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Research paper

Research on project cost control of construction engineering contracting enterprises based on owner satisfaction in China

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Abstract: The profit margin of construction enterprises has been continuously declining over the past few years, and the competition for contracts among construction enterprises turns out to be increasingly fierce. Construction contracting enterprises should consider the profitability of the construction contracting enterprise and its ability to continuously obtain orders when setting cost budget targets for project management departments. Thus, a dual objective decision-making model is built in this study, minimizing overall construction costs and maximizing owner satisfaction to clarify the contracting conditions of the project management department and facilitate decision-making optimization of cost and owner satisfaction goals. Moreover, the actual effect of the proposed model method is verified through case calculations. As indicated by the results, under the premise of maximizing owner satisfaction, the model optimization cost is lower than the actual cost that has already occurred. Furthermore, it conforms to the goal of maximizing owner satisfaction while fulfilling the goal of minimizing engineering costs.

Keywords: construction project contracting enterprise, cost control, owner satisfaction, double objective decision-making

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1. Introduction

The profit margin of construction enterprises has been declining recently, and the competition for contracts among construction enterprises has become progressively intensified. At present, construction engineering contracting enterprises in China generally use project manager contracting as an important means to motivate internal project teams to complete the performance of engineering contracting contracts. This business model places greater stress on stimulating project management departments to strengthen cost management, but generally lacks effective methods to coordinate owner satisfaction management. It is noteworthy that construction project contracting enterprises should maximize their economic benefits through cost control while fulfilling their obligations [1]. Besides, construction engineering contracting enterprises should be capable of continuously obtaining orders from owners, and owner satisfaction can determine the industry reputation and influence of the enterprise, which directly affects the bidding ability of the enterprise. Accordingly, cost control and owner satisfaction are the two core elements of construction project contracting enterprises in market competition. When formulating the cost budget goals in the project manager contract agreement between the construction engineering contracting enterprise and the project management department, it is necessary to comprehensively consider the cost goals and the owner satisfaction goals.

At present, researchers' analysis of cost control in construction enterprises mostly focuses on cost control methods. For example, Keng and Adzhar (2022) analyzed the cost control methods employed by contractors in road projects in accordance with a survey questionnaire and proposed possible strategies. The cost control practices of road projects include record keeping, financial reporting, valuation of construction in progress, work planning, approximate quantity method, on-site cost control, and daily labor control [2]. Akhil and Das (2019) believe that in mechanical and electrical engineering, India mostly controls costs through planning software and on-site management, and suggest that more technologies such as value engineering, supply chain management, and budget control can be developed to control costs [3]. Notably, construction contractors are implementing a considerable number of cost control techniques/tools (CCTT) [4], among which Work Breakdown Structure (WBS), Earned Value Analysis (EVA), and reconciliation of actual and forecasted labor/factory and materials [5–7] have been the most common. There is also the use of new software and prediction techniques, such as linear regression/time series [7–9]. S-curves, budget control, and standard cost calculations are also used in CCTT [8–10]. However, these studies generally emphasize absolute control over cost components and do not involve decision-making in the process of project cost budgeting, nor do they propose effective budget cost decision-making methods.

In the 1960s, Dardozo first proposed the concept of user satisfaction, i.e., the origin of this concept in the field of marketing. Since then, user satisfaction has aroused wide attention in the marketing community and has been developed through the theoretical construction of multiple researchers [11]. The research on owner satisfaction by domestic and foreign scholars has primarily focused on the evaluation of owner satisfaction [12–19], using owner satisfaction as an important criterion for measuring the success of engineering projects [20–24], and the factors that affect owner satisfaction [25–29]. For example, Li (2018) used a BP neural network to analyze the evaluation indexes of the effect of the entire process of turnkey engineering on customer satisfaction, to guide construction enterprises in improving the satisfaction of owners with turnkey engineering [30]. Cho and Kim (2022) studied the construction management (CM) company's goal of maximizing owner satisfaction by improving work quality using the Kano model [31]. In recent years, there has been increasing research on customer satisfaction management in the construction industry, and it has gradually been realized that the relationship between contractor control over schedule, quality, cost, and owner satisfaction is becoming increasingly close [32].

