

A Diagnosis Method of Implementation State Management in Large-Scale Construction Projects

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Abstract In the diagnosis researches on the implementation status of large-scale construction engineering projects (CEP), two major problems remain unsolved yet by far. On one hand, there is not a scientific approach to extract and determine the diagnosis indicators for the implementation status. On the other hand, it still lacks an effective method to analyze and diagnose the implementation status. As an improvement, in this paper these two problems are studied respectively. According to the three required conditions for the implementation status diagnosis, the determination approach based on quantitative scoring for the index setup is firstly presented. All of the indicators are transformed and standardized into the range value forms within [0,1]. Then, the recursive analysis method and model of the diagnosis indicators, which combines the model-based method together with the characteristic based method at the meantime, is proposed, and the grading judgment standards for the implementation status of CEP are presented based on the windage principle. Finally, an indemnificatory housing project which contains 21 residential buildings is taken for a case study to validate the proposed method. It is shown that the proposed method is able to effectively obtain the actual implementation status of large-scale construction projects and find out the exact problems as well as the targeted measures.

Keywords: construction project, implementation state management, diagnosis index system

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1. Introduction

In order to scientifically diagnose the implementation status of the construction projects, the diagnostic index system of construction project implementation status has been established base on the researches on the engineering practice and rough set (RS) theory [1]. However, it still needs at least three conditions to carry out the established index system for the practical diagnosis. First, it requests adequate samples, data and indicators for comparison and analysis to effectively indicate whether the diagnosis index is within the normal status. Second, it requires a diagnostic method, which is able to scientifically calculate the diagnosis indicators and obtain the diagnosis evaluation, to set up the scientifically theoretical basis for the analysis on the specific problems and the impact of these problems on the implementation status. Third, it needs a criterion to detect the exact status of the project based on the data, so that the detection and the diagnosis are qualified.

Obviously, these three conditions are not only the basis of analyzing and diagnosing all kinds of problems, but also the indispensable tools to verify and detect the project implementation status. It is therefore significant to study the aforementioned issues to obtain the scientific diagnosis result on the project implementation status.

By far, there is still not a uniform regulation to determine the standard diagnosis index at home and abroad. Commonly, the diagnosis index is determined in particular according to the specific study objects. For instance, in the medical field the diagnosis index is usually established according to the statistics analysis on the sufficient cases and the experimental studies [2]. In mechanical fault diagnosis field, the normal running parameters have been already tested by large amount of experiments and these parameters can be employed as the references to detect the exact status of the machines [3]. However, in the engineering management field, the diagnosis index is generally established based on the experience, the standard citation, the reference usage, the survey, and the experiments. Since in different fields the methods are varied, the established diagnosis index systems have their specific application scopes [4].

The aim of this paper is to establish an effective diagnosis approach for the implementation state management in large-scale construction projects, with the objective of getting the aforementioned three conditions. In this paper, by following the required three conditions, the two key issues, namely the approach to extract and determine the diagnosis indicators, and the method to analyze and diagnose the implementation status of large-scale construction projects, are studied, respectively. The remainder of this paper is constructed as follows. The

approach to extract and determine the diagnosis indicators is presented in detail in Section 2, while the method to analyze and diagnose the implementation status is comprehensively studied in Section 3. Then the case study which takes an indemnificatory housing project as the study object is carried out in Section 4 to validate the proposed method. Finally, the main conclusions are drawn up in Section 5.

2. Approach to Extract and Determine Diagnosis Indicators

2.1. Analysis and Determination on Diagnosis Index

The established diagnosis index system, which has been applied in the practical construction projects, includes many kinds of diagnosis indicators. The diversity of the indicators brings in difficulties for the method selection and the setup of the diagnosis indexes. Generally, there are three types of diagnosis indicators. The first one is the indicators that have clarified indexes. Taking the project quality as an example, the national standard named *Unified Standards for Acceptance of Construction Quality* has clear items about the assessment method as well as the specific parameters such as the dimensions, the flatness, the perpendicularity, and the mechanical mechanics properties of the materials. More examples can be also found in the safety management field (with the standard named *Standard Guide for Safety Inspection*) and the environmental protection field (with the standards titled *Integrated Wastewater Discharge Standard*, *Integrated Emission Standard of Air Pollutants*, *Standard for Environmental Vibration in Urban Areas*, and *Noise Limits for Construction Site*, respectively). Since all construction projects have to follow the rules of these standards, these released standards can be employed as the references to determine the diagnosis indicators.

