Simulation Analysis of Building Energy Consumption Based on Big Data and BIM Technology

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Abstract. In order to solve the problem of discrepancy between simulation results and measured results of building energy consumption simulation and analysis, a method based on big data and BIM technology is designed. The 3D building information model is constructed by BIM technology, and the factors affecting building energy consumption are obtained. The building energy consumption is simulated and predicted by heat balance method and Design Builder. Finally, data mining technology is used to modify the prediction results, and static energy analysis method is used to analyze the revised results. So far, the design of building energy consumption simulation and analysis method based on big data and BIM technology is completed. Compared with the original method, the simulation results of this method are close to the measured ones. In summary, the energy consumption simulation ability of this method is better than the original method.

Keywords: Big data · BIM technology · Building energy consumption · Numerical simulation

1 Introduction

With the rapid development of China's economy and the gradual improvement of living standards, the proportion of building energy consumption in total social energy consumption is becoming higher and higher. According to statistics, more than 50% of the material materials obtained by human beings from nature are used to construct buildings and their ancillary facilities, which consume about 50% of the global energy in the process of construction and use; at the same time, as a developing country, in the process of rapid economic development and modernization, it is necessary to coordinate the relationship between energy utilization and environmental protection, adhere to the people-oriented and sustainable development concept, and maximize the intensive use of resources [1, 2]. Since the global energy crisis broke out in the 1970s, more and more researchers have studied it in order to reduce the building energy consumption and have achieved some results. Since the emergence of BIM technology, there has been a BIM heat wave in the global construction industry. The function of BIM technology in the whole life cycle of buildings has been widely concerned.

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Energy-saving design of buildings needs to grasp the climate, including wind, light, rain, topography, landform and other local characteristics, but the complexity of today's buildings is much more than can be grasped by the subjective judgment or experience of architects, which requires the use of advanced computer technology to carry out complex data calculation and real-time dynamic simulation, to carry out preliminary energy consumption analysis of buildings, to achieve green energy-saving design of buildings [3]. Building energy consumption simulation is to use computer modeling and energy consumption simulation technology to analyze the physical performance and energy characteristics of buildings, which can be used in both new and existing buildings.

Based on the deep study of energy consumption data and the operation mode of buildings, an energy consumption simulation model based on big data and BIM technology is proposed.

2 Materials and Methods

Aiming at the problem that the simulation results of the original building energy consumption simulation analysis method are quite different from the measured results, the building energy consumption simulation analysis method based on big data and BIM Technology is set up. To ensure the effectiveness of this method design, the construction method design framework is shown in Fig. 1.

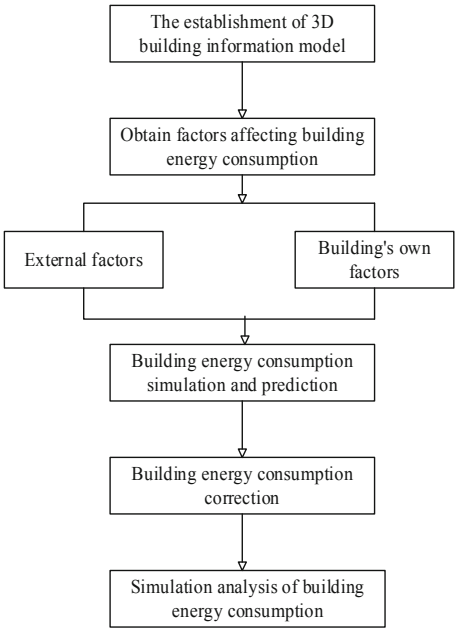
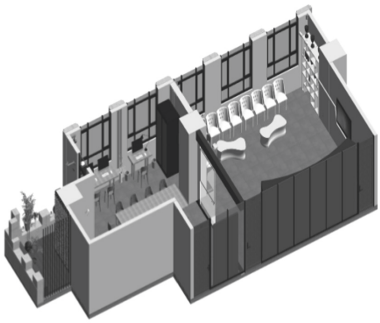