In brief, despite considerable research on cost control and owner satisfaction in the construction field, there has been insufficient research ideas to coordinate the two objectives. Notably, under the context of the project manager contracting system, how construction engineering contracting enterprises can formulate project cost goals while considering owner satisfaction has been rarely investigated. Moreover, the research methods employed in existing literature on cost prediction (e.g., neural network algorithms) are difficult to master and convenient for engineering contracting enterprises, and cannot be effectively applied to practical projects. In this study, how construction engineering contracting enterprises set scientific and reasonable project cost budget goals for the project management department in the project manager contracting agreement is primarily explored. By establishing a cost budget optimization decision-making model that meets the premise of owner satisfaction, the goal is to maximize owner satisfaction and minimize engineering costs.

The rest of this study is organized as follows. In Section 1, existing research on engineering cost control and owner satisfaction in the construction industry is comprehensively reviewed. In Section 2 representative building types are selected, and the cost of construction projects is extracted. In Section 3, the weight of cost decision indexes is determined using the QFD method. In Section 4, a dual objective decision-making model is built to minimize engineering costs and maximize owner satisfaction. In Section 5, the model is validated, and the results are investigated through practical cases. Lastly, a conclusion of the entire study is drawn.

2. Cost extraction of construction projects

Due to the numerous structural types, standards, and cost components of construction projects, the structural types and cost components should be analyzed for ease of research, the building forms and cost components that account for a large proportion should be selected, and the calculation model should be simplified appropriately.

As the main form of urban residential buildings in China, high-rise residential buildings have a construction area far higher than other types of buildings under construction. Moreover, high-rise residential buildings have characteristics such as fewer structural standards and complex types, relatively simple structural features, and have certain representativeness. Thus, for the convenience of calculation and application, the standard high-rise residential building structure type of reinforced concrete shear wall structure, which is relatively more standard and high-frequency, serves as the research object.

From the perspective of cost composition of construction projects, material costs comprise concrete costs, steel bar costs, secondary main material costs, and other auxiliary material costs. To be specific, concrete and steel bar costs have a large usage and account for a large proportion of cost. As revealed by existing research, the cost of steel bars and concrete accounts for about 60% of the material cost and approximately 35% of the total cost of construction projects [33]. There are a wide variety of other main and auxiliary materials, with cumbersome statistics and a small proportion. So only the cost of concrete and steel bars is considered in the material cost. Similarly, the cost of machinery only considers the cost of tower cranes. Other cost elements that have not been considered can be introduced as needed in subsequent applications. Table 1 lists the cost composition of construction projects after simplification.

Table 1. Simplified cost composition of construction projects

Tost Category	Cost Structure	Quantification	Variable Quantity	Notes
Direct Engineering Cost	Labor Cost	Total Labor Consumption	Unit Price of Each Labor Service	Sum of Products
	Material Cost	Quantity of Steel Bars and Concrete	Unit Price of Steel Bars and Concrete	Sum of Products
	Machinery Cost	Quantity of Tower Crane Shift	Unit Price of Tower Crane Shift	Sum of Products
Measure Expense	Template Cost	Quantity of Template	Unit Price of Template	Sum of Products
	Temporary Facility Cost	Floorage	Rate	Sum of Products
Indirect Cost and Taxes	Rule Fee	Rule Fee		Fixed Value
	Enterprise Management Fee	Contract Amount × Enterprise Management Fee Rate		Fixed Value
	Taxes	Contract Amount × Tax Rate		Fixed Value

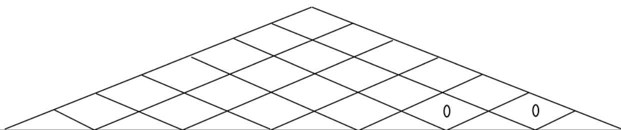
3. Using the QFD method to determine the weight of cost decision indexes based on owner satisfaction

This study attempts to employ the QFD (Quality Function Deployment) method in the screening and analysis of key indexes of owner satisfaction in the construction industry, linking owner satisfaction and cost element variables. The technical or quality characteristics based on the satisfaction needs of construction industry owners are determined by listing the functions that satisfaction characteristics and cost elements can play, On that basis, the weights of decision variables that have a strong relationship with owner satisfaction in cost decision-making can be obtained.

