Analysis of Obstacle in Promotion of Smart Construction Site Based on ISM- MICMAC Model

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Abstract. As the "last kilometer" of building information management, Smart Construction Site has not landed successfully. It is significance to accurately identify and analyze the obstacles in popularization. Based on the eight obstacle factor indicators defined by factor analysis, we set up an interpretation structure model (ISM) for the promotion of barriers in smart construction sites, and obtain the three-level hierarchical relationships among various factors. Then, MICMAC analysis method was used to calculate the dependency and driving force of each factor, and the interaction between each factor is obtained. Combining ISM and MICMAC analysis results, the obstacles to implementation are the deep-rooted obstacles in the promotion of smart construction sites, while it is linked with economic and target barriers, and has strong relevance. Therefore, three obstacles should be considered as a whole for comprehensive and effective monitoring to ensure the stability of smart construction sites used by construction enterprises.

Keywords. Smart construction site, obstacles, ISM model, MICMAC analysis.

1. Introduction
Construction projects in developing countries often face the problems of project delay and cost overrun [1]. "2016-2020 construction industry informatization development outline" points out that it is necessary to comprehensively improve the informatization level and the integrated application ability of information technology. The "smart site" is based on the structure of "cloud + mobile + Internet of things" [2], and comprehensively applies mobile technology, intelligent equipment and other information technology [3]. It focuses on the construction site management closely around the key elements such as "man-machine, material, method and environment" [4], so as to realize the goal of refined management (reduce cost, protect environment, timely, guarantee quality and quantity).

Recent years, the Ministry of housing and urban rural development has vigorously implemented the "smart site" management system, which has become an inevitable trend, but has not been really promoted [5]. The existing research mainly includes the software integration, dynamic management, and the influence of macro factors such as policy and economy. For example, Feng et al. Summarized the influencing factors as standards, human factors, enterprise capabilities, and senior management support [6]; Liu pointed out that talent guarantee, establishment and perfection of standards and information sharing of collaborative departments had significant impact on its characteristics and application status [7]; Ma proposed the research and development of new technology system, data standard support (enterprise standards, industry standards), and publicity of key projects Transmission effect is the main factor [8]; from the perspective of technical users, HE summed up work habits and thinking difficulties, which greatly affected the smooth development of cooperation [9]. The existing research involves many aspects, which are complex and various, but the evaluation of their importance...
is not clear. Therefore, we make an in-depth study on importance of influence degree of barrier factors.

2. Identification of Influencing Factors
By sorting out the relevant literature at home and abroad [10-16], this paper initially identified 23 common risk factors. On this basis, Delphi method was used to consult 9 experts (including university construction informatization research professor, construction unit engineering personnel of construction informatization direction, design unit design personnel). Combined with the experts' opinions, the opinions of "lack of application experience" are added, and the factor of small average score is deleted. After adjustment, 21 independent factors without subordination were determined, which were used as the evaluation index of barrier factors.

In order to carry out quantitative analysis, according to the industry standards, we issued questionnaires to the construction unit / real estate company / software development company / university teachers at a reasonable ratio of 16:2:1:1. The results of reliability and validity test all met the requirements. Eight barrier factors were extracted by Kaiser's standard orthogonal rotation and named according to their characteristics. By calculating the variance interpretation contribution rate, the weights of indicators are obtained as shown in table 1:

Table 1. Evaluation index system of smart site promotion obstacles.

| Primary indicators | Explanation | Secondary indicators (weight) | Rotational component |
|--------------------|-------------|--------------------------------|----------------------|
| Rule barriers (21.60%) | Reflect the lack of policies and laws | Lack of supportive policies (4.58%) | .932 |
| | | Unclear boundary of duty (4.43%) | .901 |
| | | Lack of relevant standards (4.41%) | .897 |
| | | Lack of laws on intellectual property (3.88%) | .790 |
| Technical barriers (16.80%) | Lack of technical support | Low localization of foreign software (4.4%) | .935 |
| | | Lack of domestic technical support (4.24%) | .903 |
| | | Poor compatibility between software (4.16%) | .886 |
| | | High requirements for staff quality (4.00%) | .850 |
| Economic barriers (14.52%) | Reflect the return on investment | High cost of personnel training (4.98%) | .945 |
| | | High input cost of software / hardware (4.81%) | .914 |
| | | Implicit short-term benefit, unclear ROI (4.53%) | .861 |
| Implementation barriers (12.03%) | Reflect the problems of talents and stakeholders | The external driving force of stakeholders is insufficient (4.48%) | .897 |
| | | Lack of talents (4.43%) | .887 |
| | | Lack of application experience (3.11%) | .863 |
| Management barriers (11.88%) | Overall management of Lack of overall management | The organization mode is not perfect (4.26%) | .913 |
| | | Lack of effective management mode (3.37%) | .912 |
| Cognitive barriers (11.41%) | Reflect concept cognition | Unwilling to change traditional way (3.92%) | 844 |
| | | Lack of cognition (2.93%) | 812 |
| Planning barriers (8.83%) | Reflect planning issues | Lack of planning (2.79%) | .980 |
| | | Lack of planning (2.79%) | .848 |
| Target barriers (3.07%) | Enterprise concept | The goal is not clear (2.5%) | .815 |
3. Construction of ISM-MICMIAC Model