Fig. 1. Design frame of building energy consumption simulation analysis method

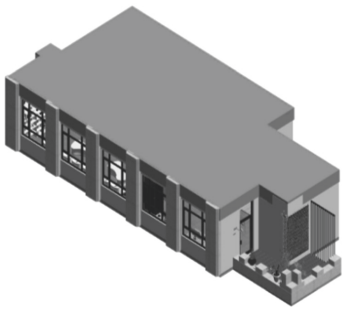
Through the design framework of Fig. 1, the method design in this study is completed. For the calculation part of the model, the calculation accuracy is set to two decimal places, so as to control the whole calculation process of the model.

2.1 Establishment of 3D Building Information Model

The first job of applying BIM technology is to establish 3D building information model by using related BIM information architecture design software according to physical and geometric information of construction project. The establishment of 3D model is the first condition to realize the function of BIM in the process of application, which includes all the digital information in the process of project construction. At the design stage, we can use different BIM design software to establish the relevant models, and then adjust the model to become the virtual model of the real project. The model can be used in the subsequent stage of the construction project. In this design, Revit Architecture, the core modeling software of BIM, is firstly used to build 3D building information model [4, 5], and then the professional software related to BIM technology is synthetically used to read the model information, check and analyze the model, and finally a perfect 3D information model is obtained. This is the basis of energy consumption simulation analysis of engineering project based on BIM technology. The building model of residential building with Revit architecture is shown in Fig. 2.



（a） Interior construction



（b）Overall appearance of the building

Fig. 2. Building information model

Using the software in Fig. 2 above, using the above software, the 3D model of the building to be measured is constructed, and the model is used as the model basis for building energy consumption simulation. The 3D building model based on BIM technology is different from the traditional 2D building model. All the components of the former have 3D information parameters, while the latter only have common 2D information. As mentioned above, BIM technology realizes the coordinated design of various specialties such as structure, HVAC and electromechanical in the whole life cycle of buildings. When the information of the component drawing element is modified or changed, the corresponding part of the building information model will be updated automatically, which reduces the tedious manual modification. This way of information sharing and the concept of coordinated design can make the designers master the overall situation, greatly reduce the errors and paper leaks in drawings, and ensure the completion of the project on schedule and with good quality and quantity (Fig. 3).

2.2 Access Factors Affecting Building Energy Consumption

According to the Study of Computer Evaluation System for Energy Conservation in Buildings, there are mainly three kinds of factors that affect the energy consumption in buildings. One is the external conditions of the surrounding environment and climatic factors of buildings; the other is the factors related to architectural design; and the third is the factors related to the operation and management of buildings [6]. This paper is

Table 1. Factors affecting building energy consumption

Index division	Types of factors	Factor content
External influence	Regional climate factors	Air temperature
		Air humidity
		Solar radiation
		Longitude and latitude
		Air pressure velocity
		Rainfall
Architectural design	Function use	The nature of the building
	Building survey data	Layer number
		Shape
		The measure of area
		Height
	Internal influence	Equipment fever
		Personnel Density
		Floor
		Home Furnishing
	Floor structure	Door and Window materials
		Vent size
		Exterior wall
		Interior wall
		Door and window area

based on the architectural design of the impact of factors on building energy consumption. Professional energy consumption simulation software is based on the impact of these three factors, and in the actual operation, the above factors also affect each other, and affect the building's energy consumption, the main factors affecting building energy consumption, as shown in Table 1.

If we want to reduce the energy consumption of buildings greatly, it is not enough to make qualitative analysis by light. It is very important to make quantitative analysis of energy consumption of buildings, to find out the relationship between energy consumption and various influencing factors, and to determine the influencing factors.