The second type is the indicators which have already been attached in the project, such as the project investment, the construction scale, the construction area, the completion time, and the concerned regulations that have been already made in advance. Once the project is carried out, the exact limitations will be applied to these indicators such as the money, the period, the materials, and the sites. Consequently, the corresponding indicators can be set up according to the exact limitations.

The third type is the indicators without specific or clear standards, such as the work efficiency of the staff, the coordination efficiency, etc. Due to the diversity of the projects, the management contents will be adjusted and revised according to the varied project requirements. However, there are still two common characteristics for these indicators. First, these indicators are often determined in a qualitative or semi-quantitative form. Second, although these indicators satisfy all the specific requirements and rules of an actual project, most contents of these indicators are still universal.

In the practical engineering, to make full use of the established standards and regulations, the project managers often carry out the evaluation by means of giving an exact score to the implementation effect. Such method has been widely used in practice and has received a common acceptance. This kind of method provides a good reference for the indicator establishing in construction projects. To make such method not only satisfies all of the requirements of the projects but also practically applicable in actual engineering, the detailed contents of the standards and rules are divided into different items which can be evaluated by varied scores. Consequently, the quantitative indicators are brought in to the original qualitative management items, and all of the diagnosis indicators of the index system can be fully determined.

2.2. Quantitative Transformation and Standardization of Indicators

During the study on the diagnosis index system, there are two extra problems that need to be considered simultaneously, namely the quantitative transformation and the standardization of the indicators.

During the assessment on the project implantation status, the analytical results obtained based on the different standards include both the qualitative indicators and the quantitative indexes. Hence, the diagnosis results of the indexes are diversified. For the sake of normalized evaluation, all of the diagnosis results need to be quantified. Generally, there are three types of diagnosis results, namely the qualitative results, the quantitative results, and the semi-quantitative results. For the first type of the diagnosis indicators, the exact score values can be obtained according to the national and the departmental standards. For the second type of the diagnosis indicators, the detailed evaluation scores can be obtained based on the difference comparison between the actual values and the planned values. For the third type of diagnosis indicators, the exact evaluation scores can be adaptively obtained based on the comparison between the standard values and the diagnosis index values given by table indexes. Finally, all of the diagnosis indicators can be transformed into the quantitative forms.

The other issues about the diagnosis standardization are caused due to the diversity of the diagnosis contents. Some of the diagnosis results may be percentage values, some may be binarization values which are either zero or one, and some may be numerical values. Therefore, although the diagnosis results have all been transformed into the quantitative forms, they are still not standard and will be inconvenient to the comprehensive assessments on the implementation status of the construction projects. To deal with this problem, the indicators need to be standardized as well when they are transformed into the quantitative forms. In this paper, all of the indicator values are transformed into the decimal forms which are in the range of [0,1] based on the practical experiment experience and experts' professional suggestions.

3. Method to Analyze and Diagnose Implementation Status

3.1. Recursive Analysis Methods and Models of Diagnosis Indicators

Since the managers at different levels request different information about the implementation status of the construction project, the analysis/diagnosis on the implementation status can be classified into two types. One is the analysis and diagnosis on the general state of the project to offer a basis for the meso and macro decision, namely the meso-macro diagnosis, while the other is the detailed analysis on the specific problems to find out the exact causes as well as the targeted measures, namely the micro diagnosis. The managers at higher levels usually focus more on the meso-macro diagnosis to make sure the project is well ongoing as scheduled, while the operators and the managers at lower levels primarily pay more attention to the micro diagnosis to make sure that they can detect and deal with the exact problems in time to keep the project under control. Given that both the meso-macro and the micro analysis/diagnosis are based on the micro diagnosis results, they should be both started with the micro analysis.

In terms of the diagnosis methods, no matter in the mechanical fault diagnosis or in the medical field, there are generally two types, namely the model based method and the characteristic based method [6]. The model based method primarily relies on the control theory and treats the study object as a dynamic system with a certain input-output mapping relationship. The analysis/diagnosis based on such method therefore needs to set up the model first. But during the model setup there are lots of nonlinear and time-varying factors which will bring in great difficulties for the diagnosis on the implementation status of the construction projects. Moreover, some feedback information is incomplete, not true, or not effective, which means the input is somewhat invalid and will greatly affect the correctness of the diagnosis result. Therefore, regardless the advantages of this method in theoretical accuracy, it is still too complex and too hard to be applied before completely and practically transformed, since there are too many disturbing noises included in the engineering data. Alternatively, the characteristic based method is employed more frequently to deal with the practical engineering problems. In this method, the valid analysis and evaluation on the characteristics of the information is the key point, since it will directly affect the determination of the diagnosis indicators whose exact values are the basis for the further diagnosis.

