



# Application and Innovation of Digital Technologies in the Design of Urban Landmark Buildings

**Dexuan Chen**

Washington University in St. Louis, St. Louis, MO 63130-4899, USA.

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\***Corresponding author:** Dexuan Chen, Washington University in St. Louis, St. Louis, MO 63130-4899, USA.

## Abstract

Against the backdrop of the deep integration of the digital economy and urbanization, urban landmark buildings, as carriers of urban culture and spirit, are undergoing profound transformations in their design concepts and implementation paths driven by digital technologies. This paper systematically sorts out the core application dimensions of digital technologies in the design of urban landmark buildings. Combining typical cases, it analyzes the innovative value of digital technologies in optimizing design processes, expanding creative expression, improving collaborative efficiency, and achieving sustainable development. It also explores the current challenges in application and proposes targeted optimization strategies. By analyzing cases such as the Shanghai Tower and the Mogao Caves in Dunhuang, this study extracts core principles, including technology-scenario matching, dual-value enhancement, and multi-technology integration. It aims to provide theoretical references and practical pathways for promoting the digital transformation of urban landmark building design, and support the creation of new urban landmarks that integrate cultural heritage, technological sophistication, and contemporary characteristics.

## Keywords

Digital technologies; Urban landmark buildings; Architectural design; BIM technology; Parametric design

## 1. Introduction

Urban landmark buildings are the core of urban spatial form and carriers of cultural spirit. In the digital era, digital technologies such as big data, artificial intelligence, and BIM have promoted the transformation of architectural design from a traditional experience-driven model to a 3D visualization and data-driven collaborative paradigm. Meanwhile, the acceleration of global urbanization has highlighted the limitations of traditional design in constructing complex forms, making digital technologies the core driving force for innovation in landmark building design. Exploring their application logic and value holds significant theoretical and practical significance.

Foreign research on digital architectural design started early, with mature applications of parametric design, BIM, VR/AR, and other technologies. Domestically, the development is rapid—for example, BIM has been successfully applied in major projects such as the National Stadium (Bird's Nest) in Beijing, and the digital renovation of Hankou Water Tower has become a model. However, there are issues such as scattered research on technology integration and insufficient discussion on humanistic care [1].

Therefore, this paper adopts the methods of literature research, case analysis and cross-case analysis, and constructs an analytical framework (a four-dimensional interactive model) for the application and innovation of digital technologies in the design of urban landmark buildings in accordance with the logical thread of “Technology Application - Innovative Value - Practical Challenges - Optimization Paths”, so as to clarify the research boundaries

and contributions. This framework consists of four collaborative dimensions: the core technology application layer focuses on the full-process coordination of the four key digital technologies; the design innovation value layer highlights four complementary values with cultural inheritance as the underlying clue; the practical application analyzes two grouped challenge dimensions covering four issues in the application process; and the optimization path adaptation layer puts forward targeted strategies.

These four dimensions form a closed-loop interactive system, and through the analysis of typical landmark building cases, the research innovation and practical value are clarified, with a forward-looking outlook on future development trends.

## 2. Core Applications of Digital Technologies in the Design of Urban Landmark Buildings

The application of digital technologies in the design of urban landmark buildings runs through the entire process of scheme conception, detailed design, construction simulation, and operation and maintenance, forming an application pattern of multi-technology integration and full-cycle coverage. Among them, parametric design, BIM technology, VR/AR technology, and digital twin technology constitute the core application system, each playing a unique role and collaborating with one another.

### 2.1 Parametric Design

As the core technical support for constructing complex forms and expressing creativity in urban landmark buildings, parametric design uses algorithms as the core to establish logical connections by setting design parameters and constraints, realizing the dynamic generation and optimization of architectural forms. It breaks through the limitations of traditional design in constructing complex forms, achieving precise alignment between creativity and technology, and plays a prominent role in the form conception and optimization stage [2, 3].

Designers can extract key elements such as urban context and natural environment, convert them into quantifiable parameters, establish correlation models with architectural forms through algorithms, and quickly generate multiple schemes for quantitative analysis and optimization. For example, in the design of the Canton Tower, parametric simulation of wind speeds and structural forces at different heights determined the “slender waist” shape, balancing structural stability, aesthetic effect, and wind tunnel performance. Additionally, this technology can unify the standardization and personalization of special-shaped components: through a unified modeling logic, it reduces construction difficulty and costs, while adjusting local parameters to meet differentiated needs, providing technical support for the innovative form of landmark buildings [4].

