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Application of machine learning based BIM in green public building design

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Research Article

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Abstract

Public activities are mostly carried out in large public buildings, which are closely related to social management. At present, people's demand for public building facilities is increasing, its shape evolution is becoming more complex, and the scientific and technological content of construction related technology is also increasing. The development trend of green public buildings is more and more strong. The traditional building design can not effectively deal with the energy consumption of public buildings and people's demand for their performance. This paper introduces BIM and machine learning technology to study their practical application in the design of green public buildings, and tests the perfect machine learning algorithm. According to the experimental test results, the building energy consumption decreased by 14.3%, the carbon emission decreased by 11.39%, and the absolute value of PMV thermal comfort decreased by 34.7%, which obviously achieved the optimization effect. BIM Technology parametric design can enable the design model formed by conceptual design research to automatically draw construction drawings, detailed drawings and other drawings according to the drawing requirements and standards, thus saving the designer's time and enabling him to transfer the drawing time to the program design. Finally, through experiments, the economy, rationality and operability of using BIM Technology to design green public buildings are confirmed. In this paper, machine learning and BIM Technology are introduced, so as to carry out design research for green public buildings design.

1. Introduction

Nowadays, the construction industry has made obvious achievements both in terms of construction technology and the total value of construction. As a place for people's daily activities and work, public building facilities are increasing [1].Public buildings can bring great convenience to People's Daily life, thus promoting economic development, but there will also be problems in the practical application process.For example, the energy consumption of public buildings is high and the functionality of some buildings is poor [2]. Although the total area of public buildings accounts for only 5% compared with that of civil buildings, the energy consumption of this part is as high as 10% of the total energy consumption, and the annual power consumption per square meter is even as high as 100–300 kwh [3]. Although there are many problems in the development of public buildings, there are also many development opportunities in the current era.The biggest opportunity is the national level to introduce a large number of policies to support the development of green public buildings, in order to solve the problem of energy consumption[4]. Compared with traditional public buildings, green public buildings can greatly save energy, water, land, environmental protection and reduce pollution in the whole life cycle, thus providing more superior space for people's daily use and symbiosis with nature [5]. From the architectural requirements and design concepts, it can be seen that the green building design process has increased the requirements for building information processing. The traditional design methods and processes, such as information processing methods, are difficult to meet the relevant requirements of green building design [6]. In this context, information technology can perfectly meet the relevant needs of green building design.

2. Relevant Work

The literature reviews the applicability of BIM Technology to green building design quality management and the specific ways and methods of applying green building design, improves and optimizes the organizational structure and design process of green building design quality control, summarizes and emphasizes the application of BIM Technology, and expounds the importance of BIM standard in technical design quality management [7–8]. The contents of integrated design in different periods, the implementation of BIM collaborative design method, BIM integrated design method and the basic stages of integrated design are discussed and explained in the literature [9]. Subsequently, the construction process of the optimization scheme is analyzed and the research method is described. Through the orthogonal theory and Ecotect software, the thermal environment and light environment energy consumption of public buildings are simulated and tested [10]. The literature uses genetic algorithm to study the lighting comfort, indoor ventilation and energy saving of public buildings, and considers other contents and projects that affect energy consumption [11]. Through the simplified model of temperature improvement frequency, natural pressure time and average natural light, the performance prediction and evaluation indexes for public buildings are constructed [12]. In the literature, BIM Technology is used to optimize the design and planning of buildings, and the optimization process is analyzed. Finally, genetic algorithm is proposed to optimize the energy consumption, lighting, ventilation and comfort of buildings [13]. Based on the multi-objective algorithm optimization theory, the paper controls the environmental factors of green buildings, and analyzes the main factors affecting the establishment of environmental parameters by using the gray correlation degree. The above factors are input into the model, and SVM and K nearest neighbor (KNN) theory are applied in this process [14]. The algorithm optimizes the parameters by introducing adaptive genetic algorithm (AGA) and

optimized adaptive particle swarm optimization (APSO), and then builds a prediction model and designs experiments to compare the prediction effect of the model [15].