However, either of these two methods has its own unique features. On one hand, for the model based method, once the inputs are determined, the output of the results will be very fast. Therefore it is quite convenient for the programming and the efficiency improvement. On the other hand, the characteristic based method is able to effectively solve the nonlinear and time-varying problems by taking into account the practical experiences of the managers.

In this paper, we propose a new approach which combines the aforementioned two methods together for the implementation status diagnosis in large-scale construction projects. The proposed approach explores the full use of the advantages of the two methods in different levels. It employs four layers of indicators for the micro diagnosis and mainly based on the characteristic analysis to up mostly deal with the nonlinear and time-varying problems, while uses three layers of indicators for the meso-macro diagnosis and primarily relies on the model based analysis to get the utmost effect in the mathematical preciseness.

Assume that there are j types of implementation status in the i stages, and each type of the implementation status contains k diagnosis indicators, then it has

$$\alpha_{ij} = \sum_1^k \alpha_{ijk} \omega_{ijk} \quad (1)$$

where α_{ijk} is the value of the diagnosis indicators, α_{ij} is the composite diagnosis result, and ω_{ijk} is the weight factor.

To obtain the implementation status of Stage i , all of α_{ij} should be calculated first, and then perform the further calculation via

$$\alpha_i = \sum_1^k \alpha_{ij} \omega_{ij} \quad (2)$$

where α_i is the composite result of the Stage i , and ω_{ij} is the weight factor. During the diagnosis, the value of j will vary according to i .

Since Eqs. (1) and (2) are universal, they are the very recursive analysis models for the implementation diagnosis.

3.2. Criteria for Diagnosis Results

After completing the diagnosis and obtaining the exact indicator values, it still needs to further assess the project implementation status and therefore requests a criterion.

In theory, it is easy to detect whether the study result is consistent to the expected one, since it can be obtained based on the general principles of the windage analysis [7]. Assume that α represents the general diagnosis value of the implementation state of the project, while $[\alpha]$ represents the allowable value of α , then the ratio of α to $[\alpha]$ could be used as the general criterion to detect whether the project is out of state. Specifically, the general criterion model can be written as

$$\lambda = \frac{\alpha - [\alpha]}{[\alpha]} = \frac{\Delta\alpha}{[\alpha]} \quad (3)$$

In the medical field, people's health condition is classified into three cases based on this model, namely healthy, sub-healthy and pathological [8]. Similarly, in the mechanical fault diagnosis field, the equipment state is also divided into three conditions, namely good, normal and abnormal [9]. In these aforementioned disciplines, the

diagnosis methods will be varied according to the state changes due to the variation of the surrounding factors. Actually, this kind of condition classification method is pretty universal. Taking the construction project as an example, the implementation status will also vary due to the changes of the impacting factors. Therefore, the diagnosis value of the complementation should be a range value.

However, the range value based method has the bad side of unstable domain boundary due to the obvious fuzziness in the determination of the threshold [8]. Therefore, it is better to modify the boundary values based on the large amount of statistics analysis and the sufficient practical experiences. Consequently, the detailed criterion to detect the exact implementation status of a construction project, which is established by taking into account the experts' suggestions and the experimental results, is shown as Table 1.

Table 1. Criterion to assess implement status of construction projects

Indicator values	>0.95	0.94-0.85	0.84-0.75	0.74-0.65	<0.65
Implement status	Excellent	good	Not bad	poor	Very poor

4. Case Study

4.1. Brief Introduction to the Case

In this section, an indemnificatory housing project, which contains 21 residential buildings and occupies the construction area of 261,200 square meters, is taken as the study case. In order to ensure the timely completion of the project, not only the detailed operating rules and the management regulations/standards are proposed, but also the specific requirements in the construction quality, the entire progress, the cost, the security, and the environmental protection aspects, are drawn up according to the national standards as well as the project investment and schedule. During the construction, the proposed method of this paper is applied to the monitoring and the management on the project.