### 2.2 BIM Technology

Based on 3D digitalization, BIM technology focuses on building a central database containing all architectural elements, realizing information sharing and collaborative work throughout the entire project life cycle. It is the key to multi-professional collaboration and efficient management of landmark buildings.

In the design phase, it breaks the traditional limitation of each profession working in isolation, allowing designers to collaborate in real time on the same platform to identify and resolve design conflicts in advance. The Shanghai Tower used BIM to integrate multi-professional information, solving pipeline layout and structural stress issues in super high-rises and reducing more than 80% of design conflicts. In the construction phase, BIM combined with schedule planning enables visual construction simulation, predicting difficulties and risks to optimize schemes, while accurately calculating material usage to reduce waste. In the operation phase, BIM serves as the core platform for operation and maintenance, integrating data such as equipment operation and energy consumption to support operational decisions and realize intelligent operation and maintenance—covering the entire life cycle of landmark building design, construction, and operation.

### 2.3 VR/AR Technology

Through immersive experience and virtual-real integration display, VR/AR technology addresses the pain points of traditional design scheme display, such as lack of intuition and low communication efficiency, providing a new path for design communication and cultural inheritance of landmark buildings.

In the scheme conception phase, VR technology allows designers to immerse themselves in a virtual space, intuitively perceive details such as spatial scale and light, accurately evaluate scheme rationality, and discover hidden problems in 2D drawings. During scheme reporting, VR/AR technology lowers the understanding threshold for non-professionals. For example, in the design of a municipal cultural center, VR enabled the client to “enter” the

virtual space to experience audio-visual effects and layout, quickly reaching a consensus. In the protection and restoration of historical landmark buildings, AR can overlay restoration schemes on the real building to show effects, while VR can construct virtual scenes to restore the original style—meeting both protection decision-making needs and cultural popularization and inheritance functions, and achieving effective connection between technology and humanity [5].

## 2.4 Digital Twin Technology

By constructing a virtual model fully mapped to the physical entity, digital twin technology realizes real-time monitoring, simulation analysis, and optimization decision-making throughout the entire life cycle. Compared with BIM, it emphasizes real-time virtual-physical linkage, completing the upgrade from “static modeling” to “dynamic management and control.”

It is deeply applied in the entire process of landmark buildings: in the design phase, it integrates site environment, meteorological and other data to real-time simulate and optimize building performance such as sunlight, ventilation, and energy consumption; in the construction phase, sensors collect and transmit data in real time, enabling the virtual model to synchronously reflect progress and quality to facilitate timely adjustment of construction schemes; in the operation phase, it integrates data such as equipment operation and pedestrian flow, realizing functions such as fault early warning and energy consumption optimization through big data analysis. The digital renovation of Hankou Water Tower is a typical case: through a digital twin model, precise protection of the building is achieved, and combined with VR, a meta-universe experience venue is created, realizing the activated utilization of historical landmarks and demonstrating the innovative value of digital twin technology in the design of new and old landmarks.

## 3. Innovative Value of Digital Technology-Driven Urban Landmark Building Design

Digital technologies have not only changed the tools and methods of urban landmark building design but also promoted design innovation from multiple dimensions such as design concepts, function realization, cultural expression, and sustainable development, endowing landmark buildings with new value connotations.

### 3.1 Dual Innovation in Design Concepts and Form Expression

Traditional urban landmark building design mostly relies on designers' experience and inspiration, with design decisions lacking quantitative data support, making it prone to subjectivity and disconnection from actual needs. The application of digital technologies has transformed design concepts from “experience-driven” to “data-driven.”

Through big data analysis, designers can collect multi-dimensional data such as urban population structure, traffic flow, cultural preferences, and environmental quality, deeply explore urban needs and contextual characteristics, and provide scientific basis for design decisions. For example, in the design of landmark buildings in urban central business districts, analyzing regional traffic flow data and office crowd demand data can accurately determine key design elements such as functional layout, entrance/exit locations, and public space scale; analyzing local meteorological data can optimize building orientation, window-to-wall ratio, and sunshade system design to improve energy-saving performance. Data-driven design concepts make landmark buildings more in line with urban development needs, achieving the unity of aesthetic value and practical value [6, 7].

### 3.2 Toward Integration of Intelligence and Humanization in Function Realization

Digital technologies have promoted the transformation of landmark buildings from “static spaces” to “intelligent dynamic spaces.” By integrating the Internet of Things, artificial intelligence, and other technologies, buildings can perceive environmental changes and user needs in real time and actively adjust service models.

