Indoor Measurement System Evaluation of Prefabricated Building Construction Based on Analytic Hierarchy Process

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Abstract: With the spread of prefabricated building construction concept in civil engineering, the traditional construction measurement technology is in the stage of technological iteration and renewal.Although the current technology update iteration is fast, there is no standard model to evaluate the merits and demerits of different measurement systems at present, which leads to the long period of putting new technology applied to indoor measurement into practice. Therefore, this paper constructs an evaluation model, which can be applied to the evaluation of various measurement systems.This paper analyzes the optimization problem of the construction acceptance measurement system under the prefabricated building construction concept. In order to better weigh the complexity factors of construction acceptance, this paper constructs an analytic hierarchy process evaluation model for the optimal construction acceptance measurement system, and carries out fuzzy comprehensive evaluation by means of expert evaluation and questionnaire survey. It is concluded that under the concept of assembly building construction measurement, emphasis should be placed on the influence of measurement precision, measurement efficiency and labor cost on the optimization of measurement system.

1. Introduction

In recent years, with the rapid development of science and technology and economy, people's demand for housing is getting higher and higher. But construction is still a less automated industry than other industries. The concept of prefabricated building [1] is put forward, which is a kind of innovation to the construction industry. At present, there are still many practical feasibility problems to fully realize the industrialization of prefabricated buildings Figure 1. This paper discusses the construction measurement problems under the prefabricated building concept, summarizes and analyzes the indoor inspection problems in the actual construction acceptance process, and constructs a more systematic survey and evaluation model for prefabricated building.With the rise of prefabricated buildings, the construction efficiency of the construction industry has been greatly improved, but the traditional mode of construction acceptance measurement has the problem of low efficiency. The inefficiency of construction acceptance and safety inspection often leads to the long construction project cycle.

Referring to PDCA cycle in quality management system [2,3], this paper proposes a cyclic quality improvement method. The method includes steps: planning, implementation, inspection and disposal. Based on the PDCA cycle theory, we get a point of view: in the whole construction process under the prefabricated building concept, inspection is one of the key links to ensure construction safety and construction quality. With the advance of prefabricated building construction, the traditional measurement methods in the construction process will gradually withdraw from the construction acceptance process. It will be replaced by more efficient, high-precision measurements. However, as a building construction environment with a high degree of non-linearity [4], the realization cycle of the automation degree of the whole industry will be longer. The main reasons include :(1) the particularity of the construction scene, and the construction technology cannot be directly promoted through a standardized technology in the entire construction industry. (2) The construction process is complex. During the whole construction process, it is necessary to rely on workers to make practical judgment on the application of the process. (3) Consistency of standards of building measurement technology. The current construction detection means have certain universality in practice with the development of science and technology. However, due to the lack of unification of measurement standards for the current process measurement accuracy with the standards of the construction industry, many construction units have not carried out relevant technology promotion.

In order to better realize the optimal building survey mode under the prefabricated building concept, the survey technical means under the construction acceptance and other scenarios are improved under the premise of ensuring the accuracy and feasibility of the construction process [5].This paper analyzes and studies the measurement and evaluation problems of construction acceptance and indoor measurement of buildings, and constructs a relatively objective evaluation model for the whole measurement standard through the actual measurement technology, evaluation standard, measurement principle and existing technical means in indoor measurement.

Figure 1: Prefabricated building construction.

2. Key Points of Measurement Technology Evaluation under the Prefabricated Building Concept

In this paper, combined with the development status of prefabricated buildings in China and measurement technology means, analysis of the current construction acceptance, building indoor measurement work technical points.

2.1. The Development Status of Prefabricated Buildings and Measurement Techniques

Prefabricated building has been developing rapidly in the global field in recent years, and concrete houses are manufactured through on-site assembly and manufacturing [6]. Compared with traditional buildings, prefabricated buildings can greatly improve production efficiency and greatly improve the utilization rate of human resources, thus shorting the production period [7]. Due to the great improvement of building efficiency, advanced digital mapping technology can promote the rapid development of China's construction industry [8]. Traditional indoor building measurement with the help of ruler and other tools sampling measurement, measurement efficiency is low, the accuracy is poor, and the level of automation is low. So based on the laser scaning sensor to the indoor measurement of automatic measuring equipment began to appear， see our example below Figure.2. Although the current has more innovative indoor measurement technology, but the current market promotion scope is small. The reason for this phenomenon is that there is not a standard for comparison between the traditional construction acceptance measurement system and the existing measurement system. If you want to continuously improve and optimize the indoor measurement system, it is necessary to build an evaluation model.