Limited by the space, the No. 10 building is taken as an example. The diagnosis and analysis is carried out on the construction quality, the construction progress, the cost, the security, the environmental protection, the risk, and the resources. The diagnosis results for each indicator of the index system are shown in Table 2.

Table 2. Diagnosis results of the study case

category	Index code	Diagnostic value	category	Index code	Diagnostic value
construction quality	IC111	0.67	Environment protection	IC511	0.00
	IC112	0.88		IC512	0.125
	IC113	0.86		IC513	0.10
	IC121	0.98		IC521	0.20
	IC122	0.00		IC522	0.00
	IC123	0.98		IC523	0.00
	IC124	1.00		IC524	0.72
	IC125	0.98		IC525	0.125
Construction progress	IC211	1.00	Construction risk	IC526	0.00
	IC212	0.80		IC527	0.00
	IC221	0.33		IC611	0.66
	IC222	0.00		IC612	0.53
project cost	IC311	0.67	resource backup	IC621	0.52
	IC312	0.53		IC622	0.40
	IC321	0.97		IC711	0.52
	IC322	0.97		IC712	0.74
construction safety	IC411	0.48	IC721	0.76	
	IC412	0.35	IC722	1.00	
	IC413	0.50	IC731	0.25	
	IC414	0.28	IC732	0.97	
	IC421	0.39	IC741	0.35	
	IC422	0.83	IC742	0.875	
	IC423	0.54	IC751	0.94	
	IC424	0.84	IC752	0.98	
Other	IC811	0.68	IC761	0.46	
	IC821	0.80	IC771	0.66	
	IC822	0.736	IC781	0.44	
			IC782	0.90	

4.2. Analysis on Implementation Status of Building 10

Assume that the diagnostic value of each indicator is α_{ijk}^m , and the weight factor is ω_{ijk}^m , where m is the building number, and $i=1\sim 8$. The meaning of the remaining symbols is consistent with the proposed diagnosis model.

Since the indoor and the outdoor facilities have not been installed and there is no exhaust gas emission, the weight factors of the construction quality and the environmental protection need to be modified. According to the revised weight factors and the diagnostic values listed in Table 2, the diagnostic results of each item are as follows.

1) Construction quality α_1^{10}

$$\alpha_1^{10} = \left| \alpha_{11}^{10} \quad \alpha_{12}^{10} \right| \left| \begin{matrix} \omega_{11}^{10} \\ \omega_{12}^{10} \end{matrix} \right|$$

$$= \left| \begin{matrix} \alpha_{111}^{10} & \alpha_{112}^{10} & \alpha_{113}^{10} & 0 \\ \alpha_{121}^{10} & \alpha_{122}^{10} & \alpha_{123}^{10} & \alpha_{124}^{10} \end{matrix} \right| \left| \begin{matrix} \omega_{111}^{10} & \omega_{121}^{10} \\ \omega_{112}^{10} & \omega_{122}^{10} \\ \omega_{113}^{10} & \omega_{123}^{10} \\ 0 & \omega_{124}^{10} \end{matrix} \right| \left| \begin{matrix} \omega_{11}^{10} \\ \omega_{12}^{10} \end{matrix} \right| \quad (4)$$

$$= \left| \begin{matrix} 0.67 & 0.88 & 0.86 & 0 \\ 0.98 & 0.98 & 1.00 & 0.98 \end{matrix} \right| \left| \begin{matrix} 0.31 & 0.26 \\ 0.35 & 0.25 \\ 0.34 & 0.25 \\ 0 & 0.24 \end{matrix} \right| \left| \begin{matrix} 0.43 \\ 0.57 \end{matrix} \right|$$

$$= |0.35 \quad 0.56| = 0.91$$

where ω_{ijk}^m is the revised weight factor.