3. Machine Learning

3.1 Basic theory

Support vector machines can be divided into linear problems and nonlinear problems. The linear problem can directly find lines or planes to classify the sample data. However, in practical problems, many problems are nonlinear problems. The final optimization problem becomes:

$$min \sum_{i,j=1}^{n} \left(\alpha_i - \alpha_i^*\right) \left(\alpha_j - \alpha_j^*\right) K\left(x_i, x_j\right) + \epsilon \sum_{i=1}^{n} \left(\alpha_i + \alpha_i^*\right) - \sum_{i=1}^{n} y_i \left(\alpha_i - \alpha_i^*\right)$$
$$s.t. \begin{cases} \sum_{i=1}^{n} \left(\alpha_i - \alpha_i^*\right) = 0 \\ 0 \le \alpha_i, \alpha_i^* \le C \end{cases}$$

1

Sigmoid kernel function:

$$K\left(x, x'\right) = \tanh\left[v\left(x^T x'\right) + c\right]$$

2

Based on the optimal parameters, the multi-objective prediction is further carried out, and the prediction curves corresponding to the training set and the test set are drawn respectively. When R^2 is close to 0, the model matching effect is not good.

$$MSE = \frac{1}{n} \sum_{i=1}^{n} \left(y_i - \widehat{y}_i\right)^2$$

3

Where: n – number of samples; y—— Target analog value

3.2 Algorithm optimization

In the actual optimization problem, it often involves several objectives that need to be optimized at the same time. These goals often have different dimensions and conflict with each other. Therefore, the multi-objective optimization problem (MOP) arises at the historic moment. Its purpose is to generate multiple objective optimal solution sets within a given parameter range, which is called "Pareto optimal solution sets". The multi-objective optimization problem is composed of two or more objective functions and many constraints. The multi-objective optimization problem can be summarized as the following formula. The multi-objective optimization problem can balance the optimal solutions of various objectives in different properties. The Pareto optimal solution set obtained contains more effective information, which is worth further exploration. It can solve many practical problems, and is widely concerned and applied.

The linear membership function μfi is defined for n groups of solutions from the Pareto optimal solution set, and its expression is as follows:

$$\mu_{fi}^{n} = \begin{cases} 0, f_i^n \le min\left(f_i\right) \\ \frac{f_i^n - \min(f_i)}{\max(f_i) - \min(f_i)}, min\left(f_i\right) < f_i^n < max\left(f_i\right) \\ 1, f_i^n \ge max\left(f_i\right) \end{cases}$$

4

Max (f) - the maximum value of the ith objective function in the solution set.

Calculation distance:

$$U_n = \sqrt{\left(\frac{\left(x_{pareto} - x_{E_{point}}\right)}{x_{E_{point}}}\right)^2 + \left(\frac{\left(y_{pareto} - y_{E_{point}}\right)}{y_{E_{point}}}\right)^2 + \left(\frac{\left(z_{pareto} - z_{E_{point}}\right)}{Z_{E_{point}}}\right)^2}$$

5

The point (X pareto. y areto, Z pareto) is the coordinate corresponding to each point in the Pareto optimal solution set, and the point with the shortest distance is the optimal solution in the Pareto optimal solution set.

3.3 Simulation analysis

The orthogonal test table is designed with allpairs software, and L54 (66) orthogonal table is selected with reference to the above orthogonal design. Some data of energy consumption, carbon emission and thermal comfort value of 50 sample groups simulated by design builder are shown in Table 1. 50 groups of sample data in the table are used as the training set of SVM multi-objective prediction, and 15 groups of data are randomly selected as the SVM multi-objective prediction test.

