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Research Article

Interior Design Effectiveness Modelling for Public Buildings with BIM-Based Technology

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In recent years, with the continuous development of urbanisation, the proportion of interior design in public buildings has been increasing year by year. At the same time, there is a tendency in many places for the interior spaces of public buildings to be upscale and retro. This indicates that people are paying more and more attention to the spiritual aspect of their lives, in addition to the materialistic pursuit of enjoyment. The current phenomenon of overdecoration in society can lead to excessive luxury and wastefulness. In these wasteful interiors, the beauty of the building itself is lost. In addition, this type of interior design is not only expensive but also poses certain safety risks to some extent. In the modern society, public buildings are essential places for public activities. To be specific, they are closely linked to public services and social management attributes. As a result, public buildings usually play a decisive role in facilitating communication and cooperation between various persons. Thus, the construction requirements of public buildings are currently increasing and the structural shapes of buildings are becoming more complex. In addition, the level of technology and the use of public buildings are becoming increasingly demanding. As a result, it is quite important to examine how modern and emerging technologies can be applied to public building design in order to improve its effectiveness. At the same time, with the continuous and rapid development of China's economy and the promotion of the concept of environmental protection, the greening of public buildings has become an object of concern and research. There are many different types of existing public buildings in China, and in the design process, the energy consumption of the building throughout its life cycle and its impact on the surrounding environment are not fully considered, resulting in problems such as high energy consumption and poor indoor comfort in the actual use of the building. However, the demolition and reconstruction of buildings can lead to waste of resources and environmental pollution. Therefore, it is feasible and necessary to study the application of green building technologies in the design of public buildings. This study models the effectiveness of public building interior design based on BIM technology from the perspective of integrated design as well as parametric design. This model enables the interior design of public buildings to become energy efficient, emission reducing, and environmentally sustainable. After all, the integration of architecture and interior design can reduce unnecessary decorative waste. In addition, this model can also respond to the government's efforts to develop an ecological civilisation, creating a new way of living that is resource efficient.

1. Introduction

The construction industry is one of the pillars of China's national economy and also one of the oldest industries in the country. The construction decoration industry is an old but new industry belonging to the construction industry, including public building decoration and residential decoration [1]. With the advancement of urbanisation, the building decoration industry has been developing at a rapid pace. As a result, the interior decoration of buildings becomes a system project that can offer a number of decorative materials and products [2]. At the same time, they can be customised and produced according to the needs and environmental requirements of the user in order to create a perfect artistic space [3]. It is a cross-regional, cross-sectoral, multi-product, high-technology emerging industry. Interior decoration provides people with a spatial environment that is easy to use, comfortable and safe, and has perfect artistry [4]. To be specific, it can greatly improve people's various needs and enhance their quality of life, thus satisfying their material

and spiritual needs. It is more artistic and environmental than traditional architecture and is characterised by its applicability, comfort, artistry, diversity, variability, and renewability [5]. There are many different types of public buildings; however, office buildings are one of the most numerous types of public buildings in cities. Large and important office buildings are essential symbols of the city and have a significant impact on the urban form [6]. With the rapid development of the tertiary sector and the knowledge economy, more than 50% of the workforce in developed Western countries is already employed in various forms of office buildings [7]. The quantity and quality of office buildings have become a crucial measure of the social, political, economic, technological, and cultural development of a city or region, as well as the degree of urbanisation.

