Research on Performance Evaluation of Prefabricated Building in Construction Stage

Shun Wang [1*], Yingchun Li [1], Zhengchao Li [2], and Shen Shen[1]

[1] Shenyang University, Shenyang 110044, China
[2] Liaoning coastal construction engineering quality testing Co., LTD, Yingkou 115004, China
*shw1973@163.com

Abstract. In order to explore the potential factors affecting the performance of prefabricated building in the construction stage, this paper studies from five aspects: society, economy, environment, management and organization, through consulting a large number of literature to determine the secondary indicators, in order to establish the index system. A questionnaire survey was used to collect the relevant data of each index, and an SEM model was established to obtain the correlation path coefficient, and the influence level of each index on the performance of prefabricated building in the construction stage is analyzed. The research has shown that the management benefits have the greatest impact, followed by environmental, organizational, social, and economic. The key to improve performance is to establish a sound management system and do a good job in coordination among all parties.

Keywords: Prefabricated building, Performance in construction stage, SEM structural equation model.

1 INTRODUCTION

The process of urbanization has led to the demolition or reconstruction of numerous buildings, The process of urbanization has led to the demolition or reconstruction of numerous buildings, resulting in a continuous surge in construction waste and resource depletion. The traditional building form is cast in situ concrete, which has a long construction period, many personnel. In the construction process, a large amount of construction waste will be generated, which greatly affects the local living environment. In order to solve the problem of sustainable development of the construction industry, the General Office of the State Council and the Ministry of Housing have successively issued the "Guiding Opinions on vigorously developing prefabricated buildings", the "'Thirteen-five' prefabricated building action plan" for prefabricated building and other relevant documents, and vigorously develop prefabricated buildings with low-carbon, environmental protection and energy saving advantages.

The development of prefabricated building in China started late, and information asymmetry is easy to appear in the construction process, and energy saving and emission reduction measures are not in place, which seriously affects the construction cost

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and deviates from the original intention of sustainable development of prefabricated building[1]. So the use of reasonable performance evaluation is imminent.

Engineering project evaluation is to use scientific evaluation methods to evaluate a certain stage or the whole process of an engineering project. Wooyong J[2] has helped Korean contractors resolve performance disparities in contract type and project profitability through performance evaluation research. Luo L[3] and Zeinab A[4] conducted a research on the performance evaluation of construction projects, respectively using structural equation model (SEM) and literature review method, and finally concluded that the key to improve performance lies in government supervision and coordination of all parties. Zhang Y[5] and Qu F [6] set up the performance evaluation system for the supply chain of prefabricated construction projects, analyzed the examples and put forward the corresponding suggestions. Hu Q and Wang Z [7] carried out dynamic performance evaluation on the construction phase of construction projects with agent construction mode, and build a dynamic performance evaluation model with set pair analysis and Markov chain coupling.

As can be seen from the above literature studies, although there are many achievements in the performance evaluation of engineering projects, there are few studies on the construction stage. In addition, the influencing factors selected by various scholars are quite different. In this paper, starting from the basic three indicators of sustainable development (social, economic and environmental), and then summarizing the indicators of numerous literatures, the two indicators of management and organization are finally selected, which are more in line with the characteristics of numerous and complex personnel and equipment in the construction stage and difficult management. In this paper, the prefabricated building construction stage is taken as the research object, and the performance level factors in this stage are studied by using literature retrieval method and questionnaire survey method. The performance evaluation system is established by SEM analysis method, and the performance evaluation model is established by AMOS software. Finally, the corresponding solutions are proposed.

2 ESTABLISHMENT OF PERFORMANCE EVALUATION SYSTEM OF PREFABRICATED BUILDING IN CONSTRUCTION STAGE

2.1 Index Retrieval

Through searching and reading relevant literature, the research on the performance of prefabricated building in construction stage can be divided into three aspects from the perspective of sustainable development performance, namely, social benefit, economic benefit and environmental benefit. Qin Y[8] pointed out that for prefabricated building, these three benefits run through the beginning and end of the construction project, and have a greater impact on the benefit level of prefabricated building. Chang Y [9] found in the study of of prefabricated building that environmental benefits and economic benefits have obvious effects on the performance of prefabricated building.

But now, to consider the performance of the whole construction stage of the prefabricated building, it can not only consider these three indexes; Around the prefabricated building performance evaluation, the common grade I indexes indicators are management, organization and so on. Zhou Y [10] and Ji Y [11] considered the influence of management benefit in his research on the performance evaluation of prefabricated building. Chang Y[9] pointed out that organizational benefits will also have an impact on the performance of prefabricated building, which should attract our attention.

