Study on BIM Maturity Model of Power Industry Based on LWD and LOWA Operator

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Abstract. The construction of domestic smart grid is accelerating, power companies pay more and more attention to the application ability of BIM technology, the three-dimensional forward design is increasingly promoted. And the owner needs a perfect evaluation model to evaluate the BIM maturity of participants, improving their BIM application capabilities. In this paper, the quantified and objective evaluation results are obtained based on LWD and LOWA operator.

Keywords: BIM maturity · LWD operator · LOWA operator

1 Introduction

With the acceleration of smart grid, 3D digital design meets the development needs of smart grid with its advanced design concept, efficient modeling technology, powerful data storage and visual presentation. At present, the State Grid Corporation has successively released many files about the application and evaluation of the three-dimensional design in power transmission and transformation projects, such as Jijianjijing [2018] 44 and Jijianjishu [2020] 25. In the past five years, more and more attention are being paid on the application of BIM technology in grid companies. And the promotion of three-dimensional design of power transmission and transformation projects has been increasingly strengthened. There are many literatures about the application and BIM maturity evaluation in civil construction industry. However, the index system of BIM technology application maturity evaluation cannot be applied to the electric power industry, due to the different industrial characteristics between the electric power industry and the civil building industry. The main reasons are as follows: (1) The power industry has high requirements on the economy and reliability of power supply, and the power grid construction project needs to be coordinated according to the regional economic development. For example, the application of BIM technology in projects with tight construction period may have non-standard process and low model integrity, which is different from the civil construction industry to some extent. (2) The traditional operation mode and information communication and coordination mode of the electric power industry are deeply rooted. Due to the need of information confidentiality and the tedious

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recruitment process of electric power equipment, the BIM model needs to be updated multiple times in the project lifecycle, and the application speed of BIM technology is lower than the civil construction industry; (3) The current academic research lacks systematic summary of driving factors of BIM application in the power industry, and the linkage analysis between factors and the study of influence mechanism. The priority of BIM application maturity evaluation factors analyzed and summarized in the civil building industry does not fully match the power industry, resulting in the lower application level in the power industry. And the systematic summary of BIM application driving factors in electric power industry is insufficient. Therefore, it is necessary to evaluate the BIM application maturity of all project participants in the power industry.

2 BIM Capability Evaluation Index System

In the whole life cycle of power transmission and transformation projects in the power industry, the selection of each participant is critical. The efficiency of BIM information transmission and the BIM model application are affected by the BIM awareness and the BIM ability of the participants, such as design company, construction company, material supplier and equipment supplier. Therefore, the owner needs comprehensive evaluation in the process of selecting participants. The BIM Capability Maturity Model is proposed in NBIMS, it specifies 11 reference indicators to measure that whether the owner's minimum needs are met, specific indicators include: the data richness, life-cycle perspective, change management, multi-professional collaboration, business processes, timeliness, information exchange methods, graphical information, spatial positioning capabilities, accuracy of information, collaborative capabilities, on this basis, the minimum maturity measurement standard for BIM users is put forward, each factor can be decomposed into 10 grades, and users can evaluate each standard according to their own application of BIM, the total score is obtained by multiplying the scores of each criterion and the weights by the model [1], as shown in Fig. 1.

In the power industry, the Owner's responsibility is to coordinate all participants. The collaboration ability in the project directly affects the success. Therefore, when selecting participants in the bidding stage, in addition to evaluating their economic, technical and credit status, attention should also be paid to the investigation of their BIM collaboration ability. On the basis of integrating various indicators in the BIM maturity model and combining the requirements for participants in the actual BIM application, the indicators for evaluating the BIM capabilities of participants are divided into four categories, as shown in Table 1.

The main meanings of the first level indicators are as follows:

a. Model production capacity: the model production capacity of the electric power industry mainly refers to the degree to which each participant constructs and deepens the model, including the construction of the model in the scheme stage, the deepening of the model in the preliminary design stage, and the secondary deepening of the manufacturer of the model in the construction drawing stage. Each participant needs to be able to read, edit, and improve the model.