2.3 Building Energy Consumption Simulation Forecast

Building energy consumption simulation and analysis is a complex calculation process related to many aspects. It is necessary to record and calculate the design parameters of the building, such as the shape coefficient of the building, the ratio of windows and walls, the thermal performance and regional characteristics of the building, the heating and air conditioning system of the building and the various building equipment. Based on the above analysis, we can see that the energy consumption analysis method should consider many indexes related to building. There are three main analysis methods: building load calculation, digital analog calculation and actual measurement.

In recent years, the digital analog platform is used to calculate and test the building energy consumption, which provides a better platform for analyzing the building energy consumption control and energy saving. In this study, the synchronous simulation method is adopted, considering the synchronous effect of building heat and cold load and air conditioning system equipment on energy consumption, which increases the simulation accuracy.

The simulation begins with a Design Builder energy consumption analysis of the 3D model of the building that has been constructed [7, 8]. Using heat balance method and Design Builder software to simulate the building environment will produce a large number of data, such as outdoor meteorological conditions, indoor thermal environment parameters hourly, the whole building hourly cooling and heating load and the dynamic load of each room hourly. This paper mainly studies and analyzes the natural room temperature of different seasons, different layers of buildings, different rooms facing the same floor, and compares the building load under different window ratios, different heat transfer coefficients and different thicknesses of the same material. First, the building model can be pretreated, then the shadow lighting calculation, then the room temperature calculation and finally the load calculation. In the process of energy consumption simulation, mainly on the following aspects of the calculation, as shown in Table 2.

The energy consumption analysis software is used to simulate the above contents, and the data simulation results are stored in the form of a data table to carry out the building energy consumption analysis.

Table 2. Main contents of energy consumption simulation

Serial number	Type	Content
1	Natural room temperature	Room temperature in different horizons
2		Room temperature of different wall structures
3	Architectural coincidence	The influence of wall materials on building compliance
4		Influence of heat transfer coefficient of external wall on building load
5		Influence of same material and different thickness on building load
6	Air conditioning system	Energy consumption of air conditioning system
7		Personnel distribution in the building

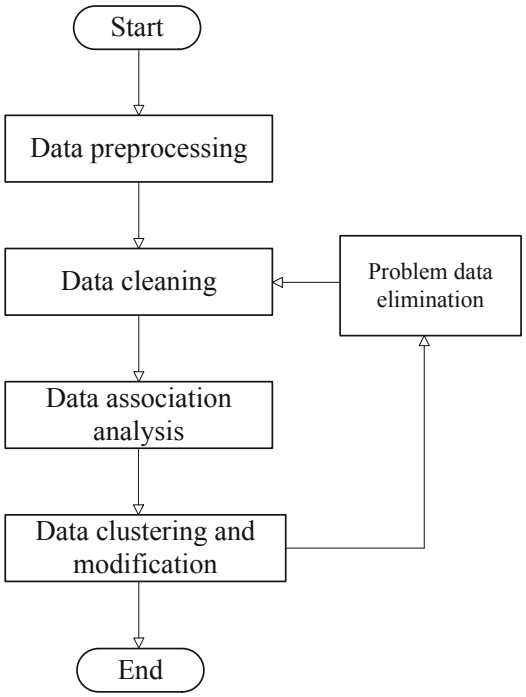


Fig. 3. Building energy consumption correction process

2.4 Building Energy Consumption Correction

In the process of data revision, the data mining technology will be used to revise the simulated building energy consumption data. The following process is used to complete the correction.

According to the process in Table 3, the problem data extraction and correction of energy consumption simulation results are completed. The data extraction part uses c-means clustering algorithm to complete the calculation process [9, 10]. Combine the modified data with the original data to form a complete energy consumption simulation data, and analyze it.

