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Computer-Aided Design AND APPLICATIONS

Application of BIM Technology in Computer-Aided Green Building Design

Peichun Tian[1,2], Soobong Kim[2], Baifan Feng[1] and Jiuyue Wang[3]

[1]School of Design, Anhui Polytechnic University, Wuhu 241000, Anhui, China
[2]Department of Landscape Architecture, Keimyung University, Daegu 42601, South Korea
[3]School of Arts, North China University of Water Resources and Electric Power, Zhengzhou 450046, Henan, China
tpcsky@ahpu.edu.cn, sbkim@kmu.ac.kr, Baifan_feng201812@126.com, wangjiuyue@naver.com

Corresponding Author: Baifan Feng, Baifan_feng201812@126.com

Abstract: As a leading specialty in the construction industry, architectural design has undergone profound changes after the information age. Building Information Modeling (BIM) is a general intelligent shared resource and a numerical expression of facilities and functional characteristics. It is a process of information sharing and a reliable basis for all decisions throughout the project cycle, which is very important for effective application in architectural design. This paper first gave an overview of BIM technology and its applications. The technical principle and function of BIM, the characteristics of BIM technology, and the application advantages of BIM technology were emphatically analyzed, and the importance of BIM technology was expounded. Then, the current application of BIM technology was introduced in three aspects: the design of a virtual building model, automatic document generation, and analysis of the building site. The survey found that the application of BIM technology in the modernization process of computer-aided structural design has further standardized the design and construction process, making the entire construction process actively participate in the operation of facilities, which has broad practical significance and plays an important role in improving the efficiency of comprehensive construction. Then, the application of BIM technology in green building design of computer-aided design was analyzed. The design optimization orientation mode has been studied, and the optimal layout mode of the building group has been set up. The optimization of the external environment and lighting has been analyzed. After that, the response surface algorithm was used to strengthen green building design and build a new green building design system. Finally, the investigation and research have been carried out. According to the investigation and research, BIM technology was introduced into architectural design, and the new green building design system built by response surface algorithm could improve the green design effect of buildings by 18%.

Keywords: Green Building, BIM Technology, Computer Architectural Design, Building System Design
DOI: https://doi.org/10.14733/cadaps.2025.S3.15-25

1. INTRODUCTION

In modern society, due to the mutual promotion and rapid development of information and computer technology, people's living conditions have been greatly improved. At the same time, modern science and technology are gradually playing an important role in the development of the construction industry. Computer-aided architectural design meets the basic requirements of architectural design, which is developing toward intelligence and humanization.

With the acceleration of urbanization, the number of construction projects has gradually increased. As an important part of construction, architectural design must be paid attention to. The purpose of Pinheiro Ana Paula was to remind people that architecture must understand nature and bring it back to daily life to increase their physical and mental comfort. Green in building restoration could have several meanings and approximations [1]. Fan Qiwei aimed to study the architectural design of the building and learn how designers could skillfully combine

green buildings with modern buildings. This study was conducted by visiting the building and collecting information about the building [2]. Cao Shi-Jie studied the impact of indoor temperature regulation on indoor air quality and energy consumption and considered a well-insulated full-size room with a top wall-mounted ventilation and heating system [3]. Alam S M believed that green concern had a profound impact on the global establishment of green competitive advantage. Therefore, green initiatives were necessary to ensure the survival of the clothing industry [4]. Ampratwum Godslove aimed to propose an implementation framework to help certification bodies make decisions on the implementation of Ghana's green building certification. This method was based on regular interviews with representatives of professional institutions with thematic knowledge [5]. Kim Ji-MYong studied the economic impact of green certification systems on educational facilities. To this end, the benefits of universities admitted by educational institutions were studied, such as building prices and maintenance and repair costs [6]. Tan Hang found that rapid urbanization had brought about problems such as increased building energy consumption, reduced green space area, poor air quality, and the heat island effect. The building envelope integrated with green plants, or vertical greening, was considered a potential solution to energy and environmental problems [7]. The above research is relatively thorough in analyzing green buildings, but it is not related to BIM technology and architectural design, which needs further improvement.

