Research on Influencing Factors of Technology Application of Prefabricated Building Based on Structural Equation

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Abstract: The prefabricated buildings have the characteristics of low pollution and low energy consumption, which meet the development requirements of green buildings. It is of practical significance to study the factors affecting the application of prefabricated building technology to promote the rapid development of prefabricated buildings. Based on the construction of the research model of the influencing factors of the application of prefabricated building technology, the paper compiled four potential variables and their observation index scales, including policy, cost, technology, and industry factors. The SEM (structural equation model) of the factors affecting the development of prefabricated buildings is built by using AMOS20.0 software, and it is studied and analyzed. The results show that the overall reliability and validity of the questionnaire are good, and the selected observation indicators are reasonable and reliable. The development of prefabricated buildings is affected by different factors. The order of importance of influence degree is: policy factor>technology factor>industry factor>cost factor.

Keywords: Prefabricated building, Technology application, Structural equation, Influencing factors

1. Introduction

The prefabricated buildings have the characteristics of low pollution and low energy consumption, which meet the development requirements of green buildings [1]. Prefabricated buildings are standardized designs by professional institutions. Some or all the accessories are prefabricated on the industrial assembly line, transported to the construction site by professional means of transportation, and connected and assembled on site by means of mechanical lifting to form building products with use functions. The State Council issued the “Several Opinions of the Central Committee of the Communist Party of China and the State Council on Further Strengthening the Management of Urban Planning and Construction” on February 6, 2016, which proposed that the construction industry should vigorously develop new construction methods and strive to increase the proportion of prefabricated buildings to 30% of new buildings in about ten years. The future development of prefabricated buildings is being raised to an unprecedented new level. In 2021, the new construction area of China's prefabricated construction industry reached 740 million square meters, up 17.69% from 2020 [2]. According to the statistics of CCPA (China Concrete & Cement-based Products Association), in the first half of 2022, the proportion of newly constructed prefabricated buildings in the country

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accounted for more than 25% of the new building area, and the total construction area of prefabricated buildings reached 2.4 billion square meters. The construction process of prefabricated buildings draws on the industrial flow production and manufacturing mode of manufacturing industry, realizes the industrial flow production of prefabricated parts and components and the mechanized assembly and construction of the construction site, and innovates the traditional and backward management mode [3]. During the production and construction of prefabricated buildings, we can minimize the waste of water and land resources, reduce the consumption of building materials and limited energy, and bring considerable economic and environmental benefits to today's rapidly developing modern society. Although prefabricated building is the inevitable trend of the future development of the construction industry, it is at the early stage of development and is affected by many factors, resulting in its slow development. Therefore, it is of great practical significance to study the influencing factors and their degrees in the application of prefabricated building technology [4].

2. Recognition of influencing factors

In order to accurately measure the various influencing factors of the application of prefabricated building technology and ensure the reliability and validity of the measurement tools, this paper tries to use the measurement indicators that have been used in the existing domestic and foreign literature when selecting indicators, and constructs the final prefabricated building cost measurement indicator system based on the suggestions of relevant experts [5]. This paper chooses to use the structural equation modelling method SEM (Structural Equation Modelling) to build the conceptual model between various potential variables, and analyse the degree of influence of these factors: assuming that the policy factors, economic factors, technical factors, and industry factors are four external potential variables, and the promotion and application of prefabricated buildings are internal potential variables [6]. The above four and influencing factors can be further divided into fourteen secondary influencing factors. The path assumption relationship between each potential variable is shown in Table 1:

Table 1. Table of influencing factors of technology application of prefabricated building

Primary influencing factors	**Secondary influencing factors**	**Identification**
Policy factors	Policy support	A1
	Policy guarantees	A2
	Policy guidance	A3
Economic factors	R&D investment	B1
	Initial investment	B2
	Production costs	B3
	Logistics cost	B4
Technical factors	Technical system	C1
	Construction technology	C2

	Construction difficulty	C3
	Component standard	C4
Industry factors	Industry awareness	D1
	Industrial chain	D2
	Personnel training	D3

We make the following four assumptions：

H1: It is assumed that the policy factor has a significant positive correlation with the promotion and application of prefabricated buildings. Policy factors mainly include three observation indicators: policy support, policy guarantees and policy guidance.

H2: Assume that economic factors have a significant positive correlation with the promotion and application of prefabricated buildings. Scientific research investment, early investment, production cost and logistics cost have a positive impact on economic factors.