Table 1
Table of simulation data samples based on orthogonal design

No.	Window to wall ratio	Heat transfer coefficient of external window (W/(m^2·K)>	External wall heat transfer coefficient (W/(m^2·K))	Roof heat transfer coefficient (W/(m^2·K))	Heating set temperature (°C)	Cooling set temperature (°C)	Energy consumption (MWh)	Carbon emission (ton)	Thermal comfort (absolute value)
1	0.2	1.1	0.23	0.22	18	23	2751.17	4664.42	0.24
2	0.2	1.5	0.33	0.24	19	24	2701.64	4415.53	0.27
3	0.2	2.1	0.44	0.32	20	25	2660.49	4246.70	0.30
4	0.2	2.5	0.59	0.36	21	26	2664.28	4168.30	0.33
5	0.2	3.2	0.68	0.40	22	27	2680.55	4130.19	0.34
...	...	...	...	...	...	...	...	...	...
46	0.7	1.6	0.22	0.26	18	25	2584.63	4434.31	0.16
47	0.2	1.1	0.41	0.42	20	28	2503.83	4116.85	0.16
48	0.2	1.4	0.57	0.49	21	27	2606.68	4117.80	0.25
49	0.2	3.0	0.21	0.30	19	28	2443.04	4405.67	0.27
50	0.2	3.6	0.33	0.36	18	27	2474.89	4224.68	0.35

In the Pareto optimal solution set composed of these 60 points, the ideal point method is used to find the optimal solution. According to the actual engineering situation, the distance between P (2418.183953.96, 0.17) and the ideal point is the shortest. Therefore, the design parameters corresponding to this point are the best optimization method. The comparison of design parameters and target values between the original design and the optimized design is shown in Table 2.

Table 2
Comparison of original scheme and optimized scheme

Option	Original scheme	Optimized scheme
Window	0.36	0.20
Exterior window heat transfer coefficient (W/(m2 k))	1.98	1.01
External wall heat transfer coefficient (W/(m2 k))	0.46	0.51
The roof heat transfer coefficient (W/(m2 k))	0.26	0.22
Heating setting temperature (°C)	20.20	18.28
Refrigeration setting temperature (°C)	23.23	28.28
Energy consumption (MWH)	2866.23	2418.18
Carbon emissions (ton)	4426.33	3953.96
Hot and comfortable (absolute value)	0.26	0.17

4. Bim Technology Applied In Green Public Building

4.1 BIM evaluation and Application

In the design stage, public buildings must meet the requirements of all control elements in the standard, and are divided into three green levels according to the satisfaction of general projects and expected projects.

Whether it is an ordinary project or a preferred project, there are assessment points in the assessment process, and relevant supporting materials must be submitted. For example, the terms of saving land and external environment "do not bring light pollution to surrounding buildings and do not affect the sunshine required by surrounding residential buildings". In the evaluation, the first thing to consider is whether to use high reflection mirror aluminum alloy decorative exterior wall or glass curtain wall; Whether the outdoor landscape light is directly into the air, etc. The supporting materials to be submitted include drawings, design descriptions and inspection reports of the day provided by the design unit. In addition, there are also relevant requirements for certification materials, such as the spatial relationship between surrounding residential buildings and new projects through the general plan; When it is necessary to adopt glass curtain wall design, the light pollution caused by the curtain wall to surrounding buildings shall be provided in relevant design documents and analysis reports. It can be said that the evaluation points and requirements of the test materials explain the provisions of the green building evaluation standards.

4.2 Design method

During the BIM -based green architectural design process, professionals from various tasks such as designers, engineers and other types of work participated in each design process, and coordinated people to provide a basis for decision -making. In different design stages, the role and importance of design participants are constantly adjusted. Figure 1 lists the development of the main participants in the design of the BIM -based green building design.

The concept design almost depends on the knowledge and experience of architects in conventional design. After the plan is formed, it is passed on to other members of the design team for refinement and analysis. If the analysis results do not meet the construction goals, the plan should be modified according to the feedback to form an alternative plan before analyzing. After the project is finalized, it takes a lot of time to deepen the design and drawing construction drawings. This can be clearly seen from Fig. 2.

4.3 Design evaluation and influencing factors

An effective evaluation must first establish an evaluation index system, which is a unified scale to compare and measure various factors. The goal itself is a description of the general effect that can be achieved in any system. Generally speaking, this description is abstracted and blurred, and does not include conditions and measurable values that are directly used as the basis of assessment. The construction of the evaluation index system, as the requirements for the reasonable implementation of the entire evaluation, must follow three basic principles, namely:

Target -oriented: First explain the evaluation requirements and target orientation, the goal as the center of the evaluation indicator system, and guide the evaluation indicators to be closer to the direction of real and comprehensive behavior. The guidance principle requires the value evaluation direction of each indicator in the system to be equal and consistent with the goals.