For these five grade I indexes, many scholars have different grade II indexes, but most of them include: customer satisfaction, degree of civilization, natural environment, etc. Because the prefabricated building is more special and needs to transport prefabricated components, the transportation cost is greatly increased and has to be considered, and the prefabricated components need to be lifted on site, so the working environment of the lifting equipment is also particularly important.

2.2 Determination of Index System

After reading a lot of literature, this paper summarizes the performance evaluation indicators of prefabricated building in the construction stage from the perspective of sustainable development and combined with the research focus of prefabricated building performance evaluation, as shown in Table 1. After screening, this paper will evaluate the performance of prefabricated building in the construction stage from five aspects. In addition to the three indicators of society, economy and environment, two indicators of management and organization will be added, and the performance level of prefabricated building in construction stage will be considered more comprehensively. Each grade I indexes contains multiple grade II indexes. Each grade II indexes is numbered with the first letter of the two Chinese names of the f grade I indexes, for example, the social acceptance is SH1.

Table 1. Summary of performance evaluation index of prefabricated building in construction stage

grade I indexes	grade II indexes	serial number
social benefit	Social acceptance	SH1
	Service customer satisfaction	SH2
	Staff satisfaction	SH3
	Construction civilization	SH4
	Engineering accident rate	SH5
economic benefit	Construction personnel cost	JJ1
	Mechanical equipment use and maintenance	JJ2
	transportation cost	JJ3
	Production cost of prefabricated components	JJ4
	operational and maintenance cost	JJ5
environmental benefit	Living conditions for staff	HJ1
	Natural climatic environment	HJ2
	Construction waste control	HJ3

	Hoisting equipment construction environment	HJ4
	Storage yard placement of components	HJ5
management benefit	Degree of information management	GL1
	Construction site management system	GL2
	Mechanization degree of construction site	GL3
	Construction personnel skills training	GL4
	Building materials management	GL5
Organizational benefit	Good supplier relationship	ZZ1
	Strategic buy-in by stakeholders	ZZ2
	Communication and coordination	ZZ3
	Information sharing degree	ZZ4
	Coordination and scheduling of machinery	ZZ5

2.3 The Establishment of Hypothetical Models

SEM (Structural Equation Model) includes two statistical techniques, factor analysis and path analysis, which can explore the relationship between multiple variables at the same time. The most important point is that it can accept the error of variable measurement and estimate the overall fit degree of the model. Path analysis consists of measurement model and structure model. The calculation formula of the measurement model is as follows:

$$X = \Lambda_x \xi + \delta \tag{1}$$

$$Y = \Lambda_y \eta + \varepsilon \tag{2}$$

Equation (1) defines the relationship between the explicit observed variable X and the implicit observed variable ξ; Equation (2) defines the relationship between the explicit tlatent variable Y and the implicit latent variable η. δ is the residual of the dominant observed variable X; η is the residual of the dominant latent variable Y; Λ_x is the regression coefficient of ξ; Λ_y is the regression coefficient of η.

The mathematical expression of the structure model is as follows.

$$\eta = B\eta + \Gamma\xi + \zeta \tag{3}$$

Equation (3) represents the relationship between the implicit observed variable ξ and the implicit latent variable η. B is the coefficient matrix between implicit latent variables; Γ is the coefficient matrix composed of implicit observed variables and implicit latent variables; ζ is the residual of the structural equation.

According to the research content of this paper, an SEM hypothesis model is established, as shown in Fig 1. Five grade I indexes constitute latent variables, and 25 grade II indexes constitute measurement observation variables of latent variables. The numbers of observation variables are shown in Table 1.

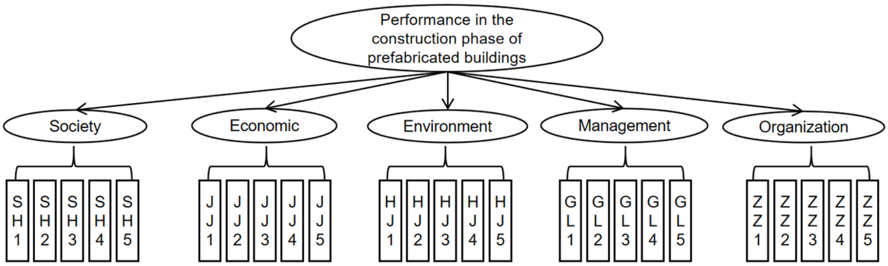

Fig. 1. Model assumptions for performance evaluation

3 RELIABILITY AND VALIDITY ANALYSIS

3.1 Questionnaire Survey

The utilization of SEM methodology for analysis necessitates a substantial quantity of samples, In general, if one desires to achieve consistent results in SEM analysis, it is recommended that the number of tested samples exceed 200[12].