For example, the Supertree Light Show at Gardens by the Bay in Singapore can adjust effects according to real-time light and pedestrian flow, balancing immersive experience and efficient energy use; large stadiums use digital technologies to realize functions such as seat reservation and intelligent navigation, significantly improving operational efficiency and user experience—achieving the organic unity of intelligent functions and humanistic needs.

### 3.3 Digital Empowerment for the Inheritance of Historical Context and the Innovation of Cultural Heritage

For historical urban landmark buildings, digital technologies break the limitations of traditional methods and open up new paths for the active utilization of culture. Relying on digital modeling, VR/AR, digital twin, and other

technologies, precise protection, virtual restoration, and global dissemination of historical buildings can be achieved, breathing new life into cultural context in the digital age. The digital renovation of Hankou Water Tower and the Digital Exhibition Center of the Mogao Caves in Dunhuang are typical cases. High-precision digital reproduction combined with immersive VR viewing not only avoids damage to cultural relics but also expands the boundaries of cultural communication. What's more, digital twin technology can balance the principle of "restoring the old as it was" with functional upgrading, enabling historical buildings to adapt to the life of modern cities [6, 8].

### **3.4 Digital Technologies Boost the Low-Carbon and Sustainable Development of Modern Landmarks**

Digital technologies cover the entire life cycle of architectural design, construction, operation, and maintenance. Through full-cycle energy consumption simulation, intelligent monitoring, and scheme optimization, they realize precise control of energy consumption and create benchmark green buildings with high efficiency and low carbon emissions. Taking the Shanghai Tower as an example, its digital energy-saving management system achieves refined energy consumption control and intelligent regulation, greatly reducing the overall energy consumption of the building and fully demonstrating the core of green development. Empowered by digital technologies, the whole process of construction is upgraded, making modern landmarks balance practical functions with ecological value and boosting the high-quality and sustainable development of urban architecture [9, 10].

## **4. Practical Challenges and Optimization Strategies of Digital Technologies in the Design of Urban Landmark Buildings**

Despite the many innovative values brought by digital technologies to urban landmark building design, their practical application still faces challenges in technology, standards, talents, culture, and other aspects, restricting the in-depth application and effectiveness of digital technologies.

### **4.1 Challenges and Optimization Paths in Technology Integration and Industry Standards**

In terms of technology integration and industry standards, the current digital design is faced with such challenges as the isolated application of core technologies, the formation of "data silos" due to incompatible data formats, and imperfect collaborative mechanisms. In addition, there is a lack of unified industry standards, insufficient protection of intellectual property rights, prominent security risks of sensitive data, and the absence of a sound security guarantee system. To address the above problems, it is necessary to strengthen research on the integration of core technologies such as parametric design and BIM, formulate unified data exchange standards, and build an integrated collaborative design platform and an efficient collaborative mechanism. It is also essential to improve the data security guarantee system, strengthen protection technologies and regulatory efforts, accelerate the construction of industry standards and achievement evaluation systems, and improve laws and regulations to strengthen the protection of intellectual property rights [11-13].

### **4.2 Challenges and Optimization Paths in Talent Supply and Humanistic Integration**

In terms of talent supply and humanistic integration, the shortage of interdisciplinary talents and the lag of university education and industry training make it difficult to adapt to the needs of digital transformation. In addition, some design practices overemphasize technology while neglecting humanistic care, ignoring the inheritance of urban context, and leading to the disconnection between buildings and their cultural context. In this regard, it is necessary to optimize the education system of architectural majors in universities, add digital technology-related courses, and establish a normalized industry training mechanism, so as to cultivate targeted interdisciplinary talents through industry-university-research cooperation. At the same time, it is vital to strengthen the awareness of humanistic care and cultural inheritance in design, integrate urban context and regional characteristics into architectural design, and interpret cultural symbols by virtue of digital technologies, so as to realize the organic integration of technological innovation and humanistic inheritance [12, 14, 15].

## **5. Typical Cases of Digital Technologies Empowering Urban Landmark Buildings**

The scope of landmark buildings studied in this paper includes both newly built urban landmarks and historically significant landmark heritage spaces. This paper selects a newly built modern landmark (the Shanghai Tower) and a renovated historical landmark (the Mogao Caves in Dunhuang) as research samples. The two represent the core application directions of digital technologies in the construction of modern super high-rise landmarks and the

activated utilization of historical and cultural landmarks, respectively. Through comprehensive analysis of technology application scenarios, efficiency, and practical pathways, core principles of digital technologies empowering the design and development of urban landmark buildings can be extracted, providing universal references for industrial practice.