2.5 Simulation Analysis of Building Energy Consumption

In this part, the static energy consumption analysis method is used to analyze the modified energy consumption simulation results [11, 12]. First of all, the overall benefit of the building power and refrigeration power calculation, the specific formula as follows:

$$Q_R = \frac{o_i}{\partial_R} \sum_{n} (T - T_I) \tag{1}$$

$$Q_L = \frac{o}{\partial_L} \sum_{n_2} (T_I - T) \tag{2}$$

In the above formula, Q_R is set as the annual heating power; Q_L is the annual cooling power; T_L is the daily average outdoor temperature; T is the outdoor temperature corresponding to the balance of room heat gain and heat loss; o is the building heat loss coefficient; o_i is the heat transfer coefficient of the enclosure; ∂_R is the thermal efficiency of heating equipment; ∂_L is the efficiency of refrigeration equipment; n and n_2 are the days of using heating and refrigeration equipment respectively. Through the above formula, the obtained data simulation results are calculated, and the corresponding energy consumption characteristics of the building numerical simulation results are analyzed [13, 14]. In order to ensure the rationality and accuracy of the analysis, the above design results are combined with the effective heat transfer coefficient to calculate the energy consumption and heat of the building and improve the accuracy of the analysis [15, 16]. The specific calculation formula is as follows.

$$w_R = w_{RY} + w_{INF} - w_{U,H} \tag{3}$$

In the above formula, w_R is the heat consumption index of the building; w_{RY} is the heat transfer heat consumption of the enclosure structure of the unit building area; w_{INF} is the air penetration heat consumption of the unit building area; $w_{U,H}$ is the internal heat gain of the building of the unit building area.

3 Results

Aiming at the simulation analysis method of building energy consumption based on big data and BIM technology, the simulation experiment environment is designed in this research, and its application effect is studied.

3.1 Experimental Design

In this experiment, the method of building energy consumption simulation and analysis, which is designed in this paper, will be systematically studied by comparing with the original method. The experiment will be in the form of simulation experiments, comparing the differences between the two methods in use. A building in a city is chosen as the experimental object, and the energy consumption is simulated. The accuracy of energy consumption simulation of the two methods is compared and reflected by simulation curve. In order to improve the reliability of the experimental results, the simulated curves obtained by the two methods are compared with the measured curves, and the experimental process is completed.

Select the following experimental equipment and software to complete the experimental process, and the specific parameters are shown in Table 3.

Table 3. Experimental Equipment and Software

Serial number	Parameter	Model
1	CPU	Intel
2	Hard disk	16G
3	Memory	8G
4	Input device	Digital plate
5	Data base	SQL2016
6	Simulation software	Revit Architecture
7	Data analysis software	Design Builder

Use the above design to complete the design of the experimental environment, and use the above equipment to obtain the three-dimensional framework of the experimental target, as shown in Fig. 4.

The design method is used to analyze the energy consumption of the experimental object, and to compare the difference between the trend of energy consumption and the measured data. In this experiment, will be half a year as the experimental length, the completion of experimental comparison. In order to improve the precision of the experiment, the experiment is divided into two parts, and the differences between the original method and the design method are compared.

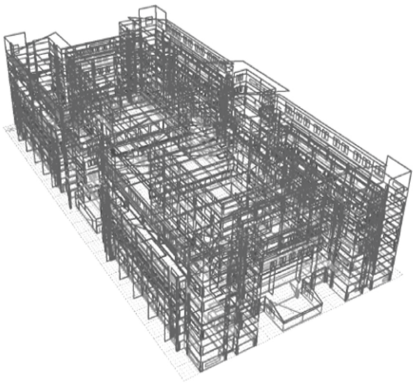


Fig. 4. Three-dimensional diagram of experimental object

3.2 Experimental Results Without Considering Environmental Factors

According to the experimental results in Fig. 5, on the premise of not taking into account the external environment, the trend of the design method and the measured curve is consistent, and the difference between the design method and the measured curve data is low, and the difference between the original method and the measured results is large (Fig. 6).

