Research on life cycle cost control model of prefabricated building based on system dynamics

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Abstract: This paper takes BIM as the platform and system dynamics as the research method, establishes the life cycle cost control model of prefabricated buildings, draws causality diagram and flow inventory diagram by Vensim software, obtains the main influencing factors of assembly building cost control, and then gives the cost control measures. In this paper, BIM, prefabricated building and system dynamics are combined to study the cost control of prefabricated building from a new perspective, and reasonable suggestions are given to provide new ideas for promoting the development of prefabricated building in China.

1. Introduction
Under the background of rapid changes and development of China's construction industrialization, prefabricated buildings stand out with its unique advantages of green environmental protection, high efficiency and high quality. At present, the development of prefabricated building in China is not mature, the technology is not comprehensive, the construction is complex, and the investment cost is large. These factors seriously hinder the development momentum of prefabricated building. The emergence of BIM Technology has put forward new ideas for the cost control of prefabricated buildings. However, due to the rise of BIM Technology and prefabricated buildings in China in recent years, there are still problems such as low government support and lack of technical talents.

At present, many scholars have carried out a lot of research on the cost management of prefabricated buildings. Tang Yexi (2020) analyzed the cost of prefabricated buildings from the three stages of component design, production and transportation, construction and installation, and gave corresponding suggestions [1]; Lin Xianzhi (2019) analyzed the application obstacles of BIM Technology in prefabricated buildings, and proposed specific measures to reduce the construction cost [2]; Wang Yingchun (2018) comprehensively analyzed the advantages of BIM Technology, and applied BIM Technology to all stages of the life cycle of prefabricated buildings, which effectively improved the cost management effect [3]. Rao Pingping (2020) took system dynamics as the research method, compared and analyzed the data of BIM engineering projects and those without BIM Technology, and concluded that the application of BIM Technology has brought great benefits to the project [4]. Chen Yan (2017) established a system dynamics model for the cost control of a whole set of matching buildings. Through the simulation and analysis of the cost relationship among various projects through the Vensim software, the key factors affecting the cost were found out, and based on this, the highly targeted measures were proposed to control the cost. Through the existing research of scholars, it is found that scholars have made deep research on BIM Technology, prefabricated building cost control and system dynamics, but
the combination of the three is still very few. Therefore, based on BIM platform, this paper uses the method of system dynamics to explore the factors that affect the cost control from the whole life cycle of prefabricated buildings, draw the corresponding causality diagram, and draw the corresponding flow inventory diagram, and then simulate and put forward targeted cost control measures, hoping to provide some reference for related research.

2. Application advantages of system dynamics in life cycle cost control of prefabricated buildings

a) The core intention of system dynamics is to produce a feedback structure of one or several engineering project system behaviors, so as to provide effective reference for enterprise managers to formulate macro strategy. On the BIM platform, the life cycle cost of prefabricated building is mainly reflected in six stages: preliminary preparation, component design, component production, component transportation, on-site construction and installation, operation and maintenance. The costs in these six stages have mutual influence. We should analyze the cost of prefabricated building from the perspective of the whole process, and system dynamics is from the perspective of the whole process. From the perspective of the whole process, this paper quantitatively analyzes the relationship between the factors affecting the life cycle cost of prefabricated buildings, and according to the simulation results, it provides effective suggestions for the cost control of prefabricated buildings.

b) The most typical cost control theory in system dynamics can simulate dynamically, analyze and control the cost relationship between various projects. BIM Technology has the characteristics of data, simulation and collaboration, which can be well applied in prefabricated buildings, which makes the cost control of prefabricated buildings with high dynamic characteristics. When it is applied in the prefabricated building, the cost control of prefabricated building has the characteristics of high dynamic. This paper combines the three and uses the method of system dynamics to study the cost control of prefabricated building based on BIM, which makes the research more convincing.