In the study, for the convenience of analysis, it is assumed that the variables (price and grade) of each cost decision element are linearly correlated with the quality of the material (or service), i.e., the higher the unit price of the higher quality cost element, the lower the unit price of the lower quality cost element, and vice versa. In general construction cost procurement, this assumption is consistent with reality when decision-makers are not affected by other interests.

The satisfaction points of owners are listed [34], and a survey questionnaire "Survey Questionnaire on the Weights of Owner Satisfaction Indexes in the Construction Engineering Contracting Industry" is generated in accordance with the four major categories of project construction progress, safe and civilized construction, construction costs, and construction quality that owners are concerned with. A total of 44 survey questionnaires are distributed to employees of owner units in the construction engineering contracting industry, of which 42 are valid. According to the statistics and organization of the owner satisfaction survey questionnaire, the significance level corresponding to the owner satisfaction needs is obtained (Fig. 1). The smaller the score, the less important the index is, and 9 suggests the most important.

Related Values	
Strong Correlation	9
Moderate Correlation	3
General Correlation	1
Irrelevance	0



Cost Control Measures / Owner Satisfaction Needs	Importance Degree	Labor Employment Level	Material Price Level	Price Level of Mechanical Equipment	Template Price Level	Price Level of Temporary Facilities	The Level of Enterprise Management Fee, Rule Fee, and Taxes	Share Proportion of Project Management department in The Contract Agreement
Construction Schedule	7	9	1	9	3	0	0	3
Display Sensory Effects on Construction Site	5	0	0	3	3	9	3	3
Safety Accidents and Adverse Effects	9	3	0	0	0	9	0	3
Rework, Negotiate Changes, Add Items, etc	7	3	1	0	0	0	0	3
Structural Verticality and Deviation	6	9	3	0	9	0	0	0
Clean, Tidy and Flawless Structural Surface	6	3	3	0	9	0	0	0
Structural Strength Test Meets the Standard	5	1	9	0	3	0	0	0
Absolute Weight		188	95	78	159	126	15	84
Relative Weight		0.252	0.128	0.105	0.213	0.169	0.020	0.113

Fig. 1. HOQ for cost control of construction projects

Fill in the satisfaction needs of the owner on the left side of the house of quality (HOQ) and fill in the significance level. Fill in the cost decision indexes corresponding to the cost components in Table 1 on the top of the HOQ, and indicate their interrelationships. In addition, the proportion of the project management department's share in the contract agreement signed between the construction engineering contracting enterprise and the project management department should also be considered. Fill in the relationship matrix between owner satisfaction and cost decision indexes in the HOQ, and its value represents the degree of relationship between owner satisfaction and cost decision indexes. The closer the relationship, the larger the value. 9 is strong correlation, 3 is moderate correlation, 1 is general correlation, and 0 is not related. After calculation, the absolute and relative weights of each cost decision index can be obtained, as shown in Fig. 1.

From Fig. 1, it can be seen that the calculation weight of enterprise management fee, rule fee and taxes is much lower than other indexes. Based on practical experience, enterprise management fee, rule fee, and taxes are all fixed values, and their effect on owner satisfaction as a decision-making index is indeed relatively weak. Accordingly, removing this index and recalculating the above calculation to obtain a new weight is shown in Table 2.

Table 2. Revised cost decision index weights

Order Number	Cost Decision Indexes	Absolute Weight	Relative Weight
1	Labor Employment Level	188	0.257
2	Material Price Level	95	0.130
3	Price Level of Mechanical Equipment	78	0.107
4	Template Price Level	159	0.218
5	Price Level of Temporary Facilities	126	0.173
6	Share Proportion of Project Management department in the Contract Agreement	84	0.115

4. Model building

To solve the problem of balancing cost objectives and owner satisfaction objectives, with the goal of minimizing cost and maximizing owner satisfaction, an objective function is established, including cost function and owner satisfaction function.

$$\text{MinCost} = \sum_{i=1}^{6} \left(P_i^k \cdot S_i\right) + W \cdot r \tag{4.1}$$

$$\text{MaxCSR} = \sum_{i=1}^{7} (U_i \cdot V_i) \tag{4.2}$$

Where, MinCost is the minimum cost objective function; MaxCSR is the objective function for maximizing owner satisfaction; P_i^k is the unit price of the k-th level of the i-th cost element; S_i is the quantity of the i-th cost element; W is the charging base for fixed rate cost items; r is the charging ratio of fixed rate cost items; U_i is the grade relationship coefficient of the i-th cost element; V_i is the category relationship coefficient of the i-th cost element; i is the cost element number; k is the level corresponding to the cost element, $k \in \{1, 2, 3\}$.