BIM technology is not only a software system, but also a tool that uses 3D digital technology to simulate building. The main objective of Ahmed Shakil's research was to identify the most critical obstacles to the implementation of building information modeling and determine their relative impact on the problem. The study was conducted through a comprehensive literature review, and necessary data were collected through a literature review [8]. Song ZhanPing found that the emergence of building information modeling technology had provided a powerful technical means for realizing informatization and digitalization in the field of engineering construction, and had greatly promoted the transformation and progress of engineering construction production and management mode [9]. Al-Ashmori Yasser Yahya believed that the implementation of the building information model was considered a daunting reality [10]. The research method of Taha Farah Faaq was to use building information modeling technology in 3D simulation and energy analysis. The research aimed to improve the indoor daylight performance of buildings by building information modeling technology, and determine the appropriate and comfortable artificial lighting and its cost of buildings [11]. Lee Ghang found that the construction industry had been plagued by the well-known low efficiency, high error rate, and a large number of budget and time overruns. The main reason was that the information management mainly based on two-dimensional drawings was insufficient and inefficient [12]. Kupriyanovsky Vasily discussed digital twins and their application in building information modeling technology. The purpose of Meng Qingfeng was to systematically summarize the current application of building information modeling, integration of related technologies, trends, and challenges, and summarize the interaction mode between building information modeling and other related technologies [13]. The above research is relatively thorough for BIM technical analysis, but it is not related to green buildings and architectural design, which needs further improvement.

BIM technology is the product of the development of computer information technology. Different from traditional computer-aided architectural design software, BIM technology allows designers to participate in the design of architectural models directly and improves their design sensitivity. The past computer-aided design technology no longer meets the requirements of the rapid development of the modern construction industry. BIM technology can make up for its shortcomings and accelerate the development of the construction industry.

2. OVERVIEW OF BIM TECHNOLOGY AND ITS APPLICATION

(1) Technical principle and function of BIM

At different stages of the project, different participants can conduct information analysis in BIM technology to support the implementation of the scheme. 2D drawing can obtain the basic properties of buildings more intuitively and reflect the multidimensional characteristics of buildings. In fact, BIM technology is not only a software system but also a tool that uses 3D digital technology to simulate models. Everyone has different definitions of it. It can help architects observe and analyze the small-scale of complex and large-scale engineering systems so as to improve the quality of building-related projects and enhance the construction efficiency of various connections in buildings, as shown in Figure 1. The BIM technology itself is not used alone. It needs to connect the relevant technical information databases between departments to carry out planning, construction, operation, demolition, and other construction processes so as to ensure fine project management.

(2) Features of BIM technology

The appearance of BIM technology provides a platform for the visual display of building models. It can strengthen the coordination between enterprise construction personnel and organizations, and form effective standard documents, so as to promote the construction implementation process. In addition, BIM technology can play a coordinating role in the layout and interior design of auxiliary equipment such as stairs, fire zones, pipes, and pipelines. For example, BIM technology can integrate the software data developed by the optimized technology

into the simulation system to simulate the voltage of different equipment components in the residential structure and test simulation environment. The data is mapped into statistics and the best match point is determined.

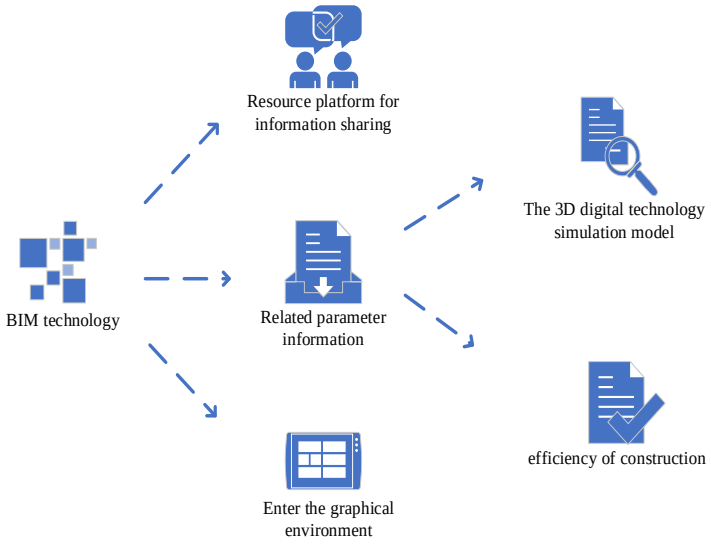

Figure 1: Technical principle and function of BIM.

(3) Application advantages

BIM technology is the most advanced and appropriate software for professional systems used by architects at present. The technology further integrates two-dimensional and three-dimensional computer graphics technology and develops technical analysis system design for construction modeling, price management, construction machinery management and control, structural analysis, etc., so as to update the three-dimensional effect. The 3D building modeling developed by BIM technology not only has the surface shape but also contains internal data and information, which can provide customers and contractors with a comprehensive design concept. If some of them are not satisfied, developers can use system technology to change relevant parameters and information, and the entire simulation design is converted to the general needs of customers. This technology enables planners, builders, and owners to introduce different parameters into buildings easily. In recent years, the establishment of an agricultural production network has become the main direction of open modern agriculture. The Agricultural Computer Science Research Institute is introducing this BIM technology into the simulation scheme of modern rural networks. After completion, the owner can place himself in a village connected to the modern network through on-site replication, which reflects the benefits of informatization to farmers. BIM technology provides the owner with an immersive feeling and increases the comfort of communication between designers and owners.