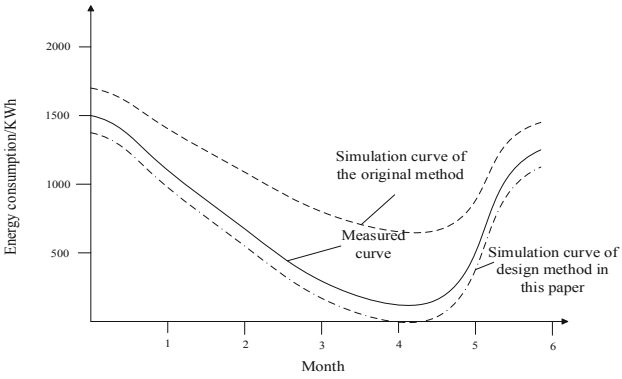


Fig. 5. Experimental results taking into account environmental factors.

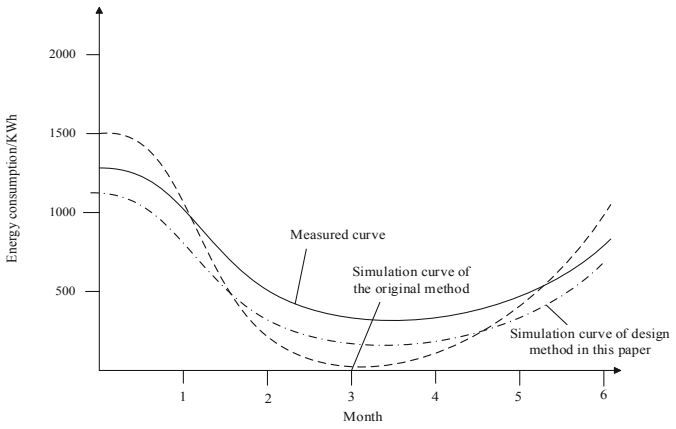


Fig. 6. Experimental results taking into account environmental factors

3.3 Experimental Results Taking into Account Environmental Factors

When environmental factors are considered, the design method is quite different from the original method. The trend of the original method is quite different from the measured results. The experimental results are combined with the previous experimental results. By comparison, the similarity between the design method and the measured results is high, while the similarity between the original method and the measured results is low. In conclusion, the energy consumption simulation accuracy of the design method is higher than that of the original design method, and the high-precision energy consumption analysis results can be obtained by using the design method in the culture medium.

It can be seen from Table 4 that for the comparison of various loads, the setting temperature and per capita area have a greater impact on the load, followed by the external wall and external window, which shows that the impact of internal factors on building energy consumption is greater than that of external factors on building energy consumption, that is, when the building is in operation and use stage, people's use mode and living habits on building energy consumption The influence of energy consumption is very great. As an important part of the external envelope, the influence of external wall and external window on indoor energy consumption is mainly realized by the real-time heat conduction between the external envelope and the outdoor environment. When the internal influence factors are certain, the external protection structure becomes the second major factor affecting the building energy consumption.

Table 4. Load simulation of combined scheme

Option	Cooling load (kwh/m2)	Thermal load (kwh/m2)	Total load (kwh/m2)
Option 1	21.40	4.01	25.63
Option 2	34.73	3.96	38.63
Option 3	39.54	6.42	46.21
Option 4	24.15	5.76	29.54
Option 5	37.59	6.25	55.35

4 Conclusion

Through the research, we can know that the traditional energy consumption analysis has corresponding shortcomings: because of the complexity of the project and the differences in form, function, content and operation of various analysis tools, it is not easy to select the analysis tools; because of the lack of deep understanding of professional issues and climate parameters, there are some differences between the building model and the actual project, which affect the accuracy of simulation results; and the combination with economy is not enough. Aided by BIM technology, it is very convenient to design, model and modify the scheme in BIM software after analyzing the energy consumption. The 3D model can be directly used to guide the field construction, and can directly output the architectural drawings in CAD format from the model. Using this research and design method can effectively reduce the cost and time of energy analysis, improve the speed and accuracy of analysis.

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