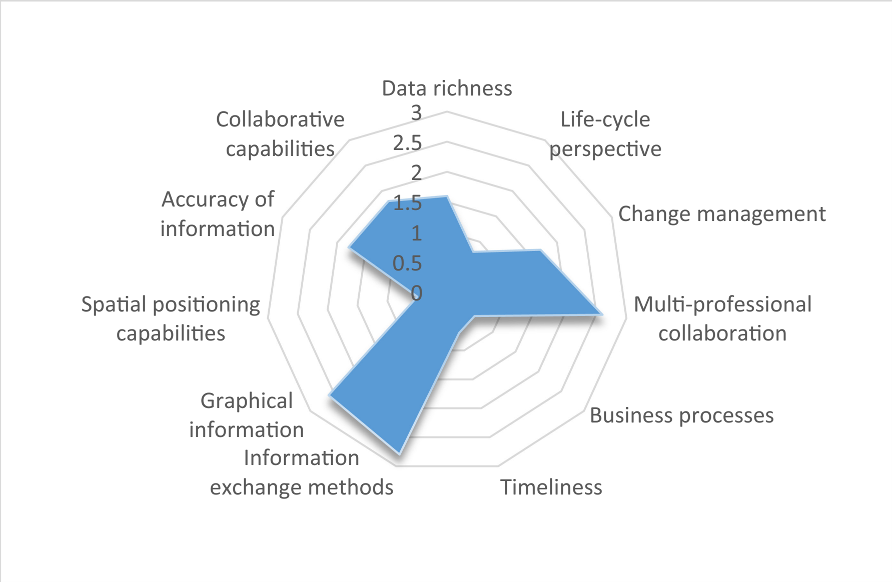

Fig. 1. BIM Maturity Scoring Results

Table 1. BIM Capability Evaluation Index System of Participants

Index	Index decomposition
Model production capacity	BIM software operation capability Accuracy of BIM model Data richness of BIM model
Model cognitive ability	BIM life cycle application Deep mining of BIM value Upgrade and R&D of BIM functions
Project management capability	Improved business processes Adjusted organizational structure Real time response and maintenance of the model
Cooperation ability	Multi professional cooperation ability Information interoperability (IFC)

b. Model cognitive ability: the power industry requires the BIM model to be delivered in GIM format, then the owner will maintenance the model in the operation and maintenance stage. They are key indicators to evaluate the maturity of the BIM application of the participants, including the application of the model in the full life cycle, BIM value mining, secondary development, etc.
c. Project management capability: power grid projects have many cross disciplines and coordination among organizations, and BIM technology integration and application

are difficult. In the whole process management of power transmission and transformation construction projects, all participants, such as the owner, design companies, consulting companies, construction companies, equipment suppliers, and operation and maintenance companies, need to improve business processes and update the organizational structure to achieve real-time response and maintenance of model information.

d. Team cooperation ability: BIM application practice in the construction industry shows that the owner is the biggest beneficiary of BIM technology application. The application of BIM technology in large-scale power transmission and transformation projects, ultra-high voltage projects, and power grid construction projects integrated with urban buildings under complex systems can effectively reduce design omissions and improve information interaction efficiency. Therefore, all participants need to work together to promote BIM technology integration and optimize the BIM collaboration platform. Realize the full sharing of resources in the whole industry chain and improve the ability of refined management.

3 Language Information Evaluation Model Based on LWD and LOWA Operators and Its Application

There is no quantitative evaluation method for the above BIM capability evaluation indicators in the actual comparison and selection process, and most of them only have qualitative language description, such as general, important, poor, etc. Therefore, this paper refers to the information group decision-making method based on language evaluation proposed by Spanish professor Herrera, The LWD (Linguistic Weighted Disjunction) operator and LOWA (Linguistic Ordered Weighted Average) operator are used as the core analysis method to gather expert opinions and rank candidate participants, and assist the power industry owner to judge the BIM application ability of each participant [2, 3].

