Research on Evaluation Method of Application Maturity of BIM Technology in Transmission and Distribution Engineering Based on Fuzzy Theory

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Abstract: With the continuous development of social economy and science and technology, the promotion and application of BIM technology in the whole process of power transmission and transformation projects is also increasing. Scientific and reasonable evaluation of the application maturity level of BIM technology in power transmission and transformation projects, and further improving the effective integration of BIM technology and power transmission and transformation project construction management, are of great significance for improving the quality of project construction and management efficiency. Therefore, on the basis of systematically sorting out the application scenarios of BIM technology in power transmission and transformation projects, this paper constructs a fuzzy theory-based method for evaluating the application maturity of BIM technology in power transmission and transformation projects, which can effectively guide the promotion and application of BIM technology and further improve transmission construction quality and management efficiency of substation projects.

1. Introduction

BIM is currently one of the most forward-looking developments in the construction industry[1]. It adds digital information technology to the three-dimensional modeling of architectural entities to make the architectural model digitized and intelligent. The connotation of information includes not only geometric information, but also There are various non-geometric information, such as various specific parameters of materials, component cost, component production status[2]. It is a complete, rich and logical building information library.

The effective integration of BIM technology and construction management of power transmission and transformation projects can further improve the quality of project construction and management efficiency[3]. However, at this stage, there is a lack of scientific and reasonable evaluation methods[4], and comprehensive evaluation of the maturity level of BIM technology application in power transmission and transformation projects cannot effectively guide the further promotion and application of BIM technology. Therefore, this article combines the status quo of the application of BIM technology and the construction characteristics of power transmission and transformation projects to construct a fuzzy theory-based evaluation model of the application maturity of BIM technology in power transmission and transformation projects. The application of this model can effectively guide the promotion and application of BIM technology in power grid companies, and
further improve the construction quality and management efficiency of power transmission and
transformation projects.

2. A review of BIM application status in power transmission and transformation projects

The construction of BIM application standards in the power industry is still in its infancy. Problems
such as BIM database construction, BIM software function definition, and BIM data transmission and
exchange and interconnection have severely restricted the application and promotion of BIM
technology in the power industry. Based on the current application status of BIM in power
transmission and transformation projects, this paper carries out an assessment of the maturity of BIM
technology, which can effectively support the application and promotion of subsequent BIM
technology, and can further enrich the scope of application of BIM technology in power grid
companies, and finally establish a coverage of the entire process of power projects A full-resource
integrated platform to create a BIM system suitable for the application of power transmission and
transformation projects, realize more scientific and efficient management of power construction, and
strive to create a new pattern of digital and informatized power grid construction.

3. Construction of BIM application maturity evaluation model for power transmission and
transformation engineering

3.1. Basic principles of the model

This article uses fuzzy analytic hierarchy process to carry out the scientific evaluation of maturity, the
main evaluation process is shown in Figure 1.

![Figure 1. Basic principles of the method.](image)

3.1.1 Basic principles of analytic hierarchy process

The Analytic Hierarchy Process (AHP) is a decision-making method that decomposes the elements
that are always related to decision-making into goals, criteria, plans, etc., on which qualitative and
quantitative analysis is performed. The analytic hierarchy process is suitable for multiple application
scenarios. The main principle of the analytic hierarchy process is to divide the decision-making
problem into different evaluation hierarchies from the top to the bottom according to the general goal,
each level of sub-goals, and evaluation criteria, which can be respectively become the target level and
the criterion Layer, scheme layer, and then combined with the actual relationship between different
levels, using the method of solving the eigenvectors of the judgment matrix, the priority of each
element of each level to an element of the previous level, and finally the weighted sum method The
final weight of each alternative plan to the overall goal is merged in order, and the one with the largest final weight is the optimal plan.

First, according to the importance scale theory, construct a pairwise comparison judgment matrix $A$:

$$ A = (a_{ij})_{n \times n} \quad (i, j = 1, 2, \ldots, n) \quad (1) $$

Then normalize the judgment matrix $A$, the calculation formula is:

$$ \bar{a}_{ij} = a_{ij} / \sum_{k=1}^{n} a_{kj} \quad (i, j = 1, 2, \ldots, n) \quad (2) $$

The calculation formula for weight is:

$$ w_i = \bar{w}_i / \sum_{i=1}^{n} \bar{w}_i \quad (i = 1, 2, \ldots, n) \quad (3) $$

Finally, the consistency is judged. If the consistency test is passed, the result is valid. Fail to adjust the results.

3.1.2 Basic Principles of Fuzzy Evaluation Analysis Method

1) Establish a set of evaluation factors: $U = \{u_1, u_2, \ldots, u_n\}$

Set $U$ is composed of many influencing factors of the evaluation object, which constitutes the evaluation index system. Among them, $u_i (i = 1, 2, \ldots, n)$ is the evaluation index, which is the influencing factor after screening.

2) Establish the judgment set $V = \{v_1, v_2, \ldots, v_m\}$

Judgment set $V$ is composed of different comment levels, such as "excellent, good, qualified", "strong, strong, weak", etc. The determination must be based on the characteristics of the evaluation object. Among them, $m$ represents the number of evaluation levels, and $v_j (j = 1, 2, \ldots, m)$ represents the comments of each indicator. Through the research on the application literature of fuzzy comprehensive evaluation method, it is found that the classification of comment grades in the evaluation process is too simple, so the comment grade standard can be established to explain appropriately.

