Research on the influencing factors and countermeasures of the development of prefabricated buildings under the background of "double carbon"

Xia Wu [*],Yaping Han

Nanchang Institute of Science& Technology, Nanchang, 330108 , China.
**Corresponding author:ncuskwuxia@163.com*

Abstract: *As a representative of green and low-carbon buildings, prefabricated buildings have gained widespread attention from the government and industry due to their significant advantages in energy conservation and emission reduction, time saving, labor saving, and high construction efficiency. However, currently, prefabricated buildings have a low market share in China and their development is slow. This article summarizes the influencing factors of the development of prefabricated buildings and constructs a causal model (FCM model) consisting of five conceptual nodes for inference and simulation analysis. The predictive analysis results show that the correlation strength between the four major influencing factors and the development of prefabricated buildings is: F2(cost environment) > F4 (policy system) > F3 (technology system) > F1(market foundation). This article proposes reasonable measures and suggestions based on the analysis results, providing reference for promoting the development of prefabricated buildings.*

Keywords: *Prefabricated buildings; Influencing factors; Fuzzy cognitive map*

1. Introduction

With the proposal of the "dual carbon" goals by the Central Committee of the Communist Party of China and the State Council, "peaking carbon emissions and achieving carbon neutrality" has been incorporated into the overall layout of China's ecological civilization construction, becoming the top-level design at the national level[1]. Developing green buildings that reduce emissions and save energy, promoting the entire construction industry to reduce carbon dioxide emissions, is an important measure for overall carbon reduction in urban development, and is also a necessary condition for the long-term healthy and sustainable development of the national economy.

With the proposal of the "dual carbon" goals by the Central Committee of the Communist Party of China and the State Council, "peaking carbon emissions and achieving carbon neutrality" has been incorporated into the overall layout of China's ecological civilization construction, becoming the top-level design at the national level. Developing green buildings that reduce emissions and save energy, promoting the entire construction industry to reduce carbon dioxide emissions, is an important measure for overall carbon reduction in urban development, and is also a necessary condition for the long-term healthy and sustainable development of the national economy. Prefabricated prefabricated buildings have advantages such as green environmental protection, fast construction speed, and labor saving, which are of great significance for promoting energy conservation and emission reduction, ensuring safe construction, improving building quality, and improving living environment. Prefabricated buildings are conducive to promoting the deep integration of the construction industry and information industrialization, cultivating new industries and driving forces, and promoting the resolution of overcapacity. It can be seen that prefabricated buildings are one of the important means and approaches to achieve ultra-low energy consumption buildings.

However, despite the significant advantages of prefabricated buildings, prefabricated building systems are not very popular in the market. The Ministry of Housing and Urban Rural Development has clearly stated that during the 14th Five Year Plan period, the proportion of prefabricated buildings in new construction should reach over 30%. Although the industry actively promotes and the country's favorable policies support the increase in the proportion of prefabricated buildings in new construction, the development of prefabricated buildings will still face arduous tasks in the coming years, and most of them are government led and supported projects, with less use of prefabricated buildings in civil construction projects. At present, the technical specifications and related standards are not mature, the system is not perfect, and the application of prefabricated buildings is not high. It is urgent to effectively promote the development and application of prefabricated buildings, and to leverage their value and advantages.

2. Research Methods

At present, many scholars at home and abroad have recognized the importance of the development of prefabricated buildings. They have studied the influencing factors of prefabricated development from various perspectives, providing project management ideas for all parties involved in prefabricated buildings. However, some studies are based on comparative analysis of cases or statistical comparison of data, and their research on the factors affecting the development of prefabricated buildings is not in-depth enough. At the same time, although some literature has adopted quantitative methods to analyze the influencing factors of prefabricated development, most of these methods are static, with less consideration given to the interactions and dynamics among the influencing factors.

Fuzzy Cognitive Map (FCM) is a soft computing method that combines fuzzy logic with neural networks. It simulates the dynamic behavior of a system through the interaction of various conceptual nodes in the entire graph [2]. It has a scientific feedback mechanism that can respond to the dynamic changes of the entire complex system that affect the development of prefabricated buildings. Fuzzy cognitive maps have two prominent features: fuzzy causal relationships and dynamic feedback mechanisms. The system can determine the initial value of the model based on on-site investigation, and then iterate the system by setting change functions and threshold functions that match the system characteristics. Fuzzy reasoning will eventually terminate the operation when the system reaches a new equilibrium state. At the same time, quantitative analysis such as forward prediction and backward inference of input and output variables can also be achieved by setting the initial values of the model.

This article uses the Fuzzy Cognitive Map (FCM) method to construct a dynamic model of FCM for the influencing factors of the development of prefabricated buildings, and based on this, conducts inference and simulation analysis to identify the main factors and root causes that affect the development of prefabricated buildings. Based on the analysis results, effective strategies and suggestions to promote the development of prefabricated buildings are proposed.