3. CURRENT APPLICATION OF BIM TECHNOLOGY

(1) Design of virtual building model

Traditional hand-drawn drawings cannot provide intelligent analysis and modeling, while the application of BIM technology can analyze the functions of drawings. The virtual architecture model contains a lot of non-type information. In order to analyze the structure, function, and energy, relevant data must be extracted from the model and imported into the simulation analysis software. Fire safety inspection, pipe collision, quality control, and other work are carried out, which makes the computer carry out complex analysis and modeling to improve work efficiency and ensure the accuracy of data analysis, so as to realize the practical significance of computer-aided design. The intuitive understanding of building modeling space, focusing on the characteristics of the internal structure of the building, is the basis of design and manufacturing. When selecting building materials and colors, software can be used to fill the building with colors, and then fill the model with different colors to produce effects.

(2) Automatic document generation

In the existing working environment, all drawings exist independently and need to be spliced. In addition, during the design process, the drawings need to be modified according to the actual situation. It takes a long time just

to modify the drawings, which causes a huge waste of human resources. However, BIM technology has revolutionized design based on drawings rather than models. When creating a model, all sheets are created automatically. Architects can automatically draw building plans and 3D graphics, as well as the budget and cost of building materials. In fact, the building model is a large database containing all building materials. Compilers can provide data from different perspectives as required, and also classify and synthesize similar information.

(3) Analysis of construction site

The use of a Geographic Information System can solve the problem of location analysis in the application of BIM technology. The construction model must consider the planning content of the construction site. The construction planning must fully consider the actual situation of the construction site to ensure the true and accurate evaluation of the construction site [14-15]. Research and effective work are conducted on the construction site. After the technical transformation of the two-dimensional drawing system, architects have spent a lot of time and energy on comprehensive modification and coordination, resulting in a huge waste of human resources. However, BIM technologies vary. Based on the model of BIM technology, the working diagram can be directly generated. Even if the building changes, the chart can be adjusted automatically. All data is created in one database. Therefore, architects can get rid of complex drawing changes, which greatly improves work efficiency. Finally, BIM can enable architects to focus more time on design to improve the quality of architectural design. Designers can make full use of 3D software design to help the final design of buildings, as shown in Figure 2.

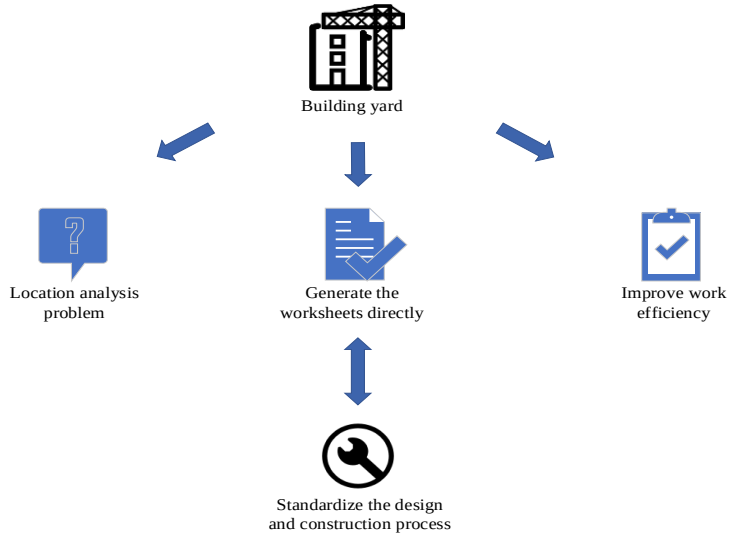

Figure 2: Analysis of the construction site.

4. APPLICATION OF BIM TECHNOLOGY IN GREEN BUILDING DESIGN OF COMPUTER-AIDED DESIGN

(1) Oriented design optimization mode

When BIM technology is applied in model design, designers must make full use of a 3D design program to maximize the efficiency of the final design of buildings. Practical research is helpful in understanding the actual needs of the owner. These requirements should be taken into account when building the model. The planning of green building projects should focus on optimizing project priorities. The internal natural ventilation of the building shall aim at optimizing the design. In summer, the wind direction and longitudinal axis of the building shall be vertically adjusted to improve indoor lighting and meet the building's energy-saving requirements.