In the evaluation process, we make the following assumptions:

1) The set of evaluated participants: $S = \{S_1, S_2, \cdots S_n\}(n \geq 2)$, S_i represents the participant I;
2) The evaluation indicator set: $P = \left\{P_1, P_2, \cdots P_q\right\}(q \geq 2)$, P_j represents indicator j;
3) The expert set: $E = \{E_1, E_2, \cdots E_m\}(m \geq 2)$, E_k represents expert k;
4) Weight vector with linguistic form of the evaluation indicator set P made by expert E_k: $R = (r_1^k, r_2^k, \cdots r_q^k)^T$, r_j^k represents that the expert E_k selects an element from the predefined natural language evaluation set to describe the importance of the indicator.
5) Decision Matrix: $A^k = (a_{ij}^k)_{n\times q}$, a_{ij}^k represents that the expert E_k selects an element from the evaluation set as the evaluation value of the participant S_i corresponding to the index P_j.

6) L is a set of seven language phrases: L = {L_0 = FC(Terrible), L_1 = HC(Very poor), L_2 = C(Poor), L_3 = YB(Average), L_4 = Z(Important), L_5 = HZ (Very important), L_6 = FZ(Extremely important)}L has the following properties: ①Orderliness: when $i \geq j$, $L_i \geq L_j$,$i \geq j$ stands for better than or equal to; ②Inverse operator "*Neg*" existence: when $j = T - i$, $Neg(L_i) = L_j$,T represents the number of elements in the collection; ③Maximization and minimization: when $L_i \geq L_j$,$MAX\left(L_i, L_j\right) = L_i$, $MIN\left(L_i, L_j\right) = L_j$.

The basic steps of the evaluation method as follow:

Step 1: Collecting the language evaluation information given by each expert as the comprehensive language evaluation value of candidate participants. Gather language information a_{ij}^k and r_j^k into participant S_i through LWD operator and LOWA operator

$$(a_i^k, r^k) = \varphi[(a_{i1}^k, r_1^k), (a_{i2}^k, r_2^k), \cdots, (a_{iq}^k, r_q^k)], i = 1, 2, \cdots, n, k = 1, 2, \cdots, m$$

a_i^k represents the evaluation value of the expert E_k, r^k represents; φ represents LWD operator:

$$a_i^k = MaxMin(a_{ij}^k, r_j^k), \quad i = 1, 2, \cdots, n, \quad k = 1, 2, \cdots, m \tag{1}$$

$$r^k = \phi_Q\left(r_1^k, r_2^k, \cdots, r_q^k\right), \quad k = 1, 2, \cdots, m \quad r^k \in L, \ \phi_Q \text{ represents LOWA operator} \tag{2}$$

$$r^k = \phi_Q(r_1^k, r_2^k, \cdots, r_q^k) = W^T B = \xi^q\{w_t, r_{\sigma(t)}^k, t = 1, 2, \cdots, q\} = w_1 \otimes r_{\sigma(1)}^k \oplus (1 - w_1) \otimes \xi^{q-1}\{\beta_h, r_{\sigma(h)}^k, h = 2, 3, \cdots, q \tag{3}$$

$W = (w_1, w_2, \cdots w_q)^T$ is a weight vector $w_t \in [0, 1], \sum_{t=1}^{q} w_t = 1, \beta_h = w_h / \sum_{h=2}^{q} w_h, h = 2, 3, \cdots, q$;

$B = (r_{\sigma(1)}^k, r_{\sigma(2)}^k, \cdots r_{\sigma(q)}^k)^T, \forall i \leq j, r_{\sigma(i)}^k \geq r_{\sigma(j)}^k, \sigma(\Theta)$ is an arrangement of natural language R, ξ^q is an operator for convex combination of q linguistic phrases.

When $q = 2, \xi^2\{w_t, r_{\sigma(t)}^k, t = 1, 2\} = w_1 \otimes r_{\sigma(1)}^k \oplus (1 - w_1)\otimes, r_{\sigma(2)}^k = w_1 \otimes L_j \oplus (1 - w_1) \otimes L_i = L_l \; L_i, L_j \in L, (j \geq i), l = Min\{T, i + round(w_1(j - i))\}, r_{\sigma(1)}^k = L_j, r_{\sigma(2)}^k = L_i$

$w_t = Q(t/q) - Q((t - 1)/q), t = 1, 2, \cdots, q$ $Q(u)$ is a fuzzy quantization operator.

$$Q(u) = \begin{cases} 0 & u < d \\ \frac{u-d}{f-d} & d \leq u \leq f \\ 1 & u > f \end{cases} \quad d, f, u \in [0, 1].$$

When adopting: "at least half", "most" and "as much as possible", their corresponding parameters (d, f) is (0, 0.5), (0.3, 0.8), (0.5, 1).