The cost element number i has different values in the two objective functions. In the cost objective function, the cost elements include six items: labor, concrete, steel bars, templates, tower cranes, and temporary facilities; In the owner satisfaction function, besides the six items mentioned above, it also includes the proportion of the project management department in the contract agreement, such that i is 7. The value of k corresponds to the price and quality level of the cost elements in the procurement decision. In this model, the default is that the price is strictly positively correlated with quality. When k is taken as 1, 2, and 3, respectively, the price of the cost element is the lowest, moderate, and highest, and the quality is low, medium, and high-end.

The $W \cot r$ in the cost objective function refers to a fixed value in the cost item, including enterprise management fees, rule fees, and taxes. It does not affect the decision objective of minimizing cost and can be directly removed from the cost function. The cost objective function is simplified as:

$$\text{MinCost} = \sum_{i=1}^{6} \left(P_i^k \cdot S_i \right) \tag{4.3}$$

In the owner satisfaction function, the category relationship coefficient V_i represents the weight of the effect of different cost elements on owner satisfaction, indicating the influence of different category cost elements on owner satisfaction indexes. The grade relationship coefficient U represents the effect of different grades of cost elements on the owner satisfaction index, indicating the direct effect of quality differences in different grades on owner satisfaction. For ease of calculation, the grade relationship coefficient U can be set to take values from a set of discontinuous values, namely:

$$U_i = 1 + (k - 2)/5 \tag{4.4}$$

After trial calculation, when choosing to purchase high-end cost elements ($k = 3$), U is 1.2. When selecting intermediate cost elements for procurement, ($k = 2$), U is 1. When choosing to purchase low-grade cost elements, ($k = 1$), U is 0.8, $U_i \in \{0.8, 1, 1.2\}$.

5. Example validation

5.1. Project overview

The B project undertaken by A Construction Engineering Company in Hebi City, Henan Province is a high-rise residential community with standard floors above the ground and a reinforced concrete shear wall structure. Select one of the completed and settled buildings, Building 1, as an example for verification. Building 1 has a total of 17 floors, with a total construction area of 18983.6 square meters and a total construction period of 18 months. Table 3 lists the organization of relevant cost element information.

5.2. Modeling

Substitute the case data and cost decision index weights into equations (4.3) and (4.2) to obtain the cost function and owner satisfaction function for this case:

$$\begin{aligned} \text{MinCost} = {} & 18983.6 \cdot P_1^k + 9418.92 \cdot P_2^k + 969.45 \cdot P_3^k + \\ & + 12 \cdot P_4^k + 34578.85 \cdot P_5^k + 18983.6 \cdot P_6^k \end{aligned} \tag{5.1}$$

Table 3. Cost element Information of building 1

Order Number	Classification	Quantity		Price				
		Unit	Value	Unit	Actual Value	High-grade Value	Mid-grade Value	Low-grade Value
1	Labor Employment	m^2	18983.6	Yuan	531	600	500	400
2	Concrete	m^3	9418.92	Yuan	413.23	500	440	400
3	Rebar	t	969.45	Yuan	4590	4700	4300	4200
4	Tower Crane	Month	12	Yuan	6500	8000	7000	6500
5	Formwork	m^2	34578.85	Yuan	25	40	25	20
6	Temporary Facilities	m^2	18983.6	Yuan	38.5	50	35	25
7	Share Proportion of Project Management Department in the Contract Agreement	%	40	%	40	60	50	40

Note: Due to the multiple specifications and classifications of different cost elements, prices are calculated based on the average. The price of steel bars fluctuates frequently, and its value is calculated based on the average of the information prices of consecutive months during the construction period. The tower crane adopts QTZ125, which is commonly used in this type of project.

$$\begin{aligned} \text{MaxCSR} = U_1 \cdot 0.257 + U_2 \cdot 0.13 + U_3 \cdot 0.13 + U_4 \cdot 0.107 + \\ + U_5 \cdot 0.218 + U_6 \cdot 0.173 + U_7 \cdot 0.115 \end{aligned} \tag{5.2}$$

