Analysis of Urban Public Building Space Design Strategies in the Digital Age

Pan Liang[1,2]*, Sharul Azim Sharudin[1]

[1]City University Malaysia, Petaling Jaya 46100, Selangor, Malaysia
[2]Lishui Vocational and Technical College, Lishui 323000, Zhejiang Province, China

*Corresponding author: Pan Liang, pl08041615@sina.cn

Abstract: Urban public building spaces involve various aspects of people's daily activities and interactions, making the rationality and scientific nature of the design of these spaces crucial. This article first discusses the role and impact of digitization in the design of public building spaces, covering aspects such as digital design methods, visual expression and presentation, augmented reality's spatial interaction experience, and integrated design and construction. Following that, it analyzes the process of digitized urban public building space design by exploring topics like digital space design and modeling, visual representation of digital spaces, digital performance analysis of spaces, and the integration of digital projects. This article aims to provide insights and references for urban public building space design in the digital era.

Keywords: Digital age; Public building; Space design; Strategies

1. Introduction

Buildings are the business cards of a city. Buildings can be classified into four major categories based on their functions: residential buildings, public buildings, industrial buildings, and agricultural buildings [1]. Among these, public buildings hold a significant proportion in urban architecture due to their distinct functions and purposes. Many well-known buildings are public buildings, such as the Burj Khalifa in Dubai, the Bird's Nest in China, and the Petronas Towers in Malaysia. Public buildings, compared to other types, place a greater emphasis on the uniqueness and novelty of design in terms of architectural form and spatial layout. This poses a challenge for designers, especially in the traditional approach of flat drawing, where designers often struggle to accurately convey the overall form and local structure of the building. Therefore, new technologies are needed to change the design paradigm of flat drawing. The commonly used CAD drawing method, as Li *et al.* [2] argue, is merely a tool for computer-aided design and does not inherently support the design process itself.

With the advent of the digital age, digital technology has seen significant development in the field of architecture. The application of digital technology has extended throughout the entire lifecycle of buildings, including design, construction, and operation. A digitalized design approach is becoming a trend in the design

of public buildings. Currently, some large public buildings utilize digital technology to design surfaces and lay out architectural plans. Digital applications assist in completing projects, achieving high quality and efficiency [3].

2. The role of digitization in public building space design

With the development of society, people's demands for public building spaces are constantly changing. Digital technology can assist designers in better reflecting design effects and spatial interactive experiences in public building space design, thereby enhancing the quality of spatial design.

2.1. Digital design methods

Urban public building space design involves various disciplines, including architectural design, structural design, mechanical and electrical design, decoration design, etc. Dedicated professionals are needed for each discipline, and the professionals only focus on their own discipline. The use of 2D drawings makes it challenging to assess the completeness of spatial design.

Digital design methods present the three-dimensional spatial relationships of the design more clearly, comprehensively, and in detail. Additionally, it allows for a comprehensive demonstration of the development process of design concepts using three-dimensional architectural elements [4]. The digitalized design methods for public building space design include parameterized design for irregular architectural spaces, coordinating multidisciplinary BIM forward design, performance design analyzing spatial organization rationality, and AI-assisted design to help designers expand their design thinking. The digitalized design methods, characterized by informatization, dataization, and standardization, significantly enhance the efficiency of designers and the rationality of design solutions.

2.2. Visual expression and presentation

Three-dimensional visualization is the presentation of information within a three-dimensional space using technologies such as computers and information networks, displayed in the forms of animation, graphics, text, etc [5]. The distinctive feature of three-dimensional visualization lies in its ability to intuitively display the internal relationships and detailed nodes of architectural spaces. Replacing the two-dimensional flat design approach with three-dimensional models allows for a more intuitive and comprehensive presentation of the organization, layout, as well as spatial relationships between construction and decoration in public building spaces. This effectively avoids clashes between multiple disciplines within the same space. Furthermore, the use of three-dimensional visualization facilitates collaboration and communication among design professionals from various disciplines, reducing the likelihood of misunderstandings and design flaws. Additionally, visual representation and display aid in the arrangement and material selection for architectural spaces, assisting designers in optimizing overall spatial plans. It also enables construction personnel and users to conveniently preview the effects of architectural spaces.

2.3. Extended reality interactive experience

With the increasing demands and expectations for living spaces, making spaces respond more actively and considerately to people's behaviors and psychological needs has become a forefront issue in digital architectural design research. In this context, "interaction" has become one of the key terms for the future development of intelligent buildings [6]. Daily behaviors and activities of individuals within public building spaces are more frequent, requiring designers to consider the interactive experience between space and people. The emergence of immersive digital technologies such as virtual reality (VR), augmented reality (AR), and mixed reality

(MR) provides designers with approaches and methods. **Table 1** shows a comparison between VR, AR, and MR [7]. Immersive digital technology enables the seamless integration of digital and physical spaces, realizing interaction among individuals, space, and the environment.