Step 2: aggregate the comprehensive linguistic evaluation values of each decision maker's scheme into the group's scheme evaluation values. Specifically, linguistic information is still aggregated into group evaluation information through LWD operator and LOWA operator.

$$(a_i, r) = \varphi\Big[\Big(a_i^1, r^1\Big), \Big(a_i^2, r^2\Big), \cdots \Big(a_i^m, r^m\Big)\Big], i = 1, 2, \cdots, n \quad (4)$$

a_i represents the evaluation value of the group's scheme $r \in L$,

$$a_i = MaxMin\Big(a_i^k, r^k\Big), \quad i = 1, 2, \cdots, n \quad r = \phi_Q\Big(r^1, r^2, \cdots, r^m\Big) \quad (5)$$

In the formula, the specific calculation method of r is completely similar to the previous calculation process of r^k.

Step 3: Participants are preferred. According to the selection of participants with optimal BIM capabilities, it can be seen from the above steps that a_i is still the utility value of natural language, so the optimal participant can be selected according to the order of natural language evaluation set L.

4 Application Example of BIM Maturity Model

At present, an electric power company needs to select one of the four design companies for scheme design. The Owner will evaluate the BIM application ability of the four companies to ensure the smooth implementation of the BIM application of the project. It is proposed to adopt a multi index comprehensive evaluation method based on language evaluation information for evaluation. Four types of indicators in Table 1 are selected as evaluation indicators, namely: model productivity (P_1), model cognitive ability (P_2), project management ability (P_3), and team cooperation ability (P_4). The expert group is composed of professional BIM engineers and BIM managers hired by the owner and experts with rich experience in field management. The evaluation opinions of the expert group are used as the initial language data. Expert 1 is the professional project manager of the BIM department of the owner; Expert 2 is the consulting engineer of the whole-process BIM consulting team hired by the owner, who is responsible for the whole-process reading, information load and information transmission of the BIM model; Expert 3 is the chief BIM engineer of Electric Power Design Institute, who is engaged in the secondary development of a lot of BIM software and the formulation of data standards. The evaluation opinions shall be used as the initial language data. The index weight vector and decision matrix they give are:$R^1 = (Z, FZ, C, Z)^T R^2 = (HZ, FZ, HC, YB)^T R^3 = (FZ, YB, Z, FZ)^T$

The language evaluation set of the four units evaluated by the three experts is as follows:

EXPERT1	MODEL PRODUCTION CAPACITY	MODEL COGNITIVE ABILITY	PROJECT MANAGEMENT CAPABILITY	COOPERATION ABILITY
UNIT A	Average	Average	Basically OK	Poor
UNIT B	Basically OK	Very good	Average	Average
UNIT C	Very good	Basically OK	Poor	Basically OK
UNIT D	Average	Poor	Basically OK	Very good

EXPERT2	MODEL PRODUCTION CAPACITY	MODEL COGNITIVE ABILITY	PROJECT MANAGEMENT CAPABILITY	COOPERATION ABILITY
UNIT A	Average	Very poor	Basically OK	Very good
UNIT B	Very good	Basically OK	Poor	Average
UNIT C	Basically OK	poor	Very Poor	Average
UNIT D	Average	Poor	Basically OK	Basically OK

EXPERT3	MODEL PRODUCTION CAPACITY	MODEL COGNITIVE ABILITY	PROJECT MANAGEMENT CAPABILITY	COOPERATION ABILITY
UNIT A	Average	Basically OK	Poor	Average
UNIT B	Basically OK	Very good	Average	Basically OK
UNIT C	Very good	Average	Very Poor	Very good
UNIT D	Basically OK	Basically OK	Average	Basically OK