This paper adopts the form of questionnaire survey to collect data, and a total of 319 valid data were recovered. The questionnaire survey is designed by Likert 5-level scale method. The questionnaire is distributed online and distributed to the construction industry or prefabricated construction-related employees. About 55% of the respondents are construction workers, 28% are designers, and 16% are managers and project leaders, and more than half of them are between 30 and 40 years old.

3.2 Reliability Analysis

Reliability analysis is a way to measure the reliability of data. Cronbach's Alpha is usually used to test the reliability of Likert scales, the test formula is as follows. In this paper, SPSS26.0 software is used to test the questionnaire data, as shown in Table 2.

$$\alpha = (1 - \Sigma\sigma_i^2/\sigma^2)K/(K+1) \quad (4)$$

In equation (4), K represents the number of relevant items in the questionnaire, $\sigma_i^2\sigma^2$is the result variance of the i th item and the result variance of all items respectively.

Table 2. Cronbach's Alpha coefficient test analysis

grade I indexes	Number of observed variables	Alpha coefficient
social benefit	5	0.884
economic benefit	5	0.919
environmental benefit	5	0.902
management benefit	5	0.886
Organizational benefit	5	0.892

The Cronbach's α coefficients of the five latent variables studied in this paper are all above 0.8, which indicates that the questionnaire has good reliability and reliability, and can be used for structural equation fitting test.

3.3 Validity Analysis

Validity analysis refers to the agreement between the measured results and the expected results. This paper analyzes the structure validity of the recovered data through KMO value and Bartlett sphere test, and the analysis results are shown in Table 3. Through SPSS26.0 software analysis, the overall KMO value of the scale was 0.949, and the p value of Bartlett sphere test was less than 0.001, indicating a high correlation and good validity of the data as a whole.

Table 3. KMO test and Bartlett sphere test were analyzed

variable	KMO test and Bartlett sphere test Alpha coefficient		
totality	KMO test	KMO value	0.949
	Bartlett sphere test	Approximate chi-square	5543.337
		df	300
		p value	0.000

4 SEM MODEL ESTABLISHMENT AND MODIFICATION

In this paper, Amos26.0 software is used to establish an evaluation model, and the overall fitting degree of the model is evaluated.

The overall fitting test results of the first-order model are in an acceptable poor fitting state, and the model needs further modification. The model was modified according to the software's suggestions on the model operation results in the analysis process. All five latent variables (grade I indexes) were retained, while the number of observed variables (grade II indexes) was reduced to 22, and the observation variables removed were SH1, GL3 and ZZ5.

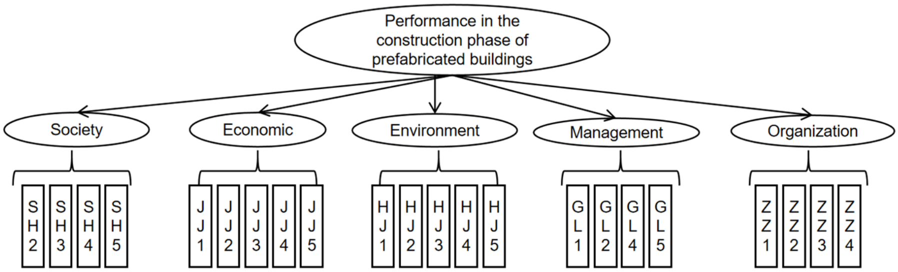

Fig. 2. Revised assumptions for performance evaluation model

The modified model is a second-order model. The Chi-square degree of freedom ratio of the second-order model is 1.791, indicating that the modified second-order model has a good fit, which is improved compared with the first-order model. The fittest results of the second-order model are shown in Table 4.