3) Establish a fuzzy relationship matrix $R$ from $U$ to $V$ (membership matrix)

Summarize the fuzzy membership subsets of each index to obtain the fuzzy relationship matrix $R$, namely:

$$ R = \begin{bmatrix} R_1 \\ R_2 \\ \vdots \\ R_n \end{bmatrix} = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ r_{n1} & r_{n2} & \cdots & r_{nm} \end{bmatrix} \quad (4) $$

4) Determine the weight vector $W = \{w_1, w_2, \ldots, w_n\}$ of the evaluation factor.

5) Synthetic fuzzy comprehensive evaluation result matrix $S$

In summary, the final result of the fuzzy comprehensive evaluation (matrix $S$) is the combination of the weight vector $W$ and the membership matrix $R$, as follows:

$$ S = W \ast R = \begin{bmatrix} w_1 & w_2 & \cdots & w_n \end{bmatrix} \ast \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ r_{n1} & r_{n2} & \cdots & r_{nm} \end{bmatrix} = [s_1, s_2, \ldots, s_m] \quad (5) $$

Where:
\[ s_j = \sum_{i=1}^{n} w_i \cdot r_{ij}, j = 1, 2, \ldots, m \]  

3.2. Construction of evaluation index system and empirical analysis

According to the main field characteristics of BIM in the application of power transmission and transformation engineering, from the perspective of application effects, the extensiveness and in-depthness of BIM in the application of power transmission and transformation engineering are analyzed. Therefore, this article divides the evaluation dimensions into breadth, depth and functional application. Functional completeness refers to the technical ability and problem-solving ability of applying BIM functions, which is measured by indicators such as the degree of model development, information completeness, information interaction ability, information sharing degree, and hardware configuration. The application breadth level is mainly through the application of a single project and different non-professional applications. The application depth level refers to the standard specification and collaboration level of BIM application in the construction process. Therefore, based on the above analysis, an evaluation index system for the application maturity of BIM in power transmission and transformation projects has been established.

Table 1. BIM application maturity evaluation index system.

| First level indicator | Secondary indicators |
|-----------------------|----------------------|
| Application breadth level | Application breadth throughout the project |
|                       | Different professional application breadth |
| Function complete level | BIM function development level |
|                       | BIM information sharing level |
|                       | Completeness of BIM standards |
| Application depth level | BIM application efficiency level |
|                       | Depth level of collaboration |

3.3. Determination of indicator weights

3.3.1 Index weight calculation

According to the basic principles of the Analytic Hierarchy Process in Chapter 3.2, the evaluation index weights are shown in the following table:

Table 2. Calculation results of evaluation index weight value.

| Indicator name                        | Weights |
|---------------------------------------|---------|
| Application breadth throughout the project | 0.1492  |
| Different professional application breadth | 0.0512  |
| BIM information interaction level      | 0.0887  |
| BIM function development level         | 0.0305  |
| BIM information sharing level          | 0.0610  |
| Completeness of BIM standards          | 0.0610  |
| BIM application efficiency level       | 0.1861  |
3.3.2 Determination of evaluation set

The evaluation set is a collection of various general evaluation results that the evaluator may make to the evaluation object. For the comprehensive evaluation and analysis of project effectiveness, the evaluation set is defined:

$$V = \{V_1, V_2, V_3, V_4, V_5\}$$  \hspace{1cm} (7)

Among them, $V_1$, $V_2$, $V_3$, $V_4$, and $V_5$ indicate very mature, mature, medium, generally mature, and immature, respectively. When compiling the scoring table, the four levels of fuzzy expression as shown above are used. The specific results are shown in Table 3.

Table 3. The calculation results of membership degree.

| Indicator name                           | Very mature | Mature | Medium maturity | Generally mature | Immature |
|------------------------------------------|-------------|--------|-----------------|------------------|----------|
| Application breadth throughout the project | 0.52        | 0.25   | 0.13            | 0.10             | 0        |
| Different professional application breadth | 0.56        | 0.34   | 0.10            | 0                | 0        |
| BIM information interaction level        | 0.52        | 0.27   | 0.10            | 0.11             | 0        |
| BIM function development level           | 0.44        | 0.21   | 0.23            | 0.12             | 0        |
| BIM information sharing level            | 0.48        | 0.35   | 0.17            | 0                | 0        |
| Completeness of BIM standards            | 0.41        | 0.36   | 0.12            | 0.11             | 0        |
| BIM application efficiency level          | 0.68        | 0.12   | 0.13            | 0.07             | 0        |
| Depth level of collaboration              | 0.63        | 0.22   | 0.15            | 0                | 0        |

3.3.3 Fuzzy comprehensive evaluation

Fuzzy comprehensive evaluation method is to use fuzzy mathematics and fuzzy statistical methods to make decisions from single factor to multiple factors. Through the establishment of fuzzy matrix, comprehensive evaluation is carried out from the bottom layer to layer by layer, and the evaluation result is obtained. It can be seen from the above that the fuzzy membership degree set of the evaluation index is: $B=(0.583038 \ 0.223731 \ 0.14061 \ 0.052621 \ 0)$ According to the comprehensive judgment of the maximum membership criterion, the BIM application maturity evaluation result is very mature.

4. Conclusion

The deep integration of BIM technology and the construction of power transmission and transformation projects is an inevitable development trend. Therefore, on the basis of analyzing the application scenarios of BIM technology in power transmission and transformation engineering, this paper constructs an evaluation index system for the application maturity of BIM technology from the three dimensions of application breadth, application depth and complete functions, and then constructs an evaluation based on fuzzy theory.

References

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