In recent years, as the pace of urban planning and construction has accelerated, the layout, design, and decoration of public buildings have also faced higher requirements [8]. The image and tone of public buildings must be in harmony with the overall outline of the city and the natural environment. At present, the consumption of interior decoration in public buildings in China accounts for a large proportion and is on the rise, and the cost of interior decoration in public buildings is enormous [9]. For instance, Figure 1 shows that the interiors of some public buildings are becoming very wasteful. Also, the construction waste during the design phase becomes a severe issue [10]. Another major problem facing architectural decoration is the loss of the timelessness of the artistic value of architecture as a result of the boom in popular culture. This has led to the disappearance of the truly valuable principles of the architectural system, with financial gain taking over as the only criterion for evaluation [11]. In today's human-centred world, the most essential issue in the design of architectural interiors is also safety, with problems arising from changes to the structure of houses during renovation or from the environmental quality of materials [12]. As the concept of low carbon and environmental protection continues to grow, the environmental and safety aspects of interior decoration are becoming increasingly essential. In recent years, as environmental degradation and resource scarcity continue to occur, all walks of life are focusing on the topic of low carbon [13, 14]. There is a growing awareness that sustainable development can only be achieved through low-carbon production and low-carbon lifestyles. Also, in recent years, the world has been focusing on green buildings, and the same is true for the interior design of our public buildings, which are so productive [15]. To be specific, it is important to look not only at the environmental aspects of decorative materials but also to fundamentally change people's attitudes. Only in this way, can we reduce the waste of social resources and thus achieve a healthy development of interior design.

After nearly 40 years of rapid development since reform and opening up, China's construction industry has achieved world-renowned results [16]. Both the total number of buildings and the construction techniques have developed significantly. Public buildings, in particular, have been increasing in recent years as important places of work and activity [17]. These public buildings provide a great deal of convenience for the production and living of urban dwellers, and they also contribute significantly to the country's social and economic development. However, behind the economic prosperity, there are many problems with public buildings, such as huge energy consumption [18] and poor functionality [19]. Specifically, although the total floor area of many large public buildings is less than 3% of that of civil buildings, the energy consumption of these buildings accounts for more than 20% of the total energy consumption of civil buildings [20]. The rapid development of China's construction industry has brought with it huge energy consumption, of which public buildings account for a large proportion (Table 1). Public buildings, because of their function and characteristics, have a relatively high energy consumption. On the other hand, the pursuit of more and more diversified building forms, the increasing demand for intelligent and functional buildings, and the increasing complexity of building construction techniques are becoming more and more important [21]. In this context, traditional architectural design concepts are becoming increasingly insignificant in the face of increasing building forms and construction requirements.

Despite the many challenges facing the development of public buildings, there are also many opportunities for the construction industry due to the development of new technologies and concepts. One great opportunity is the support being given to the development of green buildings in order to address the high energy consumption of the construction industry [22]. Green buildings emphasise the need to maximise environmental protection and reduce pollution throughout the life cycle of a building, thus providing a healthy, suitable, and efficient space for people to use. As can be seen from the construction requirements and its design philosophy, the green building design process requires an ever-increasing amount of building information to be processed [23]. Traditional design methods and processes are no longer sufficient to meet the needs of green buildings. However, the rapid development of information technology has met this demand for green building design [24]. In essence, green building is the implementation of a mindset of architectural design. This means that the current destructive way of life must be adapted to maintain a balance with the fragile living environment. On the other hand, architects must approach all design elements with a green mindset and be innovative in their approach to new technical measures to bring architectural work into greater harmony with the environment.

Information is now one of the three main elements of social development, along with matter and energy [25]. The model is a way of representing information to enable people to better understand, analyse, and transform things. The core concept of BIM technology is to integrate all kinds of information about a building into a model and to use the model to represent all kinds of information about the building [26]. BIM technology puts the information about the building and its components in a central database and digitises all the properties of the building and its components. This ensures that the building information is

Figure 1: Overdecorated public buildings.

Table 1: Energy consumption of various types of buildings.

	Coal for construction	Electricity for residential use	Electricity for public buildings	Electricity for private buildings
Energy consumption	25–30 kgce/(m^{2*}year)	15–25 kWh/(m^{2*}year)	150–2500 kWh/(m^{2*}year)	30–60 kWh/m^2/year

inherently uniform and computable and avoids the information silos caused by the current two-dimensional diagrams. In addition, BIM technology uses parametric modelling, which allows the building information contained in the BIM model to be coordinated and computable [27]. This building information will make it easier to analyse energy efficiency and the environment in the design process of green buildings.