Table 4. Second-order model fit test

category	Statistical test	Before modification	Statistical test
absolute fit index	χ^2/df	2.185>2	1.791<2, well-fit
	GFI	0.865>0.80	0.902>0.80, accept
	AGFI	0.838>0.80	0.876>0.80, accept
	RMSEA	0.064<0.80	0.053, well-fit
relative fit index	NFI	0.897>0.80	0.930>0.80, well-fit
	IFI	0.941>0.80	0.968>0.80, well-fit
	TLI(NNFI)	0.934>0.80	0.963>0.80, well-fit
	CFI	0.941>0.80	0.968>0.80, well-fit
reduced fit index	PGFI	0.718>0.50	0.716>0.50, well-fit
	PNFI	0.807>0.50	0.809>0.50, well-fit

After this revision, the final model is obtained, which consists of 5 latent variables and 22 measurement observation variables. See Fig 3 for the structure diagram of the standardized path coefficient of the SEM model.

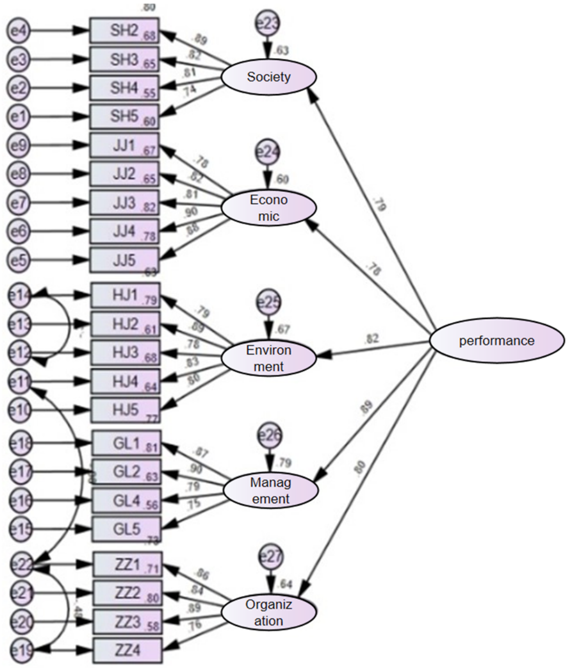

Fig. 3. Standardized path coefficient of the modified second-order SEM model

5 EXPLANATORY MODELS

The modified model has 5 latent variables and 22 observed variables, and the fit is good. Through the model analysis of the relationship between each latent variable and observed variable in the construction process of prefabricated building, the influence of each index on the performance level of prefabricated buildings in the construction stage is calculated, and relevant suggestions are proposed for the construction stage according to the calculation results.

According to Fig 2, among the five potential variables affecting the performance of prefabricated building in construction stage, management benefit has the strongest explanatory power, and the standardized path coefficient is 0.89. The path coefficient of economic benefit standardization is the lowest(0.78). According to the standardized path coefficient, the five potential variables were environmental benefit (0.82), organizational benefit (0.80), social benefit (0.79) and economic benefit (0.78).

For management benefit, the results show that the construction site management system has the greatest impact on the management performance of prefabricated building in the construction stage. We should establish and improve the management system of prefabricated buildings, clarify the management responsibilities and processes, strengthen the implementation, and ensure the effective implementation of quality control, schedule control, cost control and other aspects in the construction process. In addition, the information management level of the construction site should be improved, this contributes to better management and decision-making.

The most influential environmental benefit is the natural climate environment (0.89), because the natural climate condition directly determines the construction time of the project. The second is the hoisting equipment construction environment, prefabricated buildings have higher requirements for hoisting equipment, so a good hoisting equipment construction environment is the key to improve efficiency. The standardization path coefficients of the other three indicators have a small difference, but the influence cannot be ignored, and it is also necessary to optimize them.

The most influential indicator of organizational effectiveness is communication and coordination among partner members (0.89), followed by good supplier relations (0.86), Timely communication with partners is the key to improve organizational efficiency. Good information exchange will maximize the interests of all parties, and organizational efficiency will also be improved. While pursuing economic benefits, we also need to fully consider the realization of social benefits. The most influential social benefit is customer satisfaction, which indicates that the high satisfaction of the direct service object of the project is helpful to the promotion and benefit of the project. The production cost of prefabricated component is the most influential economic benefit. Prefabricated buildings require a large number of prefabricated components to be produced in the factory in advance, which will raise a lot of costs, and increase a lot of transportation costs.

6 CONCLUSION

This paper takes the performance evaluation of prefabricated buildings in the construction stage as the research object, and finally establishes a comprehensive evaluation system based on 5 primary indicators and 22 secondary indicators. After studying, we can know that t he performance of prefabricated buildings in the construction stage is affected by many factors. By comprehensively considering social, economic, environmental, management and organizational factors, and taking effective measures to improve and optimize them, the performance level of prefabricated buildings in the construction stage can be significantly improved and the sustainable and healthy development of its industry can be promoted.

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