3. Construction of FCM Model for Development Analysis of Prefabricated Buildings

3.1 Factors influencing the development of prefabricated buildings

The identification and determination of factors affecting the development of prefabricated buildings is the cornerstone of later research work and the key to model establishment and simulation analysis. By reading relevant literature on prefabricated buildings and summarizing various factors that affect the development of prefabricated buildings, the following four main factors are listed in Table 1.

Table 1. Factors Influencing the Development of Prefabricated Buildings

Item	Variables	Descriptions
F1	Market Fundamentals	It mainly refers to the number of prefabricated component industry bases in the region, the willingness of construction enterprises to accept prefabricated buildings, the degree of resident recognition, market demand, and the size of the prefabricated building market in different regions.
F2	Cost Environment	The cost environment mainly involves the production cost of prefabricated components, the one-time investment cost of prefabricated component factories, the length of investment payback period, the early research and development cost of components, and the transportation cost of components. If all costs are low, the cost environment is good; otherwise, the cost environment is poor.
F3	Technical System	As a technological innovation in the construction industry, technological level and industrial chain are important bottlenecks affecting the development of prefabricated buildings, mainly including the degree of uniformity and standardization of prefabricated component molds, prefabricated building design, production and transportation of

		prefabricated components, on-site hoisting construction, collaborative management, professional knowledge and talents related to prefabricated buildings, etc.
F4	Policy System	Has the local government introduced a policy system, industry standard specification system, and development promotion mechanism with implementable and actionable incentives, support, and supervision for the development of prefabricated buildings.

Concept nodes are one of the elements in the fuzzy cognitive map model. Through the above research, four influencing factors on the development of prefabricated buildings have been identified and classified. Construct the FCM model using the four influencing factors in Table 1 and the development of prefabricated buildings as conceptual nodes. The reason concept node is represented by Fi, where F1, F2, F3, and F4 represent four factors influencing the development of prefabricated buildings, and T represents the target concept node in the model - the development of prefabricated buildings. Therefore, this study will have 5 conceptual nodes to form a causal FCM model.

3.2 Determine causal relationships and weight values

The determination of causal relationships and weight values is the key to model construction, and the FCM model uses directed arcs to represent the causal relationships between conceptual nodes. The strength of the causal relationship between two different conceptual nodes in the system is represented by weight, and the degree of influence is described by a numerical value in the [-1,1] interval.

In this article, the expert scoring method will be used to determine the relationships and weights between the 5 concept nodes. The expert scoring method first invites domain experts to evaluate each project based on their own experience according to the given evaluation criteria, and then aggregates them. Therefore, it is also a method of transforming qualitative descriptions into quantitative ones. To ensure high authority and representativeness of the data, six industry experienced experts were selected for research.

3.3 Selection of threshold function

The threshold function used in the FCM model is the hyperbolic tangent function (Equation 1), which not only represents the trend of node activity increasing or decreasing, but also shows the degree of enhancement or weakening. Moreover, hyperbolic tangent functions can map x values to the [-1,1] interval.

$$\text{Hyperbolic tangent function: } f(x) = \tanh(x) = \frac{e^x - e^{-x}}{e^x + e^{-x}} \quad (1)$$

where tanh(x) represents the hyper tangent of an angle.

3.4 Construction of FCM model

This article uses the FCM causal model to study the impact of various factors on the development of prefabricated buildings. Fuzzy cognitive graph is a graph method for representing causal knowledge, consisting of nodes and directed arcs. Among them, nodes can be concepts, entities, etc. Arcs represent the causal relationships between these concepts or entities. The arrow of the arc points from the cause concept to the result concept, and the magnitude of the impact is reflected by weights. After determining the conceptual nodes, causal arcs, and weights, a fuzzy cognitive map model (FCM model) for the cost system of prefabricated buildings is constructed.

This model consists of 5 nodes (4 causal concepts, 1 target event), and the FCM model can clearly display the interaction relationship between variables, as shown in Figure 1.

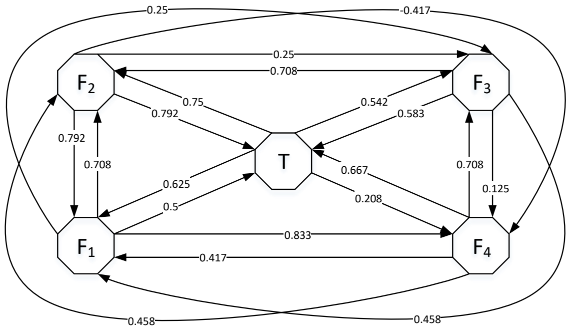

Figure. 1. FCM Model for the Development of Prefabricated Buildings

4. Simulation Analysis of FCM Model for the Development of Prefabricated Buildings

Using the software FCM Analyst 1.0, perform predictive and diagnostic analysis based on the inference function of FCM. This software is designed according to the representation method and inference mechanism of fuzzy cognitive maps, and can output the state curve and data values of model concept nodes that are iteratively updated over time.

Predictive analysis

Predictive analysis aims to predict the change of the target event over time when a variable changes. It can be used to study the changes in the target event of prefabricated building development over time when the influencing factors of a certain prefabricated building development change.