2) Construction Progress α_2^{10}

$$\alpha_2^{10} = \left| \alpha_{21}^{10} \quad \alpha_{22}^{10} \right| \left| \begin{matrix} \omega_{21}^{10} \\ \omega_{22}^{10} \end{matrix} \right| = \left| \begin{matrix} \alpha_{211}^{10} & \alpha_{212}^{10} \\ \alpha_{221}^{10} & \alpha_{222}^{10} \end{matrix} \right| \left| \begin{matrix} \omega_{211}^{10} & \omega_{221}^{10} \\ \omega_{212}^{10} & \omega_{222}^{10} \end{matrix} \right| \left| \begin{matrix} \omega_{21}^{10} \\ \omega_{22}^{10} \end{matrix} \right|$$

$$= \left| \begin{matrix} 1.00 & 0.80 \\ 0.33 & 0 \end{matrix} \right| \left| \begin{matrix} 0.49 & 0.49 \\ 0.51 & 0.51 \end{matrix} \right| \left| \begin{matrix} 0.44 \\ 0.56 \end{matrix} \right| \quad (5)$$

$$= |0.40 \quad 0.08| = 0.48$$

3) Project cost α_3^{10}

$$\alpha_3^{10} = \left| \alpha_{31}^{10} \quad \alpha_{32}^{10} \right| \left| \begin{matrix} \omega_{31}^{10} \\ \omega_{32}^{10} \end{matrix} \right|$$

$$= \left| \begin{matrix} \alpha_{311}^{10} & \alpha_{312}^{10} & 0 \\ \alpha_{321}^{10} & \alpha_{322}^{10} & \alpha_{323}^{10} \end{matrix} \right| \left| \begin{matrix} \omega_{311}^{10} & \omega_{321}^{10} \\ \omega_{312}^{10} & \omega_{322}^{10} \\ 0 & \omega_{323}^{10} \end{matrix} \right| \left| \begin{matrix} \omega_{31}^{10} \\ \omega_{32}^{10} \end{matrix} \right| \quad (6)$$

$$= \left| \begin{matrix} 0.67 & 0.53 & 0 \\ 0.97 & 0.97 & 0.80 \end{matrix} \right| \left| \begin{matrix} 0.45 & 0.36 \\ 0.55 & 0.34 \\ 0 & 0.30 \end{matrix} \right| \left| \begin{matrix} 0.44 \\ 0.56 \end{matrix} \right|$$

$$= |0.26 \quad 0.51| = 0.77$$

4) Construction safety α_4^{10}

$$\alpha_4^{10} = \left| \alpha_{41}^{10} \quad \alpha_{42}^{10} \right| \left| \begin{matrix} \omega_{41}^{10} \\ \omega_{42}^{10} \end{matrix} \right|$$

$$= \left| \begin{matrix} \alpha_{411}^{10} & \alpha_{412}^{10} & \alpha_{413}^{10} & \alpha_{414}^{10} \\ \alpha_{421}^{10} & \alpha_{422}^{10} & \alpha_{423}^{10} & \alpha_{424}^{10} \end{matrix} \right| \left| \begin{matrix} \omega_{411}^{10} & \omega_{421}^{10} \\ \omega_{412}^{10} & \omega_{422}^{10} \\ \omega_{413}^{10} & \omega_{423}^{10} \\ \omega_{414}^{10} & \omega_{424}^{10} \end{matrix} \right| \left| \begin{matrix} \omega_{41}^{10} \\ \omega_{42}^{10} \end{matrix} \right| \quad (7)$$

$$= \left| \begin{matrix} 0.48 & 0.35 & 0.50 & 0.28 \\ 0.39 & 0.83 & 0.54 & 0.84 \end{matrix} \right| \left| \begin{matrix} 0.25 & 0.26 \\ 0.27 & 0.23 \\ 0.24 & 0.26 \\ 0.24 & 0.25 \end{matrix} \right| \left| \begin{matrix} 0.41 \\ 0.59 \end{matrix} \right|$$

$$= |0.16 \quad 0.38| = 0.54$$

5) Environment protection α_5^{10}

$$\alpha_5^{10} = \left| \alpha_{51}^{10} \quad \alpha_{52}^{10} \right| \left| \begin{matrix} \omega_{51}^{10} \\ \omega_{52}^{10} \end{matrix} \right|$$

$$= \left| \begin{matrix} \alpha_{511}^{10} & \alpha_{512}^{10} & \alpha_{513}^{10} & 0 & 0 & 0 \\ \alpha_{521}^{10} & \alpha_{522}^{10} & \alpha_{523}^{10} & \alpha_{524}^{10} & \alpha_{525}^{10} & \alpha_{526}^{10} \end{matrix} \right| \left| \begin{matrix} \omega_{511}^{10} & \omega_{521}^{10} \\ \omega_{512}^{10} & \omega_{522}^{10} \\ \omega_{513}^{10} & \omega_{523}^{10} \\ 0 & \omega_{524}^{10} \\ 0 & \omega_{525}^{10} \\ 0 & \omega_{526}^{10} \end{matrix} \right| \left| \begin{matrix} \omega_{51}^{10} \\ \omega_{52}^{10} \end{matrix} \right|$$