As shown in Figure 3, in optimal orientation planning, Building Information Modeling (BIM) technology can be utilized to model wind environments. Wind environment modeling encompasses both indoor and outdoor scenarios. For outdoor wind environments, it is essential to use software to analyze the coordination between the building and its surroundings. The modeling is conducted in stages for high-rise buildings, where the software can simulate natural ventilation and assess integrated parameters.

(2) Optimized layout of buildings

BIM technology can perform virtual construction and use computer equipment to simulate the construction process [16-17]. In fact, through 3D design, architectural views and construction lists can be seen. The local optimization methods of buildings are different in different climatic regions. When designing the complex, the

characteristics of the construction in the monsoon area must be considered. If the building is in a cold area, the wind speed inside the green building can be reduced, and wind protection should be considered. The commonly used layout methods are outline layout and offset layout [18-19]. As for complex layout optimization, 3D software can be used to simulate complex reality, building temperature, and environmental climate. According to the evaluation and analysis functions of the BIM technology's data modification and assessment procedures, model coordinates can be returned to developers, as shown in Figures 4 and 5.

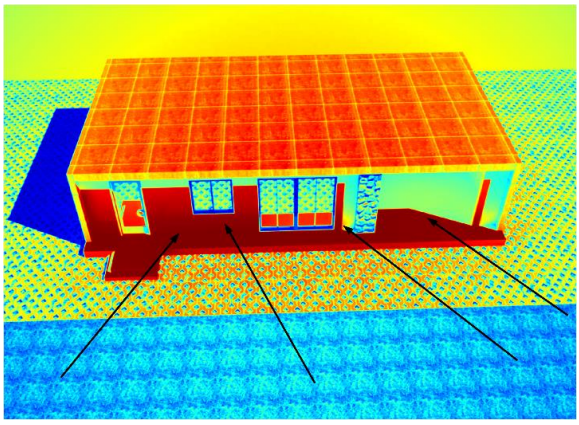

Figure 3: Wind environment modeling.

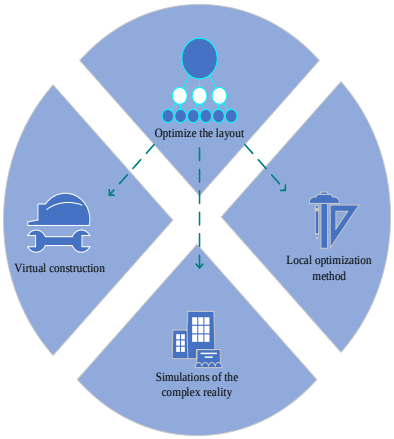

Figure 4: Optimized layout mode of the architectural complex.

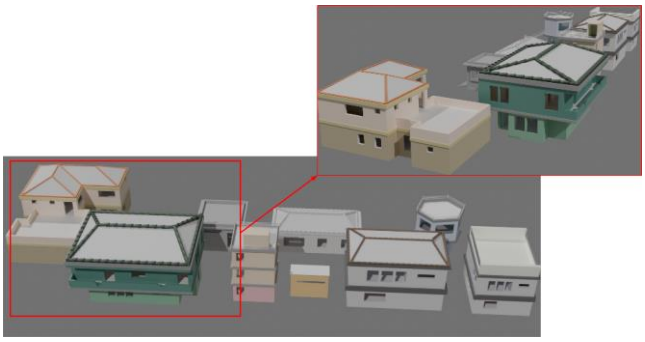

Figure 5: Optimization of building clusters under BIM technology.

(3) Optimization of external environment and lighting

The BIM technology can be used to evaluate the design model. In the design model, effective information is input into the special analysis software of the system so that each element of the design scheme, such as building area, space visibility, lighting path, pipe laying, and safe evacuation, can be scientifically and effectively evaluated. The application of BIM technology also plays an active role in controlling heating and noise. In terms of heating control, the temperature and climate in winter must be fully considered to realize the heat dissipation of solar energy in winter. This heating mode is passive. If only solar energy is used for heating in winter, green buildings are affected by heat in summer. Therefore, in the heating design, the computer can be used to simulate the heating in winter and summer for data analysis and parameter comparison to meet the needs of winter and summer. In noise design, the software can also simulate the flow of people and vehicles around the building to calculate its anti-noise ability and apply effective design methods to reduce the impact of noise on environmental buildings. Lighting software can help with appropriate lighting analysis and provide lighting and radiation modeling, as shown in Figure 6. At the same time, in order to ensure the effect of sunlight, it is necessary to simulate summer and daytime sunlight to obtain the results. The daylight optimization process based on BIM is shown in Figure 7.