BIM technology is based on computer technology and three-dimensional digital technology, through the organic integration of the advantages of modern computer technology tools and project engineering parameters. The process of establishing a BIM model is a process of editing and collating information about the overall design of the project [28]. The establishment of a 3D simulation model has a positive effect on the project from planning and design to the construction process and postconstruction operation and maintenance. To be specific, the model built using BIM technology can contain specific information about the project and its design parameters. A collaborative design platform for all parties involved in a construction project, therefore, allows BIM technology to be used throughout the life cycle of a project, from design to operation and management [29]. Designers can apply the BIM model to provide an intuitive and effective virtual reality experience for all parties involved in the project planning phase, thus enabling visualisation of the project design. In addition, the virtual reality capabilities of the model allow engineers to understand and grasp the parameters of the building system during the design and construction phase [30]. As a result, they are able to respond to possible situations in the most effective manner. In addition, once the project is completed and in use, the BIM model can be used to pinpoint the exact location of the incident and the surrounding environment. This will provide a more convenient service for project management and reduce the pressure on property management.

This study aims to provide a comprehensive understanding of the current interior design problems in public buildings and to raise awareness of the importance of interior design. In addition to this, this study investigates green building design methods by applying theories and methods related to BIM modelling, both in terms of the design process and parametric design. By breaking down the information barriers in architectural design, the BIM-based interior design effectiveness model for public buildings is constructed, thus providing a theoretical basis for the further development of information technology in construction projects. The design model is scientific, systematic, advanced, and operable and will play a role in expanding and improving the theory of public building design in China.

2. Interior Design for Public Buildings

In China, the architectural design market is growing at an average rate of around 15% per year. In such a large industry, energy consumption accounts for around 40% of total energy consumption. Since the 20th century, environmental degradation and resource scarcity have led to a focus on low-carbon issues in all sectors. There is a growing awareness that sustainable development can only be achieved through low-carbon production patterns and lifestyles. As a result, the design of public buildings must also consider the concept of green.

2.1. Analysis of Current State of Interior Design for Public Buildings. In the process of interior design and renovation of public buildings, interior safety problems are constantly arising due to the destruction of load-bearing structures by private demolition, as shown in Figure 2. For example, some buildings that could have withstood earthquakes of magnitude 5 or 6 have had their load-bearing structures destroyed by the renovation process, resulting in a significant reduction in seismic resistance. There have been many cases of people being injured by falling ceiling light fittings in luxurious decorations. The materials used in the decoration contain a large number of toxic substances, which can harm people and pollute the environment at the same time. In addition, many building materials are highly flammable and will burn quickly in the event of a fire, releasing high levels of toxic and harmful gases.

2.2. Cost Analysis of Interior Design for Public Buildings. If the interior design of a public building is not well thought out, then it can result in a significant waste of resources. On

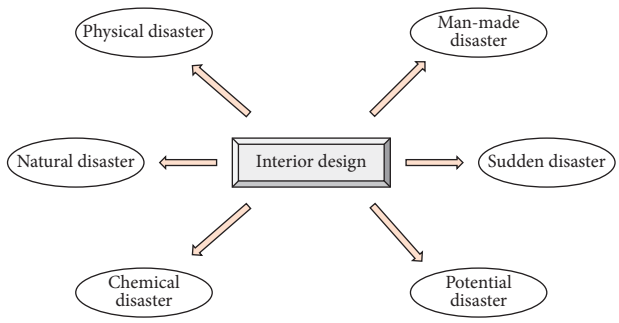

Figure 2: Indoor hazards in public buildings.

the one hand, when buildings are redecorated for various reasons, the reuse of original decorative materials becomes very low. On the other hand, the waste caused by poor design and low levels of construction can also be significant. In addition, even if reproducible resources can be used, they are consumed too quickly and can outstrip the rate of renewal.

The cost of interior decoration in public buildings is more than double the cost of the average civil construction, while the life cycle is only 3–5 years. As a result, there is a lot of unnecessary waste caused by repeated renovations. There are even many facilities that have been kept in good condition only to be removed and reinstalled because the style has become obsolete. This unnecessary waste is a burden on the country and the planet. The main components of the renovation process are the construction and material costs for civil alterations, plumbing, rewiring, and so on. Table 2 presents a cost analysis of the interior decoration of a public building.