$$= \left| \begin{matrix} 0 & 0.125 & 0.1 & 0 & 0 & 0 \\ 0.20 & 0 & 0.72 & 0.13 & 0 & 0 \end{matrix} \right| \left| \begin{matrix} 0.31 & 0.16 \\ 0.34 & 0.18 \\ 0.35 & 0.20 \\ 0 & 0.17 \\ 0 & 0.15 \\ 0 & 0.14 \end{matrix} \right| \left| \begin{matrix} 0.35 \\ 0.65 \end{matrix} \right| \quad (8)$$

$$= |0.03 \quad 0.15| = 0.18$$

where ω_{ijk}^m is the modified weight factor.

6) Risk management α_6^{10}

$$\alpha_6^{10} = \left| \alpha_{61}^{10} \quad \alpha_{62}^{10} \right| \left| \begin{matrix} \omega_{61}^{10} \\ \omega_{62}^{10} \end{matrix} \right|$$

$$= \left| \begin{matrix} \alpha_{611}^{10} & \alpha_{612}^{10} \\ \alpha_{621}^{10} & \alpha_{622}^{10} \end{matrix} \right| \left| \begin{matrix} \omega_{611}^{10} & \omega_{621}^{10} \\ \omega_{612}^{10} & \omega_{622}^{10} \end{matrix} \right| \left| \begin{matrix} \omega_{61}^{10} \\ \omega_{62}^{10} \end{matrix} \right| \quad (9)$$

$$= \left| \begin{matrix} 0.66 & 0.53 \\ 0.52 & 0.40 \end{matrix} \right| \left| \begin{matrix} 0.47 & 0.47 \\ 0.53 & 0.53 \end{matrix} \right| \left| \begin{matrix} 0.49 \\ 0.51 \end{matrix} \right|$$

$$= |0.28 \quad 0.23| = 0.51$$

7) Resource management α_7^{10}

$$\begin{aligned}
 \alpha_7^{10} &= \left| \alpha_{71}^{10} \ \alpha_{72}^{10} \ \alpha_{73}^{10} \ \alpha_{74}^{10} \ \alpha_{75}^{10} \ \alpha_{76}^{10} \ \alpha_{77}^{10} \ \alpha_{78}^{10} \right| \\
 &\quad \cdot \left| \omega_{71}^{10} \ \omega_{72}^{10} \ \omega_{73}^{10} \ \omega_{74}^{10} \ \omega_{75}^{10} \ \omega_{76}^{10} \ \omega_{77}^{10} \ \omega_{78}^{10} \right|^T \\
 &= \begin{vmatrix} \alpha_{711}^{10} & \alpha_{712}^{10} \\ \alpha_{721}^{10} & \alpha_{722}^{10} \\ \alpha_{731}^{10} & \alpha_{732}^{10} \\ \alpha_{741}^{10} & \alpha_{742}^{10} \\ \alpha_{751}^{10} & \alpha_{752}^{10} \\ \alpha_{761}^{10} & \alpha_{762}^{10} \\ \alpha_{771}^{10} & \alpha_{772}^{10} \\ \alpha_{781}^{10} & \alpha_{782}^{10} \end{vmatrix} \begin{vmatrix} \omega_{711}^{10} & \omega_{721}^{10} & \omega_{731}^{10} & \omega_{741}^{10} & \omega_{751}^{10} & \omega_{761}^{10} & \omega_{771}^{10} & \omega_{781}^{10} \\ \omega_{712}^{10} & \omega_{722}^{10} & \omega_{732}^{10} & \omega_{742}^{10} & \omega_{752}^{10} & \omega_{762}^{10} & \omega_{772}^{10} & \omega_{782}^{10} \end{vmatrix} \begin{vmatrix} \omega_{71}^{10} \\ \omega_{72}^{10} \\ \omega_{73}^{10} \\ \omega_{74}^{10} \\ \omega_{75}^{10} \\ \omega_{76}^{10} \\ \omega_{77}^{10} \\ \omega_{78}^{10} \end{vmatrix} \\
 &= \begin{vmatrix} 0.52 & 0.74 \\ 0.76 & 1.00 \\ 0.75 & 0.97 \\ 0.65 & 0.88 \\ 0.94 & 0.98 \\ 0.46 & 0 \\ 0.66 & 0 \\ 0.44 & 0.90 \end{vmatrix} \begin{vmatrix} 0.50 & 0.48 & 0.60 & 0.66 & 0.51 & 1.00 & 1.00 & 0.48 \\ 0.50 & 0.52 & 0.40 & 0.34 & 0.49 & 0 & 0 & 0.52 \end{vmatrix} \begin{vmatrix} 0.10 \\ 0.12 \\ 0.14 \\ 0.13 \\ 0.11 \\ 0.15 \\ 0.12 \\ 0.13 \end{vmatrix} \\
 &= \begin{vmatrix} 0.063 & 0.106 & 0.117 & 0.090 & 0.105 & 0.069 & 0.079 & 0.088 \end{vmatrix} \\
 &= 0.717
 \end{aligned} \tag{10}$$