Reasonable structure: After the overall goal is clear, the next step is to form a reasonable indicator hierarchical structure. The indicators of each layer of the system should be unique, complete and relatively independent, to avoid each other or overlap.

The indicators are the same: The final evaluation is the comparison of the indicator and the system factors. The evaluation indicators should adopt unified or recognized concepts and standards as much as possible, eliminate or correct uncertain factors and inconsistent factors, so that the evaluation indicators will always penetrate the system, similar to the evaluation model.

It is mainly composed of design quality problems and related influencing factors, as shown in Fig. 3.

This article proposes a comprehensive meteorological indicator, that is, human comfort indicators, and its expression method is shown in 8:

$$D = f(T) + g(U) + h(V)$$

6

In the formula, D is the comfort index of the human body; T is the average daily temperature, and the unit's degree Celsius; U is a daily average relative humidity, the unit is%; V is the average daily wind speed, and the unit is M/S. It is recommended to use the temperature index to predict the comfort of the human body and the relationship between the temperature index and the indoor temperature. It can be expressed as a formula 9:

$$E_t = T_d - 0.55 \times (1 - R)(T_d - 58)$$

7

When using the support vector machine algorithm to predict the modeling, the basic idea is: the input space X in the input space is mapped to the high -vitamin symbol space through non -linear mapping ϕ (x), and then the high -dimensional linear space is returned.

$$y = f(x) = w^T \phi(x) + b, b \in R$$

8

The maximum value of the ai solution function:

$$Q(a) = \sum_{i=1}^{n} a_i - \frac{1}{2} \sum_{i,j=1}^{n} a_i a_j y_i y_j (x_i \cdot x_j)$$

9

Here is a nuclear function K to achieve non -linear transformation. The nuclear function meets K (xi, XJ) = ϕ (xi) ϕ (yj).

$$Q(a) = \sum_{i=1}^{n} a_i - \frac{1}{2} \sum_{i,j=1}^{n} a_i a_j y_i y_j \times K(x_i \cdot x_j)$$

10

From the literature knowledge, it can be seen that if the prior knowledge of the model is lacking, the SVM algorithm based on the radial base function (RBF) is better than other nuclear functions. The mathematical formula is:

$$K(x_i, x_j) = \exp\left[-\frac{(x_i - x_j)^2}{\sigma^2}\right]$$

11

From the data set collected by the experiment, 200 data groups are selected as a sample set in the sequential order, and the other 25 data groups are used as prediction sets. The prediction results of different models are compared to Fig. 4.

According to the experimental data in Table 3, the model prediction results will be affected by many factors, including training methods and modeling methods.

Table 3
Comparison of indoor environmental parameter modeling results

Modeling method	Number of iterations	Average error rate
APSO-SVM	58	6.45%
APSO-FKNN	113	8.51%
AGA-SVM	99	10.67%
AGA-FKNN	152	13.58%

4.5 Energy consumption analysis of green buildings

Use Ecotect green building performance simulation software to analyze the annual energy consumption and monthly discomfort hours of the building, and calculate the discomfort caused by energy consumption each month (see Fig. 5). See Table 4 for the calculation results.

Table 4
Orthogonal test table and test results

No.	Window to wall ratio A	Wall heat transfer coefficient B ($W/m^2 \cdot K$)	Window heat transfer coefficient c ($W/m^2 \cdot K$)	Roof heat transfer coefficient D ($W/m^2 \cdot K$)	Energy consumption index (kW*h)
1	0.17	0.93	5.56	0.72	4551.77
o	0.17	0.84	4.75	0.88	5657.41
3	0.17	0.61	3.23	1.11	6737.71
4	0.33	0.91	4.75	1.11	4470.77
5	0.33	0.84	3.23	0.72	5075.25
6	0.33	0.61	5.56	0.88	4056.16
7	0.50	0.93	3.23	0.88	5381.89
8	0.50	0.82	5.56	1.11	5169.79