3. BIM Technology

Collaborative working can provide a platform for building participants in the design process and support the implementation of an integrated design process. The analysis of public building standards shows that the design process requires extensive building performance analysis in order for buildings to meet green building standards. Parametric modelling is essential to such an iterative performance analysis process. Parametric modelling makes it easier and more accurate to enter building information, which used to take up most of the workload in the performance analysis process.

3.1. Difference between BIM Design and Traditional Design. In the traditional two-dimensional design process of construction projects, different design disciplines generally adopt the software tools corresponding to their own disciplines to complete the design content of their own disciplines. Each profession uses AutoCAD as a tool to draw 2D drawings of the design content of the profession, and finally, the design results of each profession are combined together in the form of 2D drawings to form the final design results of the project. There is no effective way to exchange information between the various disciplines during the design process. As a result, changes in design information between disciplines cannot be effectively negotiated with other disciplines, and the impact of changes in one discipline on other disciplines can be overlooked. In practice, the integrated design software alone is far from being able to meet the requirements of collaborative design for complete and timely information transfer and sharing.

Both BIM-based public building interior design and traditional 3D building design are capable of constructing 3D models of buildings, but there are still differences between the two (Table 3). The BIM model is a parametric information model, but the BIM model can be used to automatically count the materials used in the model with the support of the software and eventually produce a detailed list of materials used. In this way, the BIM model provides guidance on how to control the amount of materials used in the later stages of the construction process. In addition, the BIM model supports collision checking. Specifically, the BIM software allows for collision checking of the model to effectively reduce the impact of design errors on the construction process prior to delivery of the design results. As the BIM model is a parametric information model, there is a logical correspondence between the BIM model and the final 2D construction drawings. This means that when the information in the BIM model changes, the corresponding information in the construction drawings will also change.

BIM-based collaborative design has many advantages over traditional collaborative design methods. In the traditional design process, each design discipline works individually to produce its own drawings. As a result, if there is a conflict between the design elements, then each design discipline will propose changes to the conflicting issues through a coordination meeting. However, coordination through coordination meetings alone is not efficient and many conflicting issues require negotiation of multiple factors. During the design phase of a project, the overall design of the project is completed by the designer alone without the involvement of the builder and owner. This can lead to discrepancies between the design and the owner's or contractor's requirements, which increases the potential for design changes.

3.2. Design Staff Composition. In the traditional interior design process, the design is usually carried out separately in separate disciplines. For example, architects work alone on the conceptual aspects of the design and structural engineers on the structural design. This method of working often excludes most of the key designers from the decision-making process. The result is that the design is required to start again because it does not meet the standard requirements for the interior design of public buildings. This can have a serious impact on the efficiency and quality of the design of the building, as shown in Figure 3.

However, in the BIM-based interior design process for public buildings, each process involves the involvement of designers, engineers, and other professionals from the various trades involved. Therefore, with an effective communication mechanism, they can use their expertise to inform the decisions of the overall coordinator. The roles and importance of the design participants are constantly

Table 2: Cost analysis of the interior decoration of a public building.

Project name	Unit	Quantity of construction	Price (yuan)	Unit price (yuan)	Total price (yuan)
Stone floor	m^2	214.5	2839.25	139242.21	158293.29
Ceiling	m^2	3829.4	6759.24	245283.44	267289.35
Stone wall	m^2	89.2	1208.79	92873.07	104589.71
Decorative line	m	18273.9	18273.9	78928.19	99283.98

Table 3: Difference between traditional 3D model and BIM model.