The above results are converted into a decision matrix:

$$A^1 = \begin{bmatrix} YB & YB & Z & C \\ Z & HZ & YB & YB \\ HZ & Z & C & Z \\ YB & C & Z & HZ \end{bmatrix} \quad A^2 = \begin{bmatrix} YB & HC & Z & HZ \\ HZ & Z & C & YB \\ Z & C & HC & YB \\ YB & C & Z & Z \end{bmatrix}$$

$$A^3 = \begin{bmatrix} YB & Z & C & YB \\ Z & HZ & YB & Z \\ HZ & YB & HC & HZ \\ Z & Z & YB & Z \end{bmatrix}$$

Summarize the natural language evaluation value of each expert a_{ij}^k as the language evaluation value of the scheme a_i^k.

$a_1^1 = MaxMin\left(a_{1j}^1, r_j^1\right) = Max(YB, YB, C, C) = YB;$

$a_2^1 = MaxMin\left(a_{2j}^1, r_j^1\right) = Max(Z, HZ, C, YB) = HZ;$

$a_3^1 = MaxMin\left(a_{3j}^1, r_j^1\right) = Max(Z, Z, C, Z) = Z;$

$a_4^1 = MaxMin\left(a_{4j}^1, r_j^1\right) = Max(YB, C, C, Z) = Z;$

$a_i^1 = (YB, HZ, Z, Z)^T,$

The same kind of calculation $a_i^2 = (YB, HZ, Z, YB)^T$, $a_i^3 = (YB, Z, HZ, Z)^T$, $(i = 1, 2, 3, 4)$

Under the principle of "as much as possible", the operator Q$(d, f) = (0.5, 1)$, $W = (0, 0, 0.5, 0.5)^T$. Calculate the importance of expert opinions, taking r^1 as an example:

$r^1 = \phi_Q(r_1^1, r_2^1, r_3^1, r_4^1) = W^T B = \xi^4\{w_t, r_{\sigma(t)}^1, t = 1, 2, 3, 4\} = w_1 \otimes r_{\sigma(1)}^1 \oplus (1 - w_1) \otimes \xi^3\{\beta_h, r_{\sigma(h)}^1, h = 2, 3, 4\} = \beta_2 \otimes r_{\sigma(2)}^1 \oplus (1 - \beta_2) \otimes \xi^2\{\lambda_z, r_{\sigma(z)}^1, z = 3, 4\} = \lambda_3 \otimes r_{\sigma(3)}^1 \oplus (1 - \lambda_3) \otimes r_{\sigma(4)}^1 = 1/2 \otimes L_j \oplus 1/2 \otimes L_i = L_4 = Z, r^2 = Z, r^3 = HZ.$

The group language evaluation value of the scheme can be obtained using the formula (4), (5):

$a_1 = MaxMin\left(a_1^k, r^k\right) = Max(YB, YB, YB) = YB,\ (k = 1, 2, 3);$
$a_2 = MaxMin\left(a_2^k, r^k\right) = Max(Z, Z, Z) = Z,\ (k = 1, 2, 3);$
$a_3 = HZ$, $a_4 = Z$, At the same time, the credibility of group experts' opinions is obtained, $r = HZ$, S_3 is the best.

5 Conclusion

A multi scheme optimization method based on language evaluation information is proposed based on LWD operator and LOWA operator. This algorithm can rank the BIM abilities of each candidate according to the language evaluation phrases given by the expert group, and obtain the trust of the evaluation experts. When the number of orderly evaluation phrases and experts are limited, it is possible to give the same comment to two or more schemes if there are too many candidates or too few evaluation indicators. In this case, it can be solved by increasing the number of ordered language phrase sets and the number of indicators. In general, the LWD operator and LOWA operator are used to optimize multiple schemes. The method is simple and reliable. However, the number of schemes to be selected, the setting of evaluation indicators, the number of experts, and the definition and division of ordered language phrase sets should be considered as a whole, so as to ensure the accuracy of the optimization results [4]. The research of Dr. Gao Ju of Stanford University has proved that the more organizations involved in the application of BIM, the better the application effect of BIM [5].

The application of BIM technology in the power industry has been led by the owner. The information transmission barriers between participants have been alleviated. The BIM models of power transmission and have all been delivered in three dimensions from 2021, the owner