3. Construction of system dynamics model for life cycle project cost control of prefabricated building

3.1. Analyze and screen the influencing factors of the cost control of prefabricated construction projects

In prefabricated buildings, the whole life cycle can be divided into three parts according to their different stages, including the preparation stage in advance; the design, production, transportation and installation stage of prefabricated components; and the operation and maintenance stage. The influencing factors of cost control mainly refer to the subjective and objective factors in different stages, including but not limited to human, material, machinery, management, science and technology, environment (natural and social). Because the assembly building project is a complete system, there must be a lot of factors affecting its cost control. This article takes the essence to its dregs, and based on some reasonable principles, it removes the unimportant and non key factors, and shifts the key to the core question. Because the research is based on the BIM platform, the cost factors do not include a series of BIM platforms. Cost of putting into use. Referring to the subdivision method of existing scholars [6-7], the influencing factors of life cycle cost of prefabricated buildings are sorted out and classified. The details are shown in Table 1.

| Increment | Stage | Factor |
|-----------|-------|--------|
| Cost increment in advance | Preliminary preparation stage | The formation rate of preparation cost, land acquisition and compensation cost, bidding fee, equipment purchase cost and preparation cost time |
| Incremental cost in action | design phase | The integrated design level of assembly project, the growth rate of assembly project design cost, the unit time labor cost of assembly project, and the quality of employees |
3.2. Dynamic hypothesis on cost control of prefabricated building

The so-called model is an abstract way to express one or several situations in reality. In order to focus on the research problem better, we simplify the required model. The model established in this paper is based on the following hypotheses:

a) The managers of construction enterprises have a high standard, and all the choices are made under the principle of shortening construction period, saving cost and ensuring quality.

b) The communication between the parties is harmonious and does not consider the level differences between enterprises.

c) Components are produced according to BIM simulation construction demand, there is no excess inventory.

d) BIM operators are of high quality.

3.3. Establishment of model

3.3.1. Causality diagram

According to the needs of this study, we should strictly analyze the influencing factors of prefabricated building cost control mentioned above. On the basis of summarizing the cost control models of relevant scholars, we draw the causal loop diagram of the cost management model of prefabricated building, as shown in Figure 1.
Figure 1. Causality diagram of life cycle cost control model for prefabricated building.

In the software, we can clearly see the cause tree diagram and result tree diagram of each variable. According to different stages, we can draw the following conclusions:

a) Cost generation: in advance: the generation rate of preparation cost is inversely proportional to the prefabricated construction cost; in the event: the generation rate of PC component's design, production, transportation and installation costs changes inversely with the prefabricated construction cost; afterwards, the generation rate of operation and maintenance cost of engineering project is inversely proportional to the prefabricated construction cost.

b) Cost saving: the shortening of construction schedule and material saving are directly proportional to the cost of prefabricated buildings.

We can find the way to control the cost from two directions: reducing the cost and increasing the cost.

3.3.2. Stock flow chart

Through the above causality diagram, we can easily draw the stock flow chart. The advantage of this graph is that it can analyze each variable more accurately and quantitatively, not only by qualitative analysis, but also to clarify the mathematical relationship between variables, and is the basis for the program of each variable builder and specific assignment. The cost of any stage is the corresponding cost increment minus the cost generation rate. From the causality diagram, we can know that the cost change of assembly construction project is composed of two parts, one is the cost generation, the other is the cost saving, and the project cost equals the difference between the two parts. Therefore, generation and saving become the key point of the model. Other factors are just like the stars and the moon, but they only revolve around this core. In order to analyze these two parts more intuitively, we can draw the stock flow chart respectively, as shown in Figure 2.
4. Case analysis

4.1. Project overview
The project is a prefabricated residential building in a residential district of a city, which is contracted by the company. The seismic fortification intensity is designed to be degree 6 and the seismic grade is grade 4. The total building area is 5031.5m², the floor height is 3 meters, and the total building height is 29 meters. The building is 1 floor underground and 8 floors above ground. The construction period is 15 months. The project uses BIM Technology to participate in the whole process of construction.

4.2. Model test and simulation result analysis

4.2.1. Cost control model inspection and parameter setting
In Vensim, the creation of a model is inseparable from the definition of time. Therefore, the first step is to define the time of the model as the next 64 weeks (15 months) with a time step of 1. The initial value of each variable is set and the equation corresponding to each variable is input. The input of the equation must correspond to the stock flow chart established before, and then the model is tested whether the dimension is unified or not.