	Traditional 3D model	BIM model
Function	Renderings and virtual reality	Renderings, virtual reality, analysis, and management
Parametric model	No	Yes
Coordination efficiency	Low	High

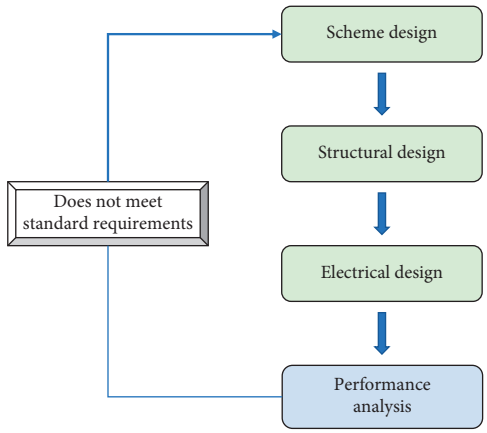

Figure 3: Process of traditional design approaches.

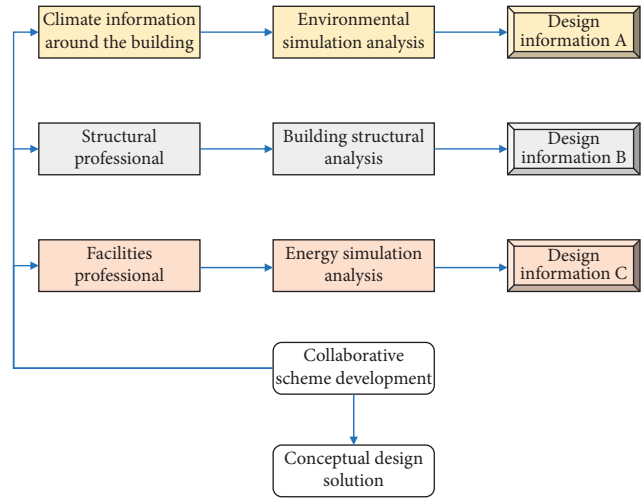

Figure 4: Involvement of key players in BIM-based interior design for public buildings.

being adjusted during the different design phases. To be specific, Figure 4 illustrates the involvement of the key players in the BIM-based interior design process for public buildings.

3.3. BIM Collaborative Design. BIM-based collaborative design requires the cooperation of designers from all disciplines. In order to achieve the ultimate goal of collaborative design, the design process of each profession should follow a certain workflow to ensure that the design tasks of each profession are carried out in an orderly manner. Figure 5 shows the general workflow of BIM collaborative design.

In order to achieve collaborative design between disciplines, a BIM design information exchange platform needs to be defined in the preparation phase of the project. At the same time, all disciplines need to share their design content on this platform. The software and hardware required for collaborative design are then determined and suitable 3D design software is selected for the construction of the BIM model. Each profession sets up its own project template under its own familiar software interface and completes the preparation of the project design. The core of collaborative design is the sharing of information between disciplines. Specifically, different disciplines can share their design information on a common professional design platform. This allows designers to access the latest model information on the shared platform at any time to meet different requirements in the design process.

Conceptual design works almost exclusively on the knowledge and experience of the architect in conventional design. If, after analysis, the construction objectives are not met, then the scheme needs to come back and be changed based on the feedback. After the scheme is finally formed, a lot of time is spent on design deepening, as shown in Figure 6. Nevertheless, in the BIM-based public building design, the parametric design of BIM technology allows the model solution formed after conceptual design to be automatically drawn in accordance with requirements and drafting standards. This approach saves the designer time in drawing production and allows the designer to spend more time and energy on the design of the scheme.

The traditional design approach to building models consists of a two-dimensional planar model made up of basic geometric elements. As a result, the model contains only flat information about the constituent elements. In contrast, the building information model constructed by BIM technology contains three-dimensional information parameters for all components. The BIM model, which consists of these basic components with three-dimensional properties, stores a