H3: It is assumed that technical factors have a significant positive correlation with the promotion and application of prefabricated buildings. Four observation indicators, such as technical system, construction process, construction difficulty and component standard, have a positive impact on technical factors.

H4: It is assumed that industry factors have a significant positive correlation with the promotion and application of prefabricated buildings. The three observation indicators of industry awareness, industry chain and talent cultivation have a positive impact on industry factors.

3. Questionnaire survey and analysis

3.1 Descriptive analysis of the questionnaire

Based on the potential variables and measurement index system of the factors affecting the application of prefabricated building technology, and in combination with the suggestions of relevant experts, we determine the final questionnaire [7]. The questionnaire is distributed in two ways, that is, online electronic questionnaire and offline paper questionnaire. The main objects of investigation include the staff of the relevant government management and supervision institutions involved in the construction of prefabricated buildings, the main principals of the design unit, the main principals of the project management of the owner, the representatives of the chief supervision engineer, the principals of the material department, and the project managers, cost managers, technical and safety principals of the contractor. In order to standardize the standard and comparability of the way the respondents evaluate the questionnaire items, the coding rules specified in the Likert scale are used for the questionnaire items, where 5 means “very agree” with the question item, and 1 means “very disagree” with the question item [8]. During the survey, a total of 200 formal questionnaires were distributed, and 196 questionnaires were successfully recovered. In order to ensure the reference value of the questionnaire, it is also necessary to screen the effectiveness of the successfully recovered questionnaire. The principles are as follows: the respondents have filled in more than 90% of the questions in the questionnaire; There is no obvious rule in the score of the questions before and after the questionnaire; The scores of the questions in the questionnaire are obviously contradictory. After screening the effective questionnaires based on this principle, it was found that 10 of them were less than 90% complete, and 10 of them had obvious rules in terms of item scoring. A total of 20 questionnaires were invalid. Therefore, the number of valid questionnaires obtained is 176.

In terms of gender, men account for 91.5%, and the proportion of men and women basically conforms to the actual situation of gender composition in the construction industry; In terms of age, it is mainly concentrated between 31 and 40 years old, accounting for 52.6%. The employees in the age range of 31 to 40 years old are mainly at the management level in the industry. They often have rich work and social experience, and have a high acceptance of prefabricated buildings. Therefore, the evaluation of questions will also be more rational; In terms of education level, 74.19% of the respondents have bachelor's degree or above, and have a high theoretical level. They can combine theory with practice in the evaluation of questions, and the scoring results are also of more reference value. From the analysis of the distribution of respondents, the distribution of respondents in the effective questionnaire is reasonable and meets the research requirements.

3.2 Reliability and validity analysis

We further verify the rationality and validity of the hypothesis of the conceptual model fit and path relationship of the factors affecting the application of prefabricated building technology. We used SPSS20.0 software to analyse the reliability and validity of the effective survey data obtained from the questionnaire.

SPSS software was used to calculate the Cronbaha coefficient named α value of each observation index and the overall index to analyze the reliability of the scale [9]. It is calculated that the overall reliability d coefficient value of the questionnaire is 0.748, and the α coefficient value of each observation index is greater than 0.6, which is in a reasonable range. As a supplement to the reliability analysis of the d coefficient, a supplementary test is carried out by calculating the corrected total phase relationship value. After the test, the corrected total phase relationship value of each item in the questionnaire were in the range of 0.352 to 0.524, which is greater than 0.3. It shows that the overall reliability level of the questionnaire is good, and the selected observation indicators are reasonable and reliable. Analyze the content validity and convergence validity of the scale of potential variables and observation indicators affecting the application of prefabricated building technology. Because the scale constructed by the research is mainly based on the mature scale formed by domestic and foreign scholars in the process of research. We modified the scale slightly according to the actual application of the research topic, so the scale has high content validity. By using KMO test and Bartley sphere test in SPSS software to analyze the convergence validity of the scale, and orthogonal rotation of the factor analysis load matrix of the scale, the KMO value of the scale is 0.701, which is more than 0.5. The Bartley sphere test Sig. value is 0.0001, which is far less than 0.05. The factor load value of each observation variable in the scale is greater than 0.5. Therefore, the overall convergence validity of the questionnaire is good, and the scale design is reasonable.