Table 1. VR/AR/MR comparison [7]

Styles	VR	AR	MR
Hardware development time	Mid 20th century	Late 20th century	Early 21st century
Common hardware carriers	High-performance computer	Mobile phones	MR all-in-one machine
Common display devices	VR glasses	Monitor	Holomorphic projection
Common auxiliary interaction devices	Handle and dynamic capture equipment	None	Hand capture
Main features of the screen	Fully virtual world	Directly superimposed on real-world light, displays virtual world	The real world is captured by cameras, overlay display of virtual world on the screen
Advantages	Immersive, complete hardware equipment, developed and applied extensively, with relatively mature technology	Civilized hardware, easy to carry use, not limited by space	Based on the real world, not restricted by space low dizziness and broad prospects for future development
Drawbacks	Less portable, difficult to use, takes up space, and causes dizziness	Weak immersion and ability to render scene lighting Backward development, poor visual effects, and unstable positioning	The technology developed relatively late, relatively immature, and from a visual perspective Low contrast, unstable interaction, and expensive price

2.4. Integrated design and construction

Traditional engineering project construction follows a linear workflow, constituting a loosely connected architectural information organization structure. The transmission of architectural information is hindered by manual translation, reducing the efficiency of information transfer and leading to issues such as errors, omissions, losses, and redundancies at various stages of construction projects [8]. In the case of public building spaces with significant information volume, adopting a linear workflow can result in information gaps. In contrast to the linear workflow, digital construction in architectural projects adopts a circular workflow. It integrates design information, construction information, and operation information based on the architectural information model, achieving the integration of design and construction and ensuring the continuity and integrity of architectural information flow. Through integrated design and construction, spatial information from various stages of the project can be input, transmitted, and stored comprehensively. Integrated design and construction smoothens the flow between design and construction information, saving project communication time and costs and enhancing the collaborative efficiency of architectural projects.

3. Urban public building space design process in the digital age

The digitalized process of public building space design differs from traditional flat space design methods, placing greater emphasis on the coherence and integrity of spatial information. It prioritizes team collaboration and meticulous control based on clearly defined roles and responsibilities.

3.1. Digital space design and modeling

Architectural space refers to the collective term for the internal and external spaces formed by various architectural elements used to meet certain production or living needs, constructed using various architectural main elements and forms. The functions of architectural space include both material and spiritual aspects, and these two aspects are inseparable [9]. In the design of public building spaces, it is necessary to consider the relationship between people, space, and the environment. People play the roles of both creators and users of space, and the spatial environment significantly influences human activities and behavior. Initially, digital design is employed to conceptualize the organization and layout of space through sketches. Wu Xiao *et al.* [10] argue that the digitization of sketches is necessary for architects dealing with relatively complex and dynamic form and space design, ensuring that their design concepts remain intact. Subsequently, after forming the initial design scheme, a three-dimensional model is created. This model encompasses the architectural, structural, mechanical, and decorative aspects within the architectural space. The use of a three-dimensional model facilitates the integration of design content, enhancing the efficiency of collaboration among various specialties and the accuracy of the overall scheme.

3.2. Digital space performance analysis

Building design is a systematic process that involves broad considerations in spatial design. Design proposals need continuous optimization, and spatial models require constant refinement. Therefore, during the deepening design phase based on the three-dimensional model of the architectural space, it is necessary to further improve the architectural spatial scheme. In the process of design refinement, adjustments must be made according to practical considerations, adding or removing certain components, and even altering the system itself [11]. Additionally, to better achieve the unity of people, space, and environment in spatial design, it is essential to conduct architectural performance analysis on the design scheme. The analysis includes aspects such as wind environment, thermal environment, safety evacuation, and the increasingly important green building analysis. Yuan [12] emphasizes that green building performance analysis, as a crucial aspect of the construction process, directly influences the overall effectiveness of green building construction. By utilizing digital analysis software, setting corresponding numerical parameters, simulating and visualizing information data, and adjusting according to relevant specifications, a rational and scientific design solution can be obtained.