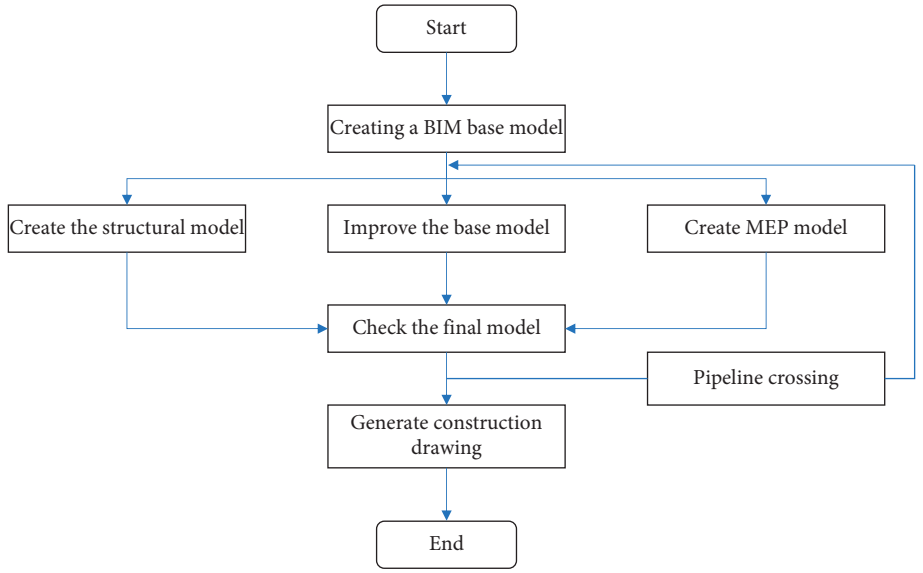

Figure 5: General workflow of BIM collaborative design.

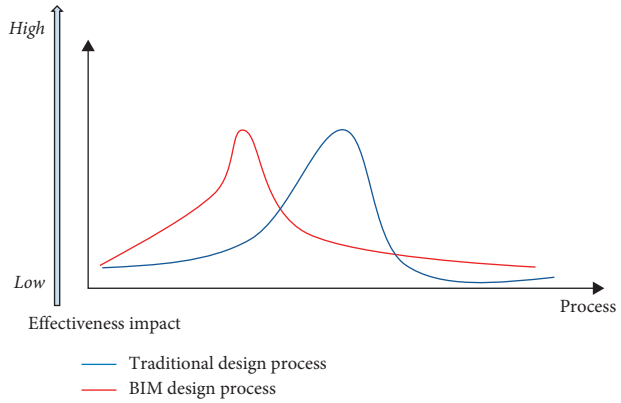

Figure 6: Relationship between effectiveness impact and the design process.

large amount of design information in the form of parameters in the large database of the model. This correlation of the modified information in the BIM model provides the basis for information sharing in collaborative design, avoiding the potential for missing information in traditional design methods and thus effectively improving the accuracy of information transfer.

4. Conclusion

The traditional process of interior design for public buildings has become difficult to adapt to the requirements of modern green building-related standards. It is therefore particularly important to consider how new techniques and theories can be used to improve the design of public buildings. This study focuses on this topic as follows:

First, this study analyses the necessity of applying BIM technology in the interior design of public buildings. The feasibility of applying BIM technology to the interior design of public buildings is investigated from a number of perspectives, including the characteristics of green buildings and the advantages of BIM technology. Second, this study investigates the application of BIM technology in green building evaluation and analyses the various forms of information transfer methods, including direct call and information extraction. In addition, this study proposes a BIM-based interior design effectiveness model for public buildings. The study also elaborates on the composition of the team, the construction of the technical platform, and the involvement of the designers in the different design phases.

However, given that BIM technology is still at an early stage of development, there are still many aspects that need further improvement. In this study, the following recommendations are conducted. Although 3D simulation software has advantages in the design process that 2D software does not have, it cannot fully meet the current requirements of designers for design work. In the subsequent software development and upgrading process, it is necessary to launch a version of the application that is more suitable for the current situation of domestic design, so as to provide good technical support for the popularisation of BIM technology. What is more, the relevant departments should revise the software-

related specifications as soon as possible and develop a unified standard suitable for China's national conditions, so as to establish a perfect industry system for the development of BIM in China.

Data Availability

The labeled data set used to support the findings of this study is available from the corresponding author upon request.

Conflicts of Interest

The author declares that there are no conflicts of interest.

Acknowledgments

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