Figure 2: Traditional＆Automatic measurement method.

2.2. Key Points of Construction Acceptance and Building Indoor Measurement and Evaluation

In order to better build the index of evaluation model for indoor measurement problems, this paper analyzes the measurement problems of construction acceptance.Construction acceptance is accompanied by the detection process of the construction process, usually in the indoor with the indoor actual measurement results to measure whether the construction is qualified. The use of precast concrete has significant advantages over traditional site construction in terms of material efficiency, safety, labor productivity and reduced time, cost and waste. At the same time, in the production of precast concrete, there are high requirements for dimensional accuracy of precast components, flexibility and reusability of formwork and stability of formwork [9]. At the same time for the innovation of measurement technology and means, the efficiency of measurement is also very important. The use of building industrialization technology to improve the economy of prefabricated buildings has attracted widespread attention in the industry [10]. The economy of building survey can be optimized both for the cost of the measurement itself and for the operating requirements of the equipment for the operators. Therefore, the evaluation criteria for building survey are summarized into the following four categories: accuracy,efficiency,the economy of measuring equipment, Practical operation of measuring equipment.

3. Measurement System Evaluation of Prefabricated Building Model Based on Analytic Hierarchy Process

In order to better construct the indoor measurement system evaluation model,this paper adopts the analytic hierarchy process to construct the hierarchical relationship of different factors. Considering the subjectivity of the AHP(analytic hierarchy process) model, this paper constructs a fuzzy evaluation matrix to realize fuzzy evaluation.

3.1. Evaluation Model Based on Analytic Hierarchy Process

Through the actual investigation of the related construction acceptance process and the technical characteristics of the existing acceptance measurement tools. In this paper, the objective is the optimal evaluation of indoor measurement methods, 11 indicators are selected as the initial evaluation indicators from four aspects: Accuracy of measurement, Efficiency of measurement, Economies of measurement, Operation characteristics of measurement.

Table 1: This caption has one line so it is centered.

Target layer	Guidelines Layer	Indicator Layer
Prefabricated building construction measurement constraint Factor U	Accuracy of measurement A_1	Smaller unit of measurement accuracy B_1
		Larger measurement range B_2
		Smaller measurement error B_3
	Efficiency of measurement A_2	Shorter measurement time B_4
		Shorter computation time B_5
		Fewer technicians to perform technical operations B_6
	Economies of measurement A_3	Lower costs to hire workers B_7
		Lower equipment purchase costs B_8
	Operation characteristics of measurement A_4	Higher technology maturity B_9
		Lower technical learning difficulty B_{10}
		Better human-computer interaction B_{11}

Details of evaluation [11]: (1) Accuracy of measurement is an index to measure the specific measurement accuracy in prefabricated buildings. The accuracy of measurement is the key to the evaluation of construction results. Accurate measurement tools can ensure the reliability of measurement results. The evaluation indexes of measurement accuracy in this paper are as follows:Smaller unit of measurement accuracy B1,Larger measurement range B2,Smaller measurement error B3.(2) Efficiency of measurement is a comprehensive index to measure the process time, measurement result calculation time and manual operation time in the whole measurement process in prefabricated buildings. The high efficiency of the measurement process will improve the construction efficiency and benefit the whole construction project. The evaluation indexes of measurement efficiency in this paper are as follows :Shorter measurement time B4,Shorter computation time B5,Fewer technicians to perform technical operations B6.(3) Economies of measurement is a cost index to measure the equipment required by the measurement process, and plays an important role in the process of marketing promotion of the prefabricated building concept. For construction units and construction units, cheaper measuring equipment will be more likely to be used by enterprises. The economic evaluation indexes of measurement in this paper are as follows :Lower costs to hire workers B7 ,Lower equipment purchase costs B8. (4) Operation characteristics of measurement is an evaluation index for the difficulty degree of operation technology of construction technicians. In the measurement process, although the traditional measurement technology may have the problem of backward technology, but the traditional measurement technology in the actual engineering application cycle is longer, so some of the traditional technology application maturity is higher. With the integration and optimization of new technology in the measurement process, the acceptance degree of technical workers to the operation process should be regarded as an important index to evaluate the measurement method. In this paper, the evaluation indexes for measuring practical performance are as follows:Higher technology maturity B9 ,Lower technical learning difficulty B10,Better human-computer interaction B11.