4. Structural equation modeling of influencing factors of technology application

4.1 Build structural equation model

The conceptual model and path assumption of the factors affecting the application of prefabricated building technology are basically reasonable. The policy system can indirectly influence the development of prefabricated buildings in China by directly influencing the cost system [10]. Similarly, the technical system can indirectly influence the development of prefabricated buildings by directly influencing the cost system and industry system. On this basis, the structural equation model of the factors affecting the development of prefabricated buildings is built by using AMOS20.0 software, and the model, path assumption and effective sample data are further tested for violation estimation and fitness, in which the potential variable is represented by ellipse, and the regular variable is represented by rectangle, The structural equation model (SEM) of error variables expressed in circles is a statistical method to analyse the interaction between variables based on the covariance matrix of variables. According to the factors affecting the construction progress, a structural equation model is constructed, in which four factors (policy factors, economic factors, technical factors, and industry factors) are latent variables and fourteen factors are observational variables. The data collected from the questionnaire is introduced into the software to test the model for violation estimation. If the model has negative error items, that is, the standardization coefficient is negative or close to 1 (greater than 0.95) or more than 1, it is a violation. If the judgment index fails to pass the violation estimation test, the conceptual model and path hypothesis need to be further modified and the above test repeated. The subsequent fitness test can be conducted only after the violation estimation test is passed. First, the violation estimation test of the structural equation model of the factors affecting the development of prefabricated buildings was carried out and appropriately revised. After analysis and calculation by AMOS software, it was found that the standardized path coefficient of each observation variable was between 0.55 and 0.81. It was concluded that the structural equation model of the factors affecting the development of prefabricated buildings could undergo the next step of fitness test through the violation estimation test [11]. The structural equation model of influencing factors is shown in Figure 1.

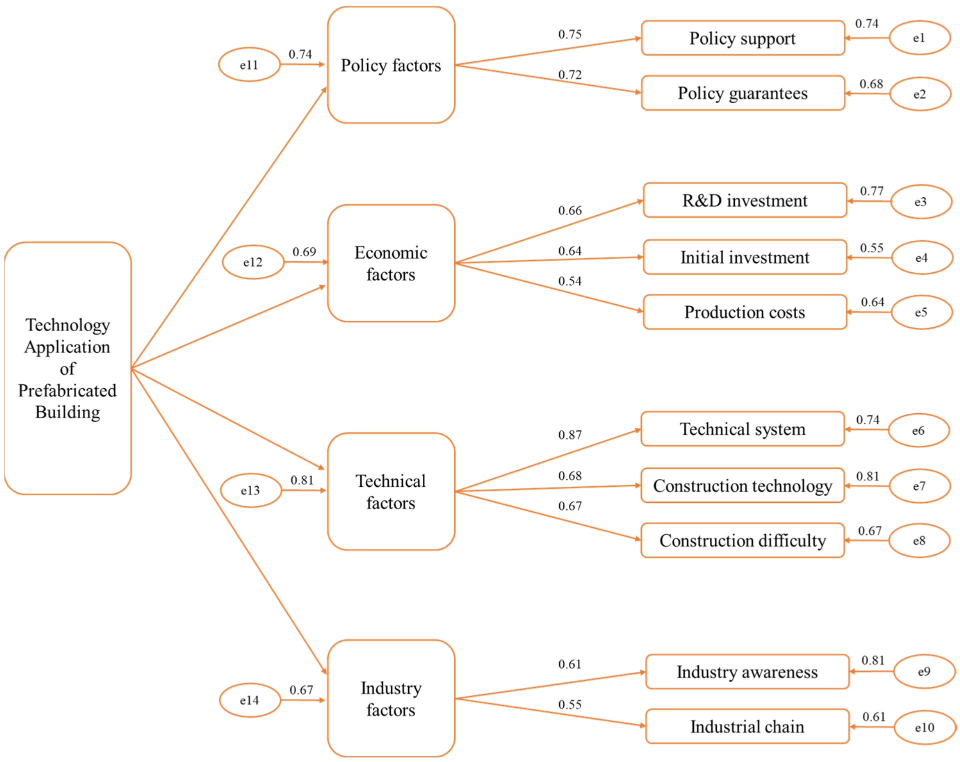

Figure 1. Structural equation model of influencing factors of technology application of prefabricated building

4.2 Analyze structural equation model

According to the fitting situation, the model fitness test can be carried out through the violation test. The fitting test results of the structural equation model is shown in Table 2.