3.3. Digital visualization space display

One of the notable characteristics of digital technology is visualization, and digital visualization is a crucial element in the design of public building spaces. This involves rendering the created three-dimensional model, adding material textures and dynamic ambient conditions, and then producing walkthrough videos. It also allows for lightweight displays to achieve a three-dimensional panoramic exploration of the architectural space, enhancing interactive experiences. Virtual reality not only presents virtual environments to users but also enables them to interact with elements within these environments, creating an immersive experience [13]. Additionally, in exhibition spaces within public buildings, creating a multi-sensory immersive experience is crucial for the audience to understand the core content of the exhibition and enhance the artistic quality of the display space [14]. Digital visualization space displays are no longer limited to the design phase but extend to construction and operational phases, providing a comprehensive interactive showcase of architectural space. In the future, there will be an increasing variety of methods for spatial interaction displays. **Figure 1** shows the visualization of the overall space.

Figure 1. Overall space

3.4. Digital project integration

Utilizing a digital three-dimensional model to integrate design phase information into the construction phase, construction personnel can grasp the basic details and information of the building project. In comparison to 2D drawings, digital models assist construction personnel in understanding the design scheme and the overall project completion more quickly and comprehensively, enhancing coordination and communication among all project stakeholders. The entire construction lifecycle of the building project necessitates digital spatial construction. Buildings are not merely about models and drawings; they are also about establishing a digital architecture based on standardized architectural information. This can be further refined down to components and elements, extending to operational surfaces and process techniques [15]. To achieve standardized construction, it is crucial during the design phase to adhere to principles of modularity and standardization, reducing the variety of applied components and ensuring their precision and standardization [16]. The essence of digital project integration lies in industrializing and standardizing construction, unifying design and construction processes.

4. Conclusion

With the advent of the digital transformation of urban public building space design, digital design concepts and processes are changing traditional spatial design approaches. Digitization brings new methods and tools such as digital design methods, visual expression and presentation, augmented reality's spatial interaction experience, and integrated design and construction to public building space design. This enhances the effectiveness and efficiency of urban public building space design, integrates the flow of architectural information, and ensures the integrity and accuracy of information throughout the entire lifecycle of the building. The digitized process of public building space design, including digital space design and modeling, visual representation of digital spaces, digital performance analysis of spaces, and the integration of digital projects, ensures the utilization of digital technology in urban public building space design.

Disclosure statement

The authors declare no conflict of interest.

References

[1] What are the Classifications of Buildings, 2022, viewed February 1, 2024, https://baijiahao.baidu.com/s?id=1746280745097850739&wfr=spider&for=pc

[2] Li B, Li B, Li G, 2009, The Changes of Architectural Design Method in Digital Age. New Architecture, 2009(3): 95–99.

[3] Li J, 2022, Fine Construction and Control of Whole Process of Digital Enabled Large Public Buildings. Building Construction, 2022(6): 1445–1448.

[4] Zhang H, 2017, The Study of Architectural Design Methods Under Digital Thinking. Decorating and Renovating World, 2017(7): 138.

[5] What is 3D Visualization, 2022, viewed February 2, 2024, https://baijiahao.baidu.com/s?id=1749835406227745058&wfr=spider&for=pc

[6] Xu W, Tang K, Philip Beesley, et al. 2022, A Multi-Disciplinary Conversation on Interactive Architecture. South Architecture, 2022(8): 1–23.

[7] Hong T, Zhu Y, Guo Y, 2023, Research on Interactive Geological Scene Modeling Method Based on XR Technology. Geological Bulletin of China, 42(2–3): 469–477.

[8] Cui W, Zhang H, Chen H, 2023, Research on Collaborative Methods of Architectural Design and Construction Based on the Perspective of Information Theory. World Architecture, 2023(9): 71–74.

[9] Wu D, 2013, Building Space Thinking Debate. Forestry Science and Technology Information, 2013(3): 22–23.

[10] Wu X, Yu G, 2007, Rethinking the Application of Digital Technology in Contemporary Architectural Design—Reflections on Reading "Contemporary Architecture and the Digital Design Process." Architectural Journal, 2007(5): 95–98.

[11] Zeng Y, 2023, Application Analysis of BIM Technology in Large Public Buildings Under New Situation. Construction & Decoration, 2023(10): 184–186.

[12] Yuan Z, 2023, Green Building Performance Analysis and Optimization Methods Based on BIM Technology. Chinese Architectural Decoration and Interior Design, 2023(21): 64–66.

[13] Lo T, Schnabel MA, 2020, Design Innovations: XR Technologies Oriented Towards Participatory Design and Its Prospective Applications. Architectural Journal, 2020(10): 108–115.

[14] Fang J, 2022, Design Strategies for Immersive Exhibition Spaces in Expo Buildings Influenced by Digital Media Technology. Hua Zhong Architecture, 2022(3): 75–80.

[15] Zhu Y, 2017, Digital Construction, the Path to Success for Future Engineering Projects. Chinese Survey and Design, 2017(8): 40–41.

[16] Pu J, 2020, Digital Building Application and its Development. The Journal of New Industrialization, 2020(4): 161–163.