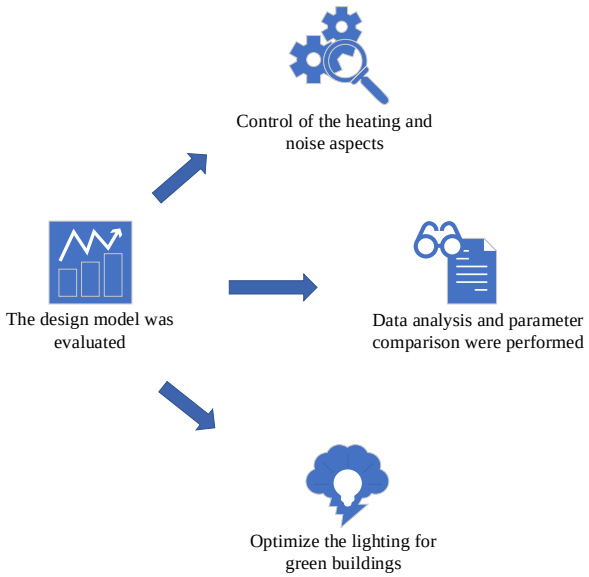

Figure 6: Optimization of external environment and lighting.

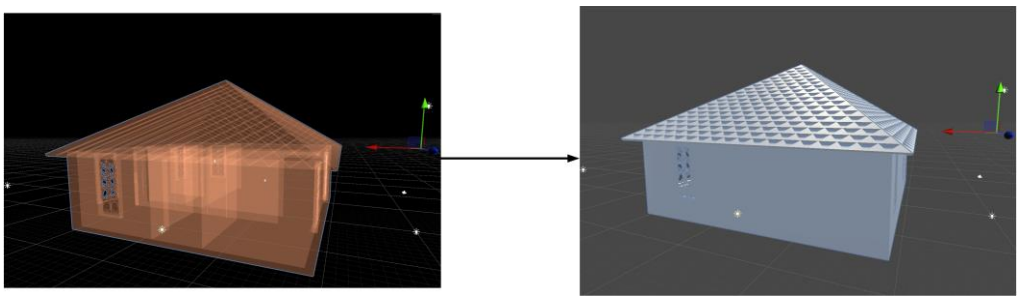

Figure 7: Light optimization based on BIM.

5. USING RESPONSE SURFACE ALGORITHM TO STRENGTHEN GREEN BUILDING DESIGN

In computer programming, there should be a unified output and expression format for the response surface, which is conducive to data processing and analysis. Supposing that the secondary response surface is adopted, and vectors express the response surface, the data is processed and calculated. First, the unified expression of the secondary response surface is specified, and the formula is as follows:

$$p = b + \sum^{n} \alpha_i x_i + \sum^{n-1}_{j=1} \sum^{n}_{k \neq 1} \alpha_{jk} x_j x_k + \sum^{n} \alpha_i x_i \tag{1}$$

In the formula, the corresponding variables, interaction terms, and correlation coefficients are stored in the vector H. After the order of coefficients is specified, the n experimental data obtained are substituted into the formula. The variable values are uniformly placed in the matrix x and expressed in the matrix. The formula is:

$$p = xh \tag{2}$$

In order to obtain a vector H, the minimum error value is obtained by the least square method. β Is the error between the response surface value and the experimental value p.

$$\beta = xh - p' \tag{3}$$

With the coefficient vector H as the variable, the square of error is derived, and the minimum square of error can be calculated as:

$$\Delta S(H) = \Delta(|\beta|^2) = \Delta((XH - P)^T (XH - Y)) = 2(XH - P)^T X = 0 \tag{4}$$

$$H = (X^T X)^{-1} X^T H \tag{5}$$

It is supposed that there is an objective function $f(x)$ and inequality constraint set $k(x)$, and the minimum or maximum value of the objective function is searched. The new function form is:

$$f(x, r^k) = f(x) + r^k \sum \frac{1}{g(x)} \tag{6}$$

By solving the quadratic formula, each time can be trimmed in the one-dimensional space of a single variable.

$$A = A_{kx} \tag{7}$$

$$B = (A + \sum^{n}_{i=1,1 \leq k} \alpha_{ik} x_i + \sum^{n}_{i \leq k} \alpha_{ik} x_i) \tag{8}$$

$$C = \sum^{n}_{i=1,1 \leq k} (\alpha_{ik} x_i^{\ 2} + \alpha_{ik} x_i) + \sum^{n}_{i \leq \mathrm{j},\ i \neq k} \sum^{n}_{j=1,\, j \neq k} \alpha_{ik} x_i x_j + A_0 - H_0 \tag{9}$$

6. CONSTRUCTION AND EXPERIMENTAL RESULTS BASED ON RESPONSE SURFACE ALGORITHM

The construction process of the algorithm for architectural layout and architectural detail design in this paper is shown separately in Figures 8 and 9.