This article simulates the values of the four factor variables mentioned above. When each factor variable is at a different initial value, it will propagate to other concepts in the network and cause a change in the outcome of the target event. Taking market based F1 simulation as an example, the initial values of F1 are set to four state values: -1.0 (extreme), -0.5 (poor), 0.5 (good), and 1.0 (excellent). Through causal reasoning and iterative operations between model concept nodes, the simulated value of prefabricated building development eventually tends to a stable value with the change of iteration times. Similarly, simulate the values of the other three variables in order to observe the changes in the development of prefabricated buildings and their stable values. The simulation results of each variable are shown in Figure 2, and it can be seen that after multiple interactions, the value of concept T will evolve and stabilize at a fixed point.

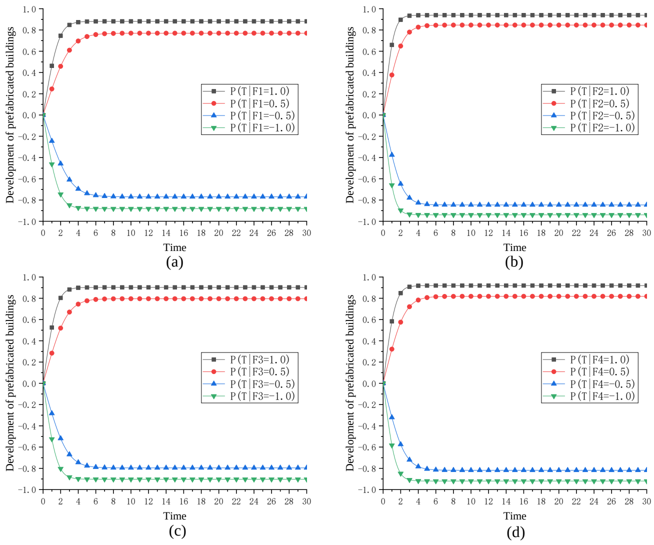

Figure. 2. Impacts of variations of various factors on the development of prefabricated buildings in the predictive analysis

From the simulation results, it can be seen that there is a significant positive correlation between the concepts F1, F2, F3, and F4 and the concept of T. When the F1(market foundation), F2(cost environment), F3(technology system), and F4(policy system) are improved or strengthened, it will lead to an increase in the development level of prefabricated buildings; The above simulation results are not difficult to understand, that is, for the development of prefabricated buildings T, when simulating the values of F1, F2, F3, and F4 respectively, and keeping all other factors unchanged, let one of them be in a favorable situation. Regardless of whether it is a moderate or strong favorable situation, the development of prefabricated buildings will continue to improve over time. On the contrary, the development of prefabricated buildings is getting worse and worse. The larger the slope in Figure 2, the faster the development process. When the variables are F1, F2, F3, or F4, the absolute slope of the change curve is (b)>(d)>(c)>(a), indicating that the correlation strength between these four factors and the development of prefabricated buildings is: F2（cost environment）> F4（policy system）> F3（technology system）> F1（market foundation）. The results of predictive analysis can help us further understand the development patterns of prefabricated buildings when influencing factors change, providing direction for improving the speed and quality of prefabricated building development.

5.Conclusion and Suggestions

Through the predictive analysis of the FCM model, it can be concluded that the correlation strength between the four major factors and the development of prefabricated buildings is: F2（cost environment）> F4（policy system）> F3（technology system）> F1（market foundation）. Based on the above analysis, the following suggestions are proposed.

(1) To effectively reduce the production cost of components, it is necessary to increase the utilization rate of templates. Therefore, in the design of unit types, efforts should be made to minimize them as much as possible; Simplify the facade and reduce the types of facade construction; Reduce the splitting of heterosexual constructions and increase the number of components of the same type, thereby improving the efficiency of assembly production lines, reduce the procurement costs of prefabricated components for construction enterprises.

(2) Further optimize policies and formulate targeted incentive policies. Include the use of prefabricated technology in regional development plans and land transfer conditions, and urge construction enterprises to accelerate their transformation; Expand the scope of policy support, increase fiscal subsidies and tax exemptions, make incentive policies more beneficial to the people, and truly guide and regulate the policies.

(3) Integrating BIM technology with RFID technology in the design, production, transportation, and construction of prefabricated buildings. The combination of the two can help establish the information flow at each stage, improve the transportation and installation efficiency of prefabricated components.

Acknowledgments

[1] Science and Technology Research Project of Nanchang Institute of Science＆Technology (NGKJ-22-13)

[2] Science and Technology Research Project of Jiangxi Provincial Department of Education (GJJ2202913)

References

[1] Luo Yi The development direction and technological application of green buildings under the "dual carbon" goal [J]. China Engineering Consulting, 2022, (05): 74-79.
[2] Voula C Georgopoulos, Georgia A Malandraki, Chrysostomos D Stylios. A fuzzy cognitive map approach to differential diagnosis of specific language implementation [J] Artistic Intelligence In Medicine, 2003, 29 (3): 261-278.