Determination of model scheme layer: The influencing factors of the prefabricated

building construction measurment are the final evaluation object of this paper, which is represented by U, and then establishes the index factor set of the guidelines layer and the indicator layer, as shown in the Table 1.

Determination of the weight of the indicator system: The judgment matrix constructs

judgment matrix according to the order of importance size by comparing two factors in the same level, and the importance level is generally determined by a scale of 1 to 9.

In this paper, 5 experts from the construction industry were invited to analyze and assign the index weights among different levels. The specific results are shown in Tables where Table 2-6 is the weight matrix among factors at different levels, and Table 7 is the weight value of all factors at different levels based on the analytic hierarchy method.

Table 2: Judgment Matrix of A1-A4.

U	A_1	A_2	A_3	A_4	W_i^{UA}	CR
A_1	1	1	1/3	3	0.223	0.057<0.1
A_2		1	1	3	0.293	
A_3			1	3	0.386	
A_4				1	0.098	

Table 3: Judgment Matrix of B1-B3.

A_1	B_1	B_2	B_3	W_i^{AB}	CR
B_1	1	3	1	0.429	0.001<0.1
B_2		1	1/3	0.142	
B_3			1	0.429	

Table 4: Judgment Matrix of B4-B6.

A_2	B_4	B_5	B_6	W_i^{AB}	CR
B_4	1	1	3	0.429	0.001<0.1
B_5		1	3	0.429	
B_6			1	0.142	

Table 5: Judgment Matrix of B7-B8.

A_3	B_7	B_8	W_i^{AB}	CR
B_7	1	3	0.750	0<0.1
B_8		1	0.250	

Table 6: Judgment Matrix of B9-B11

A_4	B_9	B_{10}	B_{11}	W_i^{AB}	CR
B_9	1	3	1	0.429	
B_{10}		1	1/3	0.142	0.001<0.1
B_{11}			1	0.429	

Table 7: Weights of All Factors.

Guidelines Layer	W_i^{UA}	Indicator Layer	W_i^{AB}	Wi^{UB}
A_1	0.223	B_1	0.429	0.096
A_2	0.293	B_2	0.143	0.032
A_3	0.386	B_3	0.429	0.096
A_4	0.098	B_4	0.429	0.126
		B_5	0.429	0.126
		B_6	0.143	0.042
		B_7	0.750	0.290
		B_8	0.250	0.097
		B_9	0.429	0.042
		B_{10}	0.143	0.014
		B_{11}	0.429	0.042

3.2. Construction of Membership Evaluation Set

In order to conduct a better practice test, this paper constructs a survey questionnaire for evaluating data collection. The whole questionnaire adopts the weight scoring system to compare the importance of two indicators, among which the degree of weight indicators used for comparison include:

By constructing five evaluation levels, relatively objective evaluation data can be achieved. According to the specific evaluation data, the evaluation results with high rationality are constructed. As an expert evaluation model, the analytic hierarchy model is very suitable for quality evaluation in the existing construction process. Moreover, the greater the statistical order of magnitude of the method, the higher the reliability of the evaluation results. Therefore, in the process of collecting experimental data, we should emphasize the following aspects: professional industry, profound experience and rationality of the experimental process. In order to meet the above standards, this paper selected 10 technical workers with specific on-site construction experience and related technical experts in the construction unit for the questionnaire survey. Meanwhile, in the process of questionnaire survey, the respondents were selected to conduct the survey under the condition of relative emotional stability, so as to ensure the objectivity and reliability of the data.

According to the data in Table 8, the results can be constructed by membership matrix, and each matrix can be used as the fuzzy set of the criterion layer.

Table 8: The Scores of Experts.