In the above-mentioned case project, the concrete aspect is affected by factors (e.g., nighttime construction, urban management law enforcement, and the location of the nearest commercial concrete station). Strategic partners have been negotiated in advance, and the price is moderate. Thus, concrete does not need to participate in decision-making, and U_2 is set to 1. Because the steel bars are located inside the structure without being exposed, their grade has a minimal effect on the satisfaction of the owner of Party A, so U_3 is chosen as 0.8. For tower cranes and temporary facilities, as the owner is a public institution and places great significance on safe and civilized construction, U_4 and U_6 are selected as 1.2. The sharing ratio of the project management department in the contract agreement is forcibly limited to 0.4 by the company; it cannot be regulated. Accordingly, $U_7 = 0.8$, there is no need to participate in decision-making, and the numerical value can be substituted. After some decision options are limited, the above two objective functions are transformed into:

$$\begin{aligned} \text{MinCost} = 18983.6 \cdot P_1^k + 9818.92 \cdot 440 + 969.45 \cdot 4200 + 12 \cdot 8000 + \\ + 34578.85 \cdot P_5^k + 18983.6 \cdot 50 = 18983.6 \cdot P_1^k + 34578.85 \cdot P_5^k + 9261194.8 \end{aligned} \tag{5.3}$$

$$\begin{aligned} \text{MaxCSR} = U_1 \cdot 0.257 + 1 \cdot 0.13 + 0.8 \cdot 0.13 + 1.2 \cdot 0.107 + U_5 \cdot 0.218 + \\ + 1.2 \cdot 0.173 + 0.8 \cdot 0.115 = U_1 \cdot 0.257 + U_5 \cdot 0.218 + 0.662 \end{aligned} \tag{5.4}$$

5.3. Model solution

For the solution of the above dual objective function, the reference objective method can be used for solving. Set a bottom-line value for the owner satisfaction objective function and convert it into a constraint condition. The project in this case has set an owner satisfaction goal of no less than 1.1, converting the dual objective function into a single objective function. The objective function is Eq. (5.3), with the following constraints:

$$U_1 \cdot 0.257 + U_5 \cdot 0.218 + 0.662 \geq 1.1 \tag{5.5}$$

The relationship between U_i and $Pk\ i$ is listed in Table 4.

Table 4. Correspondence between U_i and $Pk\ i$

k	U	P_1^1	P_1^2	P_1^3	P_5^1	P_5^2	P_5^3
1	0.8	400			20		
2	1		500			25	
3	1.2			600			40

A coordinate map is generated based on the constraint conditions as follows (Fig. 2).

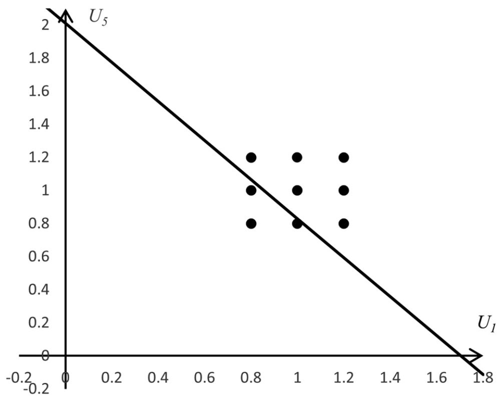


Fig. 2. Function diagram satisfying the constraint conditions of owner satisfaction

As depicted in the above figure, when $U_i \in \{0.8, 1, 1.2\}$, the six coordinate points composed of U_1 and U_5 meet the constraint conditions, and the point closest to the line is the optimal solution, i.e., $U_1 = 0.8$, $U_2 = 1.2$. These 6 values can also be converted into $Pk\ i$ according to Table 4, and $Pk\ i$ can be substituted into Eq. (5.3) to obtain the optimal solution (Table 5).

On the premise that the satisfaction of the owner is not less than 1.1, the cost of using low-end labor and high-end formwork is minimized, with a minimum cost of 1741505 yuan. In accordance with the actual value in Table 3 (the actual price value at the time of case construction), the actual cost is calculated as 20095587 yuan. The model optimization cost is lower than the actual cost that has already occurred, saving 2680282 yuan per building.