### **5.1 Technology-Scenario Matching: Precise Empowerment for Different Types of Landmarks**

Digital empowerment of landmark construction requires precise matching of technologies and scenarios based on the type and positioning of landmarks. Newly built modern landmarks focus on functional optimization, ecological low-carbon performance, and efficient operation. Taking the Shanghai Tower as an example, it integrates BIM and digital twin technologies to build a full-cycle digital collaboration platform, solving pain points such as super high-rise collaboration and pipeline layout, and realizing full-process data-driven management to meet its high-complexity construction needs. Renovated historical landmarks aim for cultural inheritance, precise protection, and active utilization. The Mogao Caves in Dunhuang rely on high-precision digital modeling and VR technologies to achieve accurate restoration of ancient sites and immersive communication while protecting cultural relics, aligning with its development goals of preservation and inheritance. The key to technological empowerment is not blind stacking of technologies, but precise adaptation based on the core needs of landmarks.

### **5.2 Dual-Value Enhancement of Landmarks Empowered by Digital Technologies**

Digital technologies are the core driver for landmarks to achieve dual enhancement of functional and added value, breaking the boundaries of traditional design and operation. The Shanghai Tower, a newly built modern landmark, optimizes spatial layout and builds an energy-saving management system via digital technologies, improving practical functions while enhancing ecological value and becoming a benchmark for urban green development. The Mogao Caves in Dunhuang, a renovated historical landmark, realize precise cultural relic protection through digital technologies and expand the scope of cultural communication with VR, synergistically improving protection functions and cultural communication value. Digital technologies transform urban landmarks from single spatial carriers into complex urban nodes integrating practical, ecological, and cultural values.

### **5.3 Technology Integration: The Core Trend of Digital Empowerment**

Both typical cases reflect the application characteristics of multi-technology synergy and integration. A single technology cannot cover the full process needs of design, construction, operation, protection, inheritance, and utilization of urban landmark buildings. The full-cycle empowerment of the Shanghai Tower relies on the integration of BIM for collaborative management, digital twin for dynamic control, parametric design for form optimization, and other technologies. The cultural activation of the Mogao Caves is completed through the collaboration of high-precision digital modeling for physical restoration and VR for immersive experience. This reveals that the application of digital technologies in urban landmark buildings is shifting from a single-technology point application to a multi-technology full-process integrated application, and the synergistic linkage between technologies is the key to achieving all-dimensional optimization of landmark construction.

## **6. Conclusion**

This study systematically analyzes the application, innovation, challenges, and optimization of digital technologies in the design of urban landmark buildings, extracting core principles and practical pathways of technological empowerment. It bears theoretical, industrial, practical, and urban development public value, providing solid theoretical support and practical guidance for high-quality urban development. The research clarifies the application logic of four core technologies, builds an implementable framework for the digital transformation of the architectural industry, corrects misunderstandings in transformation, and promotes the industry's upgrade to a data-driven and intelligent model. Meanwhile, it empowers urban construction from three dimensions: spatial quality improvement, cultural inheritance, and ecological low-carbon development, supporting the creation of urban landmarks with both cultural heritage and sustainability. The findings have potential transferability across regions and types, adapting to various landmark projects and urban development needs, and can link multiple stakeholders to ensure effective implementation. Despite ongoing challenges in current applications, with multi-pronged solutions, digital technologies will evolve toward intelligence and humanization in the future, continuously supporting the green transformation of the architectural industry, promoting the achievement of the "dual carbon" goals, and injecting strong

impetus into the long-term development of cities.

This study has certain limitations: the sample size is relatively small, the research methods are dominated by qualitative analysis, and there is a lack of methods, such as interviews or quantitative analysis, to verify the research findings, leaving room for improvement in the breadth and depth of the research. In the future, the research can be expanded to more cities and building types to enhance the universality of the conclusions. Overall, the research outcomes have strong scalability across regions and building types, which can adapt to the development needs of various landmark buildings and cities, and the effective implementation can be guaranteed through multi-stakeholder collaboration. Despite the various challenges in the current application of digital technologies, with comprehensive measures taken to address these problems, digital technologies will evolve toward intelligence and humanization in the future. They will continue to support the green transformation of the architecture industry, facilitate the achievement of carbon peaking and carbon neutrality goals, and inject strong impetus into the long-term development of cities.

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