Guidelines Layer	Indicator Layer	Evaluation results				
		Max	Bigger	Normal	Smaller	Min
Accuracy of measurement A_1	Smaller unit of measurement accuracy B_1	8	1	1	0	0
	Larger measurement range B_2	1	7	1	1	0
	Smaller measurement error B_3	3	7	0	0	0
Efficiency of measurement A_2	Shorter measurement time B_4	7	3	0	0	0
	Shorter computation time B_5	4	3	3	0	0
	Fewer technicians to perform technical operations B_6	5	1	4	0	0
Economies of measurement A_3	Lower costs to hire workers B_7	5	2	1	2	0
	Lower equipment purchase costs B_8	1	9	0	0	0
Operation characteristics of measurement A_4	Higher technology maturity B_9	1	7	2	0	0
	Lower technical learning difficulty B_{10}	2	3	5	0	0
	Better human-computer interaction B_{11}	5	5	0	0	0

The Accuracy of measurement evaluation matrix:

$$T_1 = \begin{bmatrix} 0.8 & 0.1 & 0.1 & 0 & 0 \\ 0.1 & 0.7 & 0.1 & 0.1 & 0 \\ 0.3 & 0.7 & 0 & 0 & 0 \end{bmatrix} \quad (1)$$

Efficiency of measurement evaluation matrix:

$$T_2 = \begin{bmatrix} 0.7 & 0.3 & 0 & 0 & 0 \\ 0.4 & 0.3 & 0.3 & 0 & 0 \\ 0.5 & 0.1 & 0.4 & 0 & 0 \end{bmatrix} \quad (2)$$

Economies of measurement evaluation matrix:

$$T_3 = \begin{bmatrix} 0.5 & 02 & 0.1 & 0 & 0 \\ 0.1 & 0.9 & 0 & 0 & 0 \end{bmatrix} \quad (3)$$

Operation characteristics of measurement evaluation matrix：

$$T_4 = \begin{bmatrix} 0.1 & 0.7 & 0.2 & 0 & 0 \\ 0.2 & 0.3 & 0.5 & 0 & 0 \\ 0.5 & 0.5 & 0 & 0 & 0 \end{bmatrix} \quad (4)$$

3.3. Construction of Fuzzy Analytic Hierarchy Process Model for Adaptive Evaluation

Through the formula of fuzzy evaluation formula:

$$\mathrm{M_i} = \mathrm{W_i} \times \mathrm{T_i} \quad (5)$$

the fuzzy evaluation result of each criterion layer can be obtained:

$$\begin{aligned} M_1 &= (0.4862 \quad 0.4433 \quad 0.0572 \quad 0.0143 \quad 0) \\ M_2 &= (\,0.5434 \quad 0.2717 \quad 0.1859 \quad 0 \quad 0) \\ M_3 &= (0.4000 \quad 0.3750 \quad 0.0750 \quad 0 \quad 0) \\ M_4 &= (0.2860 \quad 0.5577 \quad 0.1573 \quad 0 \quad 0) \end{aligned} \quad (6)$$

Fuzzy evaluation results of the whole model:

$$M = (4.5110 \quad 3.7890 \quad 1.1180 \quad 0.6120 \quad 0) \quad (7)$$

4. Conclusions

Combined with the whole experimental data, it can be seen that the optimization and improvement of the measurement process for construction acceptance in the construction industry need to focus on the influence of measurement accuracy and measurement efficiency on the optimization of the measurement system. Based on the evaluation system based on the indoor measurement technology, based on the expert scoring way of data collection, hierarchical analysis model, the fuzzy evaluation model is set up, weight results from the hierarchical analysis model, it is easy to found that the highest weights of Lower costs to hire workers, weigh the related factors, the author of this paper concludes the traditional human measurement method is the mainstream of indoor measurement technology, with the concept of prefabricated construction promotion and practice of this technology to the human cost is higher. From the perspective of civil engineering construction and project scheme optimization, less labor cost and non-human measurement mode will be a more promising measurement technique in the future.

Through the result of fuzzy evaluation model, it is not difficult to find that the measurement precision and measurement efficiency of equipment are still the key measurement standards of engineering technology in the whole construction acceptance measurement evaluation. At present, the prefabricated building model has been initially promoted in some construction units in China. However, with the gradual transformation of the prefabricated building concept into practice in civil engineering, the traditional technical means of civil engineering are faced with the demand of technical update, which means that more comprehensive research results need to be applied in prefabricated buildings in the future.

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