5. Conclusion

The energy consumption of public buildings is relatively high due to their functions and characteristics. On the other hand, people's pursuit of architectural forms is diverse, and the requirements for intelligent level and use of buildings are higher and higher, and the requirements for building construction technology are more and more complex. Therefore, in the face of the increasing building forms and construction requirements, the traditional two-dimensional expression of architectural design concept is insufficient. Based on this background, this paper combines machine learning technology and BIM Technology in the design of green public buildings. BIM and machine learning are introduced in the architectural design process to break the barriers between various disciplines. The design method has certain scientific, systematic, progressiveness and operability, and plays a certain role in expanding and improving the green building design theory in China.

Declarations

Compliance with Ethical Standards

Conflict of interest

The authors declare that they have no conflict of interests

Ethical approval

This article does not contain any studies with human participants performed by any of the authors.

Data Availability

Data will be made available on request.

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Figures

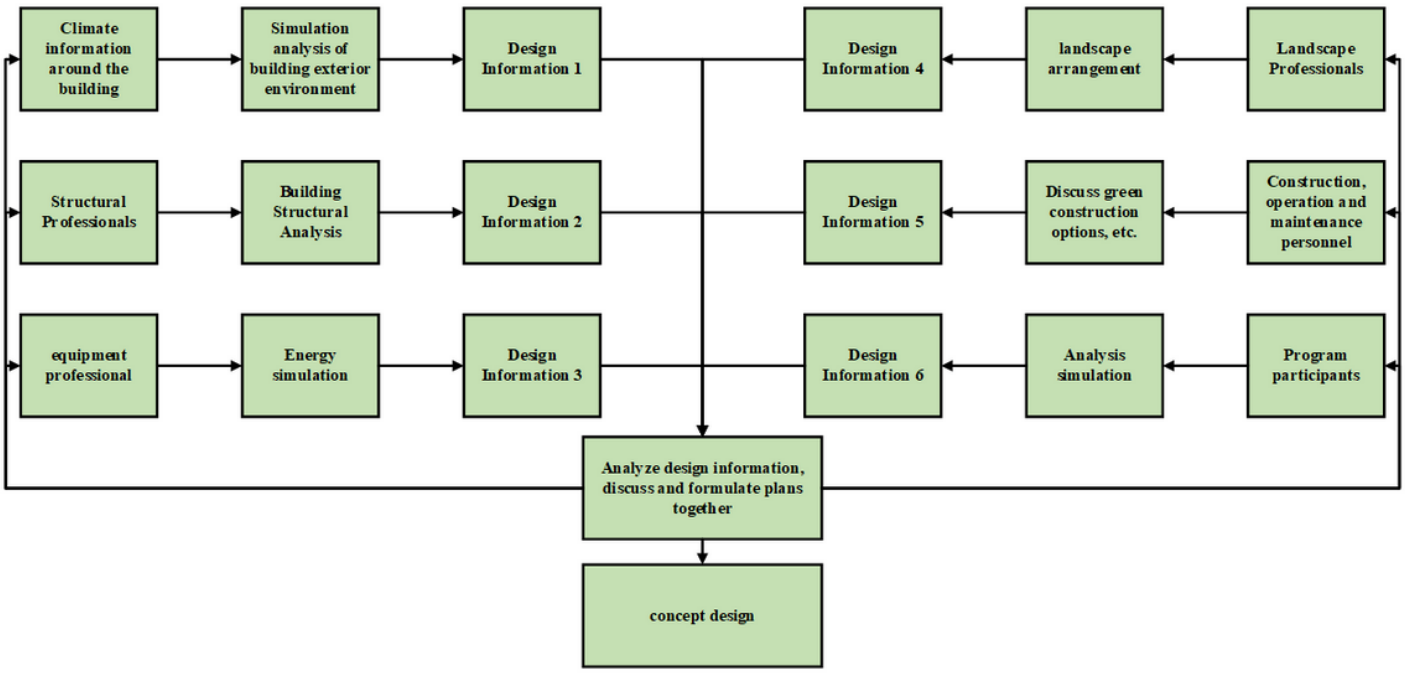

Figure 1

Determination of the concept design solution under multi -party participation