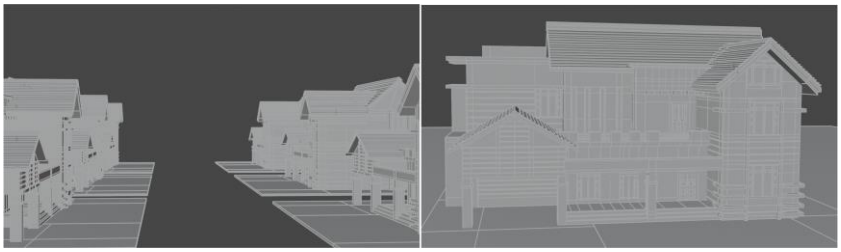

Figure 8: Architectural layout construction process.

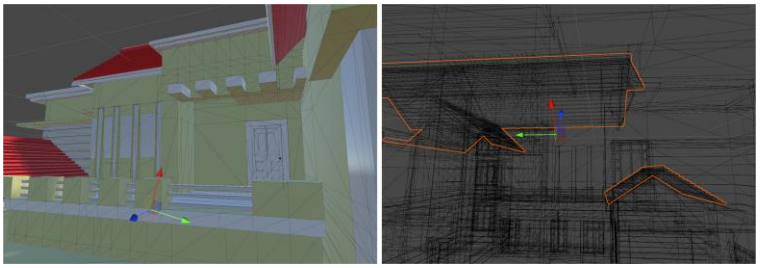

Figure 9: Architectural detail construction process.

In order to investigate the application of computer-aided design in architectural design in more detail, different construction companies are investigated. Architects from four enterprises are investigated. A total of 120 designers are surveyed in the form of questionnaires to investigate the satisfaction of architectural designers with function analysis, building modeling, site analysis, and work efficiency in current computer-aided architectural design. The four enterprises are set as A, B, C, and D. The survey results show the satisfaction of the architectural designers with different directions in the current computer-aided architectural design, as shown in Table 1.

	A	B	C	D
Functional analysis	68%	63%	69%	70%
Building modeling	72%	67%	76%	66%
Site analysis	65%	71%	68%	63%
Work efficiency	71%	70%	75%	74%

Table 1: Designers are satisfied with different directions in current computer-aided architectural design.

It can be seen from Table 1 that 120 architectural designers in the four enterprises surveyed are not satisfied with the function analysis, building modeling, site analysis, and work efficiency in the current computer-aided architectural design. Among them, the designers of Enterprise A are 68% satisfied with the current function analysis, 72% satisfied with the building modeling, 65% satisfied with the site analysis, and 71% satisfied with the work efficiency. Enterprise B designers are 63% satisfied with the current function analysis, 67% satisfied with the building modeling, 71% satisfied with the site analysis, and 70% satisfied with the work efficiency. Enterprise C designers are 69% satisfied with the current function analysis, 76% satisfied with the building modeling, 68% satisfied with the site analysis, and 75% satisfied with the work efficiency. Enterprise D designers are 70% satisfied with the current function analysis, 66% satisfied with the building modeling, 63% satisfied with the site analysis, and 74% satisfied with the work efficiency. From the survey, it can be seen that there are still some deficiencies in the current computer-aided architectural design, which need to be further improved.

In order to strengthen the application of computer-aided architectural design, BIM technology is introduced into architectural design, and a response surface algorithm is used to build a new green building design system. In order to test the effect of introducing BIM technology into architectural design, this paper investigates three construction projects A, B, and C that introduced the new green building design system, and investigates the impact of the new green building design system on architectural design and construction. The evaluation results specifically show the role of the new green building design system in the construction project. 90 designers are interviewed to investigate their satisfaction with the model construction, layout, environmental optimization, and directional planning in the new green building design system. The specific results are shown in Figure 10.