Interpretative structural modeling method decomposes complex system into multi-level hierarchical structure model by logical operation of adjacent matrix. It is effective for building system with multi-objective and complex relationship between elements. MICMIAC is a method to analyze the relationship between the factors in the system. The factors are divided into four clusters by the driving force dependence matrix.

3.1. Construction and Solution of ISM Model

Eight main barrier factors are represented by \( F_1 - F_8 \), and the adjacency matrix \( A \) is established. By using Boolean algebra method, \( A_4 \) is obtained, that is, the reachability matrix \( M = A_4 \), and the output reachability matrix \( R \):

\[
A = \begin{bmatrix}
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 2 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\
0 & 0 & 0 & 0 & 1 & 2 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{bmatrix}
\]

\[
R = \begin{bmatrix}
1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 \\
1 & 1 & 1 & 0 & 0 & 1 & 0 & 0 \\
1 & 1 & 1 & 0 & 0 & 1 & 0 & 0 \\
1 & 0 & 0 & 1 & 1 & 1 & 0 & 0 \\
1 & 1 & 0 & 0 & 1 & 0 & 1 & 1 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 0 & 1 & 1 \\
1 & 0 & 0 & 0 & 1 & 0 & 1 & 1
\end{bmatrix}
\]

The structure of the reachability matrix is divided, and the hierarchical structure of each factor is output by MATLAB, as shown in figures 1-2.

![Figure 1. Output results.](image1.png)

![Figure 2. Hierarchical structure.](image2.png)

3.2. Construction and Solution of MICMIAC Model

Furthermore, MICMIAC analysis is used for matrix iteration operation, and the Boolean number operation is carried out by MATLAB to obtain the final reachable matrix \( M \). The sum of the elements in each row represents the driving force of the factors in the row, that is, the influence of the factors on the system; the sum of the elements in each column represents the dependence of the factors in the column, that is, the influence degree of the factors by other factors. According to the driving force of each row and column, the ranking reachability matrix \( R \) is obtained. As shown in table 2.
Table 2. Driving force and dependence.

| Factors | 6 | 1 | 7 | 2 | 3 | 8 | 4 | 5 | Drive |
|---------|---|---|---|---|---|---|---|---|-------|
| 6       | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1     |
| 1       | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 3 |       |
| 7       | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 3     |
| 2       | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 4     |
| 3       | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 4     |
| 8       | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 4     |
| 4       | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 5 |       |
| 5       | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 5     |
| Dependence | 6 | 4 | 3 | 1 | 4 | 4 | 3 | -|       |

Mark each factor as a point in the four quadrants of the coordinate system, and draw the driving force dependence matrix of the barrier factors of smart site promotion, as shown in figure 3.

Figure 3. Driving force-dependence matrix of barriers factors.

4. Analysis of ISM-MICMIAC Model

4.1. Analysis of Layered Results of ISM Model

The results show that there are 8 main barriers to the promotion of smart site, which are distributed in 4 levels and influence in different ways. As can be seen from figure 3, the first level factors are directly affected by the second level and the third and fourth level indirect influence; the second level factors are directly affected by the third level; the fourth level factors are the root deep-seated barriers. The characteristics are as follows:

(1) The eight barriers were divided into four levels, with a hierarchical relationship from bottom to top. In this paper, the first level is regarded as the surface factor, namely the direct appearance barrier; the second and third level is classified as the middle level factor, namely the indirect middle level barrier; and the fourth level is classified as the deep factor, namely the root deep barrier. The deep-seated factors affect the middle-level factors and surface factors, and ultimately affect the promotion and application.