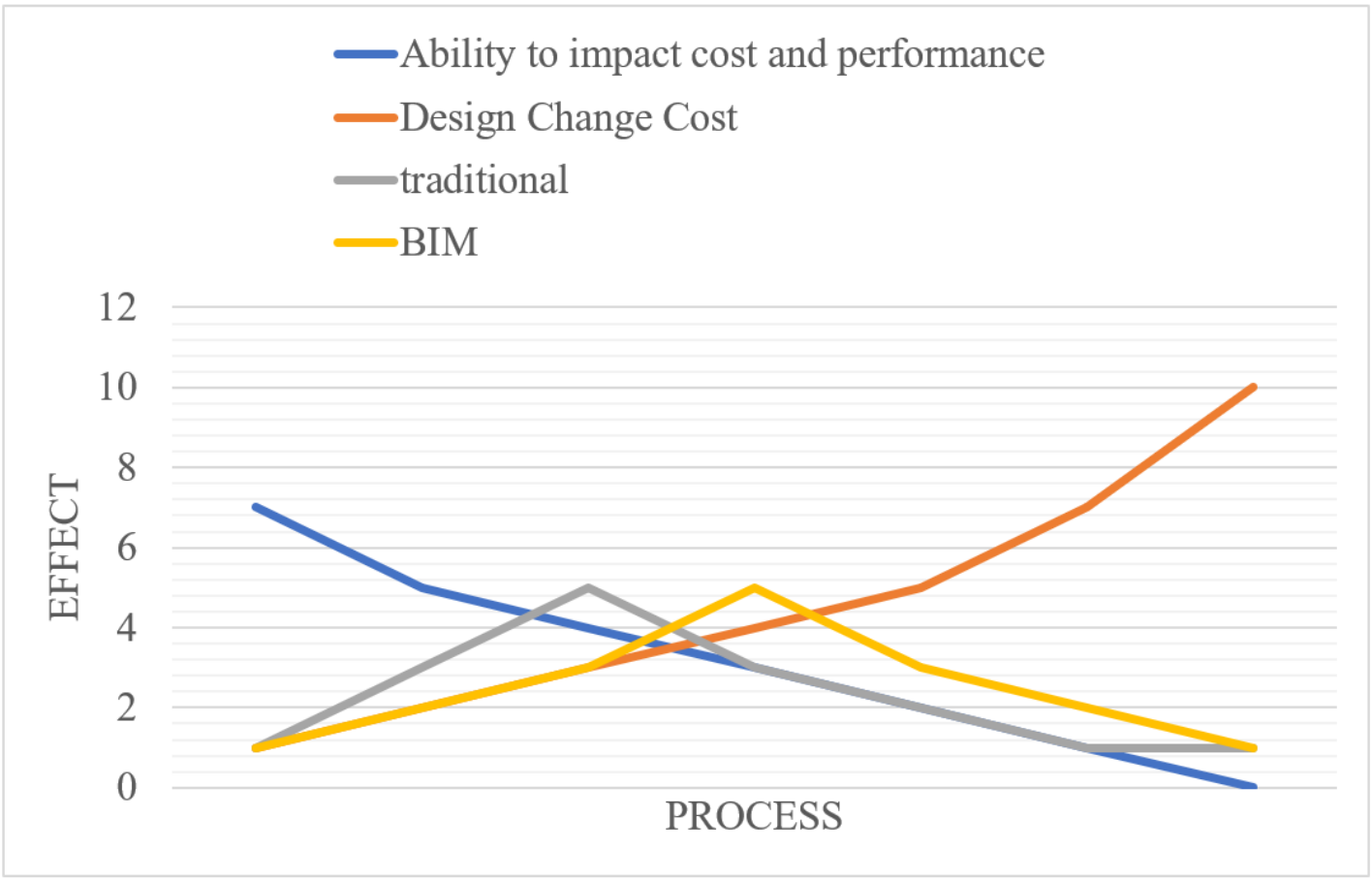

Figure 2

The relationship between cost changes and current design stages

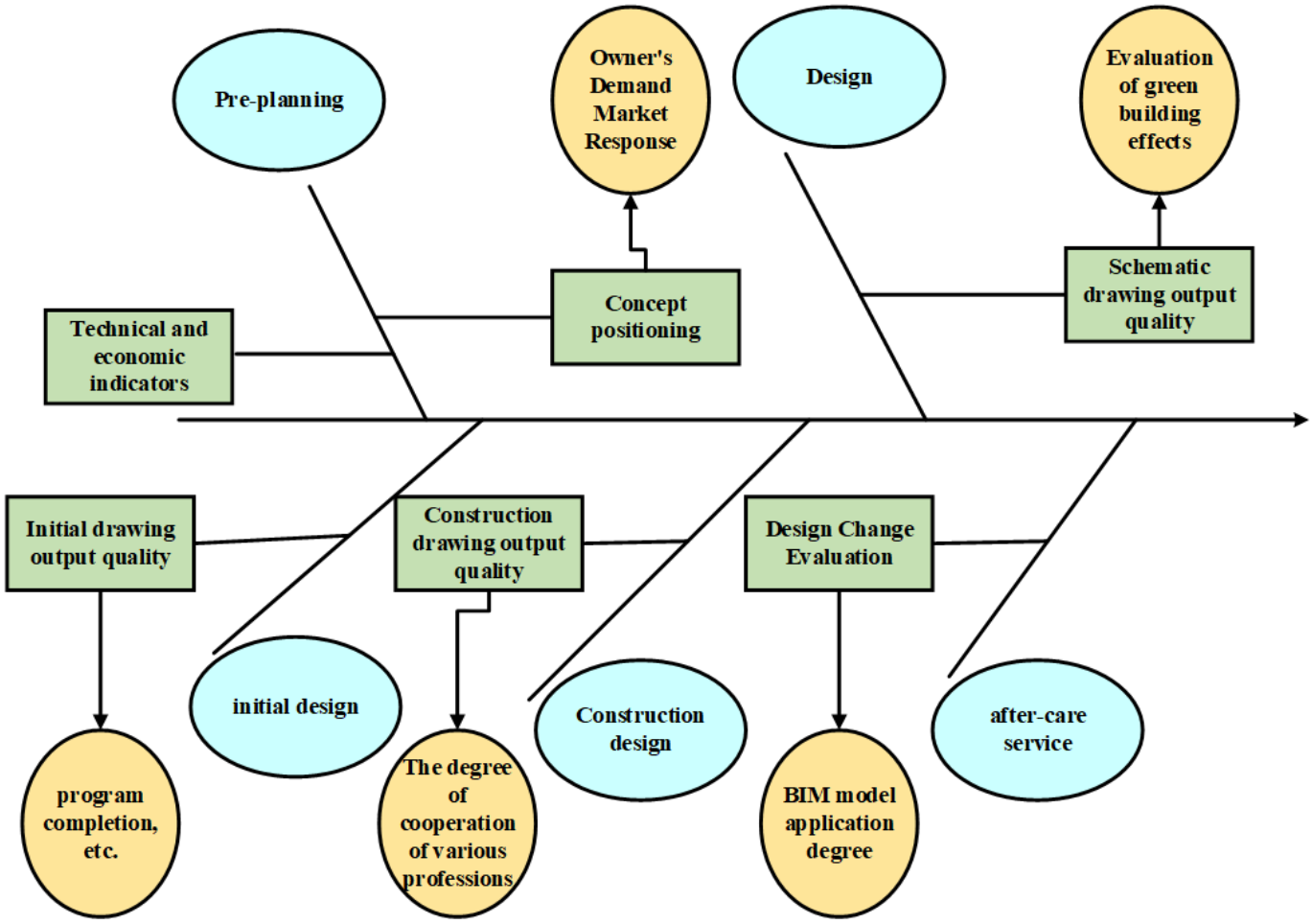

Figure 3

Green architectural design quality affects element fish bone map

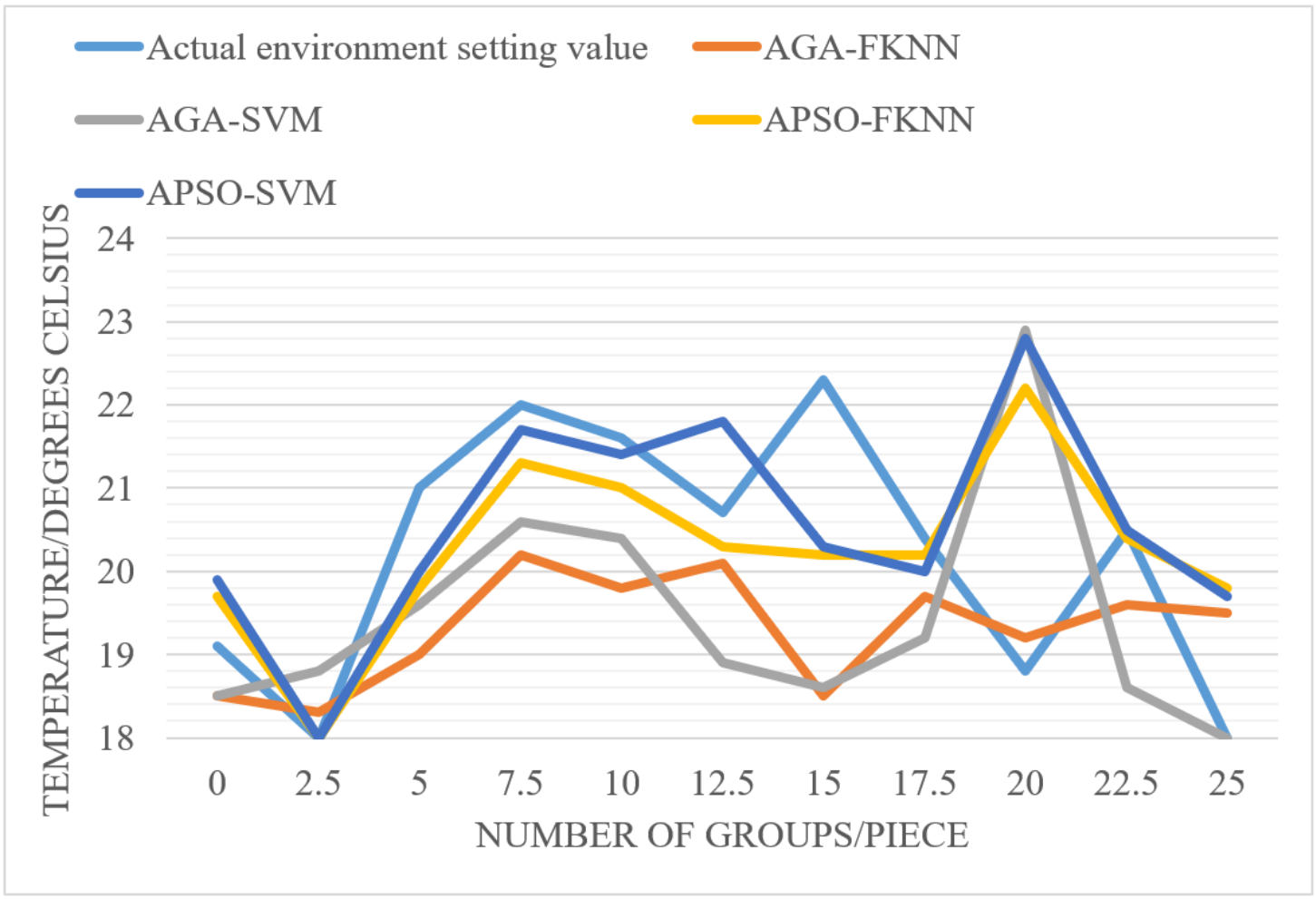

Figure 4

Comparison of prediction results of different models

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Figure 5

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