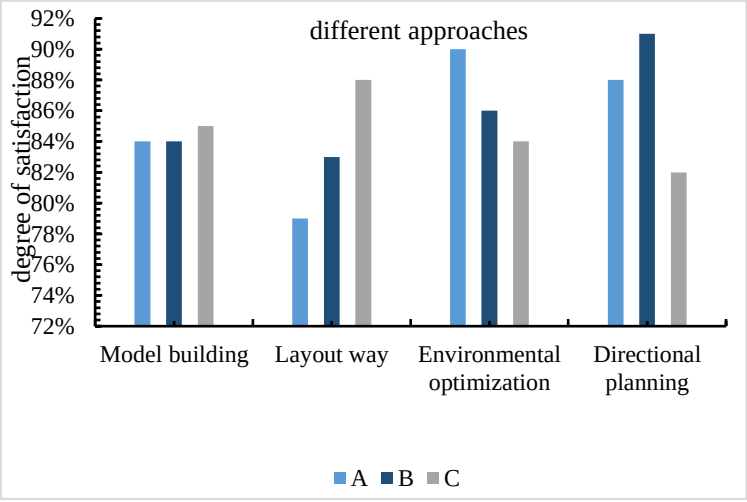

Figure 10: The role of the new green building design system in architectural design.

It can be seen from the histogram in Figure 10 that the designers of the three construction projects are satisfied with the effects of model construction, layout, environmental optimization, and directional planning in the new green building design system. Among them, the designers of Project A are 84% satisfied with the model construction in the new green building design system, 79% satisfied with the layout, 90% satisfied with the

environmental optimization, and 88% satisfied with the directional planning. The designers of Project B are 84% satisfied with the model construction in the new green building design system, 83% satisfied with the layout, 86% satisfied with the environmental optimization, and 91% satisfied with the directional planning. The designers of Project C are 85% satisfied with the model construction in the new green building design system, 88% satisfied with the layout method, 84% satisfied with the environmental optimization, and 82% satisfied with the directional planning. In general, the new green building design system built by BIM technology and response surface algorithm is still recognized by designers, which has played a great role in promoting the progress of building projects.

In order to optimize the current application of architectural design, BIM technology is introduced into architectural design, and the new green building design system built by response surface algorithm is introduced into construction companies. In order to test the satisfaction of architectural designers from different companies with the new green building design system, 120 designers from the four construction companies mentioned above are re-investigated to investigate the satisfaction of architectural designers with functional analysis, architectural modeling, site analysis, and work efficiency in the new green building design system. The survey results show the satisfaction of the architectural designers in different directions of the new green building design system, as shown in Figure 11.

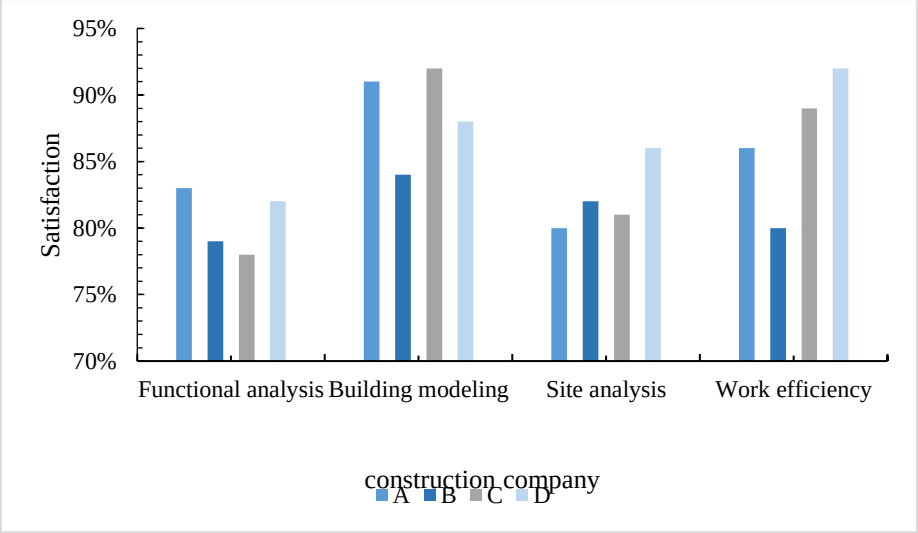

Figure 11: Designers are satisfied with different directions in the new green building design system.