(2) The barriers of rules, cognition and planning are the surface factors hindering the promotion of smart site, and also the intuitive embodiment of slow implementation. There are four middle-level factors, which are technical barriers, economic barriers, goal barriers and management barriers.

(3) Implementation barriers are the deep-seated and root factors that hinder the promotion of smart site, and have direct or indirect impact on the middle and surface layer. Its improvement is of great significance to the promotion of smart site.

4.2. Analysis of MICMIAC Model Classification Results

The results of MICMIAC are visualized in the driving force dependence coordinates.

(1) Type I. Independent barrier: planning barrier (F7). The dependence and driving force of the factor are weak, indicating that the correlation between the factor and the system is relatively weak, and the correlation between each factor is also relatively weak, as shown in quadrant I.

(2) Type II. Dependent barriers: rule disorder (F1) and cognitive impairment (F6), which have strong interdependence and weak driving force, as shown in quadrant II.
(3) Type III. Linkage barriers: implementation barrier (F4), economic barrier (F3) and target barrier (F8). The driving force and dependence of these barrier factors are strong. Each barrier factor has an impact on other barrier factors, and then feedback back to influence itself, as shown in quadrant III.

(4) Type IV. Spontaneous disturbance: The driving force is strong, but their interdependence is weak.

4.3. Comprehensive Analysis of ISM-MICMIAC Model

(1) Implementation barriers are located in the fourth layer of ISM chart, which are the deep root factors of smart site promotion, which should be focused on in the promotion process; in MICMIAC matrix, it is located in the third quadrant, and belongs to linkage barrier factors with economic barriers and target barriers, which indicates that the three barrier factors have strong correlation and should be regarded as a whole to conduct comprehensive and effective monitoring to ensure the stability of application.

(2) Rules, cognition and planning barriers are direct representation barriers, and the rules and cognitive barriers are in the second quadrant of MICMIAC, which belong to high dependence-low driving force factors. Therefore, rules and cognitive can be regarded as the most intuitive monitoring indicators. Planning barriers belong to independent clusters and have a low impact on other barriers in the system.

(3) Technical and management barriers belong to the middle-level influencing factors in ISM chart, and occupy the spontaneous factor cluster of MICMIAC. This kind of factors have a certain impact on the promotion, but the dependence is weak, which is the most direct barrier factor, and can be used as an important basis for construction enterprises in the management and planning system of smart site.

5. Conclusions and Suggestions

From the future trend and national policy, smart construction site is a revolution of construction informatization. Based on the identification of barrier factors, this paper uses ISM-MICMIAC model to construct the explanation structure model and driving force dependence matrix. This paper puts forward the incentive countermeasures from the perspectives of government and construction enterprises.

5.1. Enterprise Self Development Incentive

(1) Material incentive

The construction personnel are used to the original working mode. Therefore, it is necessary to mobilize the enthusiasm of personnel to actively apply technology through material stimulation, such as:

1) Reasonably determine the salary standard. For employees who actively study and apply new technology, their value should be reflected in the salary level.

2) Reasonable implementation of welfare. To maximize the introduction and retention of relevant technical personnel, employees who actively applied should be given corresponding welfare, such as pension and medical treatment.

(2) Spiritual inspiration

1) Training incentive. Enterprises should pay attention to the training and development of staff. Make the technical level of employees in the forefront of the industry, so as to form enterprise advantages.

2) Emotional motivation. The characteristics of it integrated application of a variety of information technology determine the need for good interaction within the enterprise. The main functions are as follows: (a) it helps to obtain the understanding of enterprise decision-making; (b) it helps personnel express their views on the problems encountered, so as to reduce their negative emotions.

3) Honor encouragement. Enterprises should attach importance to the honor incentive of employees and give affirmation to those who have made outstanding achievements and obtained research results.
5.2. Incentive Measures for Government Security

(1) Tax incentives
   1) Adopt a diversified approach. According to different regions and types of enterprises, different preferential tax policies should be formulated, such as setting up green channels, speeding up the examination and approval, deferring tax payment and other indirect ways.
   2) According to the degree of application. Guide enterprises in the whole life cycle, not limited to a certain stage or node.

(2) Financial subsidy incentive
   The government should give targeted subsidies according to the performance of enterprises or fixed subsidies according to the average level of the industry. Explore appropriate incentive mechanism to integrate the interests of both sides.

(3) Technical support services
   For the lack of standardization, the government should increase the research investment in software and related products. Set up special funds, hold competitions, etc., to improve the awareness of the society.

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