Additionally, a comparative experiment was conducted to validate the feasibility of applying augmented reality methods in participatory design by comparing the augmented reality participatory model with traditional graphic and text questionnaire participation models. Finally, this model was applied to the public space renovation of the Huanxiufang community in Guangzhou for further practical validation.

Overall, this research, through theoretical analysis and case studies, has drawn the following conclusions:

1.Proposed a participatory design method for public spaces supported by augmented reality. This method addresses the limitations of traditional participatory design in terms of subject scope, design cycle, site scale, participation methods, and design objectives, forming a more human-centered participatory design approach. At the same time, the immersive and interactive scenarios created by augmented reality technology allow participants to engage more deeply in understanding the design and expressing their needs.

2. Preliminarily established the implementation process for participatory design of public spaces supported by augmented reality. Through theoretical research and analysis of actual participatory design cases, this paper has preliminarily constructed an implementation process based on participatory needs assessment, participatory co-design, and participatory collaborative decision-making.

3. Validated the feasibility of the augmented reality participatory model through comparative experiments and practical verification. Firstly, this paper constructed spatial element indicators and subjective evaluation indicators for participation methods, and conducted evaluations through correlation analysis and frequency analysis. The results indicate that the augmented reality participation method demonstrates higher satisfaction in terms of accuracy of expression, engagement, satisfaction, utility, and across the six spatial element indicators. Secondly, further empirical research on the augmented reality participation method was conducted through design practice in the Huanxiufang community.

2. Prospects

At the same time, this study has certain limitations and shortcomings. Firstly, the current data collection and analysis primarily rely on subjective questionnaires to gather feedback information such as user satisfaction, which assists in the verification and support of the experiments. Future research could explore other methods and means to capture users' psychological and emotional changes during the participatory design process, such as using electromyography devices, facial recognition technologies, and other technical means to reveal users' emotional changes through objective physiological data, thereby providing more dimensional data support for the evaluation of participatory design methods.

Additionally, the data analysis results obtained from the experiments can be used to propose targeted optimization suggestions for the augmented reality participatory model to enhance public satisfaction.

1. Improve Learnability and Comprehensibility

Since the Learnability and Comprehensibility of the augmented reality participation method is positively correlated with other subjective evaluation indicators, the key to applying AR in participatory design lies in improving the simplicity of operations, which is significant for enhancing participation from different groups.

2. Enhance Expression of Spatial Elements

Through design practice, we found that we should focus on improving the feedback of information regarding design elements such as interfaces, layouts, and greenery in the participation method. Additionally, by increasing the variety of greenery, interface forms, and layout types in the modules, we can enhance the richness of choices, allowing residents to engage in deeper participatory design. However, while optimizing the participation methods, it is essential to ensure that the residents find the operations easy and to conduct targeted content optimization based on preliminary research data, avoiding excessive choices that could complicate the process and increase the difficulty of understanding for residents.

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Eight years have flown by, and the world has changed. Among my friends, some have settled down and started families, some are achieving great things, some are lost and struggling, while others are steadfast in their ambitions. After countless encounters, I am finally concluding my years of study here. It would be a lie to say there was no passion; even though I often mockingly say that studying is futile, I have much to be grateful for.

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Finally, I must thank myself. Time flies, and how many eight-year periods in life can one spend learning without burdens? I once held artistic dreams, hoping to capture some moments, but life is always full of regrets.

All those moments will be lost in time, like tears in rain.

Before I leave, I would like to quote a love letter by Zhu Shenghao to conclude these eight years:

"Do not worry about growing old; you will be very lovely when you are old. Moreover, if you grow ten years older, I will also be ten years older, the world will be ten years older, and God will be ten years older. Everything will be the same."

Everything will be the same.