It can be seen from Figure 11 that the surveyed architectural designers have significantly improved their satisfaction with functional analysis, building modeling, site analysis, and work efficiency in the new green building design system. Among them, the satisfaction of Enterprise A's designers with functional analysis in the new green building design system has increased by 15%. The satisfaction with building modeling has increased by 19%. The satisfaction with site analysis has increased by 15%. The satisfaction with work efficiency has increased by 15%. Enterprise B designers' satisfaction with functional analysis in the new green building design system has increased by 16%. The building modeling satisfaction has increased by 17%. The site analysis satisfaction has increased by 11%. The work efficiency satisfaction has increased by 10%. The satisfaction of Enterprise C designers with functional analysis in the new green building design system has increased by 9%. The satisfaction of building modeling has increased by 16%. The satisfaction of site analysis has increased by 13%, and the satisfaction of work efficiency has increased by 14%. The satisfaction of Enterprise D designers with functional analysis in the new green building design system has increased by 12%. The satisfaction of building modeling has increased by 22%. The satisfaction of site analysis increased by 23%. The satisfaction of work efficiency increased by 18%. From the survey, it can be seen that the new green building design system has greatly improved the defects of traditional computer-aided design of building design, and has played a huge role in promoting the development of architectural design.

Under the influence of the new green building design system built by introducing BIM technology into architectural design and using response surface algorithms, great changes have taken place in the green design process of buildings. In order to further the green design effect of the new green building design system and the traditional building design, the building projects that introduced two different building design systems are investigated. The survey direction is the owner's satisfaction with the green design effect of the new green building design system and the traditional building design. Satisfaction is satisfied, common, and discontent. A total of 200 owners were investigated, and the results are shown in Figure 12.

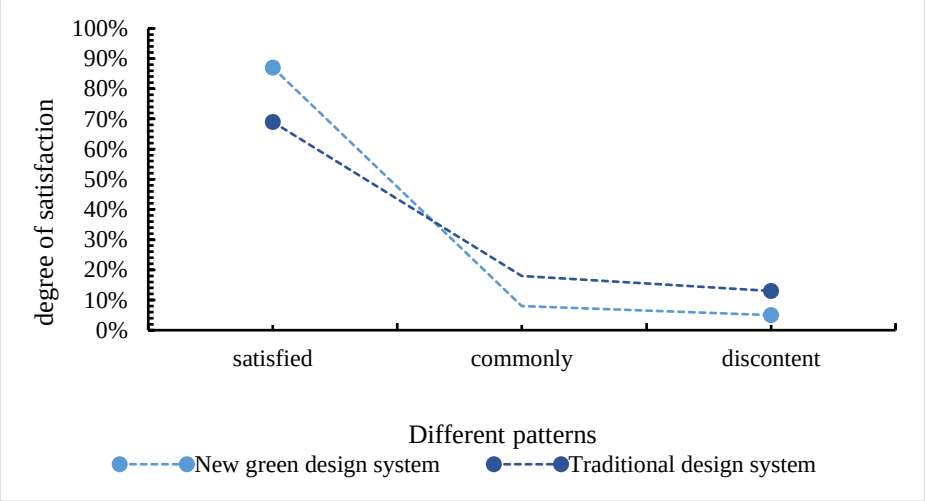

Figure 12: Owner's satisfaction with the green design effect of the new green building design system and the traditional architectural design.

It can be seen from Figure 12 that the owner's satisfaction with the green design effect of the new green building design system and the traditional building design is obviously different. The proportion of owners who are satisfied with the green design effect of the new green building design system is 87%. The general proportion is 8%, and the dissatisfied proportion is 5%. The green design effect of traditional architectural design accounts for 69% of satisfaction, 18% in general, and 13% in dissatisfaction. According to the survey and research, the new green building design system built by BIM technology and response surface algorithm can improve the green design effect of buildings by 18%.

7. CONCLUSIONS

To sum up, with the arrival of the intelligent information age, the construction industry has constantly adapted to the trends in the entire construction process and applied electronic information systems for construction. Designers can get rid of complicated and tedious work. The use of BIM technology to model not only improved the design efficiency but also could better control the cost and man hours. It can be said that BIM technology will be widely used in the design of future buildings. The introduction of BIM technology into green building projects has improved the quality of projects. The appearance of various design software has made the design more technical. In order to improve the design quality of green buildings, designers must be familiar with the working methods of various software and organically combine software with green buildings to improve the quality and efficiency of green building design.

8. FUNDING

This work was supported by the science research project of the Anhui Province Higher Education. (No.2023AH050879) and the Scientific research project of Anhui Polytechnic University (No.xjky2022176).

Peichun Tian, https://orcid.org/0000-0003-4055-7287
Soobong Kim, https://orcid.org/0009-0002-6447-9412
Baifan Feng, https://orcid.org/0009-0000-7819-4042
Jiuyue Wang, https://orcid.org/0009-0000-1339-4238

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