4.2.2. Cost control model simulation analysis
Input the variable equation to carry out simulation, and the results are shown in Figure. 3.
According to figure 3, there are many factors that affect the cost control of prefabricated building, and these factors are closely linked. Therefore, we can find out the key influencing factors of prefabricated building cost control by changing the value of parameters one by one, and then put forward reasonable and effective measures. Next, we test the cost control model of prefabricated building by changing the management level and integrated design level.

When editing the equation, in order to more intuitively reflect the changing trend of prefabricated construction cost with the change of management level, we test the three variables in the value range [0, 2], and the results are shown in Figure 4.

The three lines in Figure 4 respectively show the trend of prefabricated construction cost of managers at normal management level and after improvement of management level, which shows that project cost decreases with the improvement of management level. The influencing factors of management level mainly include knowledge reserve, practical experience and coordination personnel ability of management personnel. These influencing factors have a positive impact on management level. It can
also be seen from the figure that the impact of management level on project cost is increasingly significant over time.

The level of integrated design can reflect whether the corresponding design work is completed or not. The larger the value, the higher the work efficiency, the easier the corresponding design work can be completed. Therefore, when selecting the value here, select a pair of opposite numbers (-1, 1) and the number 0 representing the normal level, which can intuitively understand the impact of integrated design level on the cost of prefabricated building projects, such as it is shown in Figure 5.

![Figure 5. Cost simulation results of prefabricated building under different integrated design level](image)

Figure 5. Cost simulation results of prefabricated building under different integrated design level

Through figure 5, we can find and draw two conclusions: first, in the process of integrated design level gradually changing from -1 to 1, the cost of prefabricated construction project shows a downward trend, and then we can generalize that the cost of prefabricated building project changes inversely with the level of integrated design; second, the part of project cost change under different integrated design levels it will become more obvious over time.

5. Conclusion

Based on the BIM platform, this paper uses the system dynamics theory to construct the life cycle cost control model of prefabricated buildings. Through the study of the model, specific suggestions are put forward for the life cycle cost control of prefabricated buildings.

a) Preliminary preparation stage: the impact of the preliminary engineering cost on the project cost shows that we should reduce the investment in the preliminary engineering cost, increase the persuasion of the technical bidding documents by using BIM Technology, reduce the bidding cost, and use BIM Technology to carry out collision inspection in the contract signing stage, so as to reduce the engineering claim fee.

b) Component design stage: from the impact of integrated design level on the cost of engineering projects, enterprises should introduce excellent design talents, keep learning spirit and keep pace with the times to learn excellent design experience at home and abroad. In the process of modeling, we should skillfully use BIM Technology, give full play to the advantages of BIM Technology, and better combine BIM Technology with prefabricated buildings.

c) Component production stage: the production cost of PC components determines the cost generation rate of PC components. It can be seen that PC components are produced according to the national unified industry standards and standards and stored in the BIM cloud. All parties can view the size and production progress of BIM components in real time, which can accelerate the production efficiency of PC components and realize the industrialization of prefabricated building components production.

d) Component transportation stage: it is necessary to give full play to the characteristics of BIM visualization and data. Through the combination of Bim and RFID, we can arrange the order before
transportation, determine the transportation number, plan the transportation route, and implement dynamic supervision and transportation throughout the whole process, so as to reduce the problems in the component transportation stage. In this way, the transportation efficiency is also improved Pave the road for the later construction.

e) Construction and installation stage: because the management level and staff quality are inversely proportional to the project cost, the enterprise should introduce management personnel with high management level and high staff quality, and conduct regular staff quality assessment to enhance the reserve of professional knowledge.

f) Operation and maintenance stage: from the operation and maintenance cost generation rate depends on the operation and maintenance cost, we should use low-carbon, environmental protection, recyclable materials to reduce material loss, and make full use of the visual and storable features of BIM to reduce the time cost of later maintenance.

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