Table 5. Objective function solution

Order Number	U_1	U_5	P_1^1	P_1^2	P_1^3	P_5^1	P_5^2	P_5^3	*Cost*
1	0.8	1.2	400					40	17415305*
2	1	1		500			25		19086750
3	1	1.2		500				40	19441305
4	1.2	0.8			600	20			20994565
5	1.2	1			600		25		21112750
6	1.2	1.2			600			40	21467305

Note: * represents the optimal solution.

It is noteworthy that the minimum cost determined using the above model is only the total of the main cost items included in the decision. If you want to achieve the overall structural cost target, other non-major cost items should be only multiplied by the corresponding quantity based on the actual reasonable price, and then the major cost items should be added. The variable values calculated by the model should be used as guidance for cost item procurement decision-making activities in actual construction before actual construction, and the effects should be observed and feedback obtained. Only in this way can this model truly solve and guide the practical problems studied.

6. Conclusions

In this study, the problem of a lack of scientific tools for coordinating costs and owner satisfaction in construction enterprises is addressed. A dual objective decision-making model is proposed and then transformed into a single objective function based on the reference objective method for solution. This responds to the problem while serves as a simple and easy-to-understand decision-making model tool for construction enterprises and project management departments. The effectiveness and applicability of the proposed model have been verified through practical case calculations. This study conforms to real-life cases of enterprises that have been extensively present in the industry and lack reasonable solutions. In the existing environment, this issue will increasingly constrain the profitability and survival ability of enterprises. Thus, this study has practical guiding significance for construction enterprises to solve the above problems and carry out more scientific cost management. The main conclusions of this study are elucidated in the following:

1. The research method is simple and easy to use. One of the focuses of this study is to extract and solve problems, combining scenarios where construction practitioners use models to solve problems, and always focusing on the comprehensibility and usability of model tools. This study is closely combined with reality, and the concise and easy-to-use model makes it easy for market decision-makers to get started, and can be easily adjusted according to the actual situation, greatly increasing the applicability and popularity of the model.

2. The model can be adjusted and optimized timely. When the proposed model is being built, simplification is made without affecting the core logic and calculation methods of the model. In practical use, there have been inevitably issues with the applicability of models in different environments. Thus, adjustments, supplements, and verifications can be conducted to index selection, weight setting, contract scenarios, cost elements, and bottom-line values of objective functions based on the actual situation to obtain model parameters suitable for the building type. However, the solution approach of this study remains unchanged.
3. Labor and templates are key elements of construction. This study suggests that at least one item of labor and templates cannot serve as low-end products. The above-mentioned result is highly consistent with the actual situation. The labor team is the most critical element for engineering quality, speed, and safe and civilized construction, with high-quality labor teams being the core element. The grade of the template directly affects the structural output of labor work. Under the normal labor level and construction conditions, whether the template is durable, flat, and smooth can be a critical factor for the dimensional deviation and surface appearance of the building structure. The mutual verification between the calculation results of the model examples and the actual situation well demonstrates the practical utility of this model.
4. The methods for calculating the weight of decision indexes and solving models are flexible and varied. When calculating the weight of decision indexes using the QFD method, given the usage scenarios of the QFD method, the drawn conclusions may be affected and lead to bias. Accordingly, the Analytic Hierarchy Process (AHP) can be chosen to calculate the weight of decision indexes again and perform two-phase verification. Finally, make corrections based on actual situations and use them. Besides the reference objective method, the linear weighted sum method can also be employed to solve the model. To be specific, the Delphi method or the analytic hierarchy process is followed to give weight to the two objectives, respectively, the weight of the two objectives is multiplied, respectively, and the sum is added, such that the double objective function serves as a single objective function to seek the extreme value. The determination of the weighted value of the linear weighted sum method requires considerable empirical data support, and more adjustments should be made for various building structures in later applications. Compared with the two methods, the reference target method is relatively easier to execute.
5. Research deficiencies. Due to limited conditions, more detailed data are difficult to obtain, and this study is subjected to a limitation, i.e., the inability to incorporate more individual buildings and building types into case data for verification. In order to make the model better serve people's everyday work in managing investment projects, the author will continue to try to explore testing the model on other types of buildings in other markets in the future. In terms of owner satisfaction needs, more factors can be considered, such as the demand for "green" certification in Europe. In addition, due to limitations in data and other factors, a sensitivity analysis is not conducted after the case calculation, and a quantitative analysis of the adopted variable weights is conducted again to guide the improvement and practical application of the model.

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