Table 2. Fitness test results of structural equation model

Index	Inspection index	Inspection result	Reasonable scope	Model adaptation judgment
Absolute adaptation index	RMSEA	0.025	<0.08	Match
	GFI	0.883	>0.8	Match
Value-added adaptation index	CFI	0.952	>0.9	Match
	IFI	0.953	>0.9	Match
	TLI	0.921	>0.9	Match
Reduced adaptation index	PNFI	0.562	>0.5	Match
	PCFI	0.624	>0.5	Match
	PGFI	0.588	>0.5	Match
	X^2/df	1.691	<3	Match

After the violation estimation test, the structural equation model of the factors affecting the development of prefabricated buildings is tested. Under the assumptions of the structural equation model method, the structural equation model of the factors affecting the development of prefabricated buildings is modified to a certain extent according to the fitting data results obtained through the analysis and calculation of AMOS software, so that the fit indicators are within a reasonable range, and the inspection indicators are shown in the table, The overall fit of the structural equation model of the factors affecting the development of prefabricated buildings is relatively ideal. Based on this, it is necessary to calculate the construction reliability of each potential variable in the structural equation model and extract the average variance [12]. The discrimination results will be used as the evaluation criteria for the internal quality of the structural equation model. The calculation shows that the reliability value and the average variance extraction value of potential variables meet their respective standards, so the structural equation model has good internal quality. Therefore, assumptions of H1, H2, H3 and H4 all pass the significance test. It can be concluded that the potential variables of the model have a significant impact on each other and the path relationship hypothesis is all valid.

4.3 Calculate index weights

According to the above analysis, we can get the weight coefficient of each influencing factor. The calculation method is as follows. Assume that the path coefficients of latent variables are respectively $\lambda_i(1 < i < 4)$. The weight coefficient is γ_i. Then the weight calculation formula of latent variable is $\gamma_i = \lambda_i/\sum_{i=1}^{4}\lambda_i$. We get the weight of each index of the influencing factors, as shown in Table 3.

Table 3. Weights of influencing factors of technology application of prefabricated building

Primary influencing factor	**Secondary influencing factor**	**Weight of every Secondary influencing factor**	**Weight of every primary influencing factor**
Policy factors	Policy support	0.61	0.31
	Policy guarantees	0.39	
Economic factors	R&D investment	0.35	0.18
	Initial investment	0.39	
	Production costs	0.26	
Technical factors	Technical system	0.21	0.25
	Construction technology	0.36	
	Construction difficulty	0.43	
Industry factors	Industry awareness	0.44	0.26
	Industrial chain	0.56	

4.4 Achieve research results

From the construction, inspection and analysis of the above structural model, the following conclusions can be drawn: H1: policy factors have a significant positive correlation with the promotion and application of prefabricated buildings; Among the policy factors, two observation indicators have a positive impact on the policy factors. The policy guidance indicators in the hypothesis are excluded due to data mismatch. H2: Economic factors have a significant positive correlation with the promotion and application of prefabricated buildings; Among the economic factors, three observation indicators have a positive impact on the economic factors. The logistics cost indicators in the hypothesis are excluded because of data mismatch. H3: Technical factors have a significant positive correlation with the promotion and application of prefabricated buildings; Among technical factors, technical system, construction technology, construction diversity and other observation indicators have a positive impact on technical factors. The component standard index in the hypothesis is excluded because of data non-fitting. H4: Industry factors have a significant positive correlation with the promotion and application of prefabricated buildings; Among the industry factors, industry awareness and industry chain have a positive impact on industry factors. The assumed talent training indicators are excluded due to data mismatch. The above research results show that the path relationship hypothesis H1, H2, H3, and H4 all pass the significance test, from which we can get a significant positive correlation between the potential variables of the model. After excluding the data that does not fit the indicators, all assumptions are valid.

5. Conclusions

From the above analysis, we can draw the following conclusions: the impact of policy factors, economic factors, technical factors and industry factors on the promotion and application of prefabricated buildings is consistent and significantly positive. The importance of the degree of impact is ranked as policy factors are greater than industry factors, industry factors are greater than technology factors, and technology factors are greater than cost factors. The competent construction department and all participating units take targeted measures according to the importance of each system to promote the rapid development of prefabricated buildings. Due to the limited data of this study, we should conduct field engineering research, collect diverse samples, and improve the structural equation model in the future. At the same time, more specific solutions are proposed for key factors.

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