8) Other issues α_8^{10}

$$\begin{aligned}
 \alpha_8^{10} &= \left| \alpha_{81}^{10} \ \alpha_{82}^{10} \right| \begin{vmatrix} \omega_{81}^{10} \\ \omega_{82}^{10} \end{vmatrix} \\
 &= \begin{vmatrix} \alpha_{811}^{10} & \alpha_{812}^{10} \\ \alpha_{821}^{10} & \alpha_{822}^{10} \end{vmatrix} \begin{vmatrix} \omega_{811}^{10} & \omega_{821}^{10} \\ \omega_{812}^{10} & \omega_{822}^{10} \end{vmatrix} \begin{vmatrix} \omega_{81}^{10} \\ \omega_{82}^{10} \end{vmatrix} \\
 &= \begin{vmatrix} 0.68 & 0 \\ 0.80 & 0.74 \end{vmatrix} \begin{vmatrix} 1.00 & 0.34 \\ 0 & 0.66 \end{vmatrix} \begin{vmatrix} 0.61 \\ 0.39 \end{vmatrix} \\
 &= \begin{vmatrix} 0.41 & 0.30 \end{vmatrix} = 0.71
 \end{aligned} \tag{11}$$

9) General health condition assessment on Building 10

$$\begin{aligned}
 \alpha^{10} &= \left| \alpha_1^{10} \ \alpha_2^{10} \ \alpha_3^{10} \ \alpha_4^{10} \ \alpha_5^{10} \ \alpha_6^{10} \ \alpha_7^{10} \ \alpha_8^{10} \right| \\
 &\quad \cdot \left| \omega_1^{10} \ \omega_2^{10} \ \omega_3^{10} \ \omega_4^{10} \ \omega_5^{10} \ \omega_6^{10} \ \omega_7^{10} \ \omega_8^{10} \right|^T \\
 &= \begin{vmatrix} 0.91 & 0.48 & 0.77 & 0.54 & 0.18 & 0.51 & 0.72 & 0.71 \end{vmatrix} \\
 &\quad \cdot \begin{vmatrix} 0.15 & 0.15 & 0.15 & 0.13 & 0.07 & 0.13 & 0.15 & 0.07 \end{vmatrix}^T \\
 &= 0.63
 \end{aligned} \tag{12}$$

5. Conclusion

This paper proposed a diagnosis method for the implementation status of large-scale construction projects. Specifically, the way to determine the diagnosis indicators,

the method to transform and standardize the indicators, and the assessment standard to judge the diagnosis results, are presented in detail. In the meantime, a specific case study is carried out to validate the proposed method.

It is found that, during the project implementation, if the indicator values, which are employed to describe the implementation status of the project, deviate from the corresponding criteria, the implementation of the project may have been somewhat changed. The larger the deviation value is, the more serious the problem will be in the project. Therefore, the effective management and control of the project can be realized by the analysis and diagnosis on the deviations between the indicator values and the standard values.

It has been proved by several practical projects that the proposed method of this paper can not only find out the specific problems in the project, but also help to make the decision makers aware of the macro state of the project in time. In particular, by applying this method to the management information systems for the automatic diagnosis, the specific problems can be exactly found out, and the targeted measures can be provided. Therefore, the proposed method is an effective new thought and means to deal with the common issues of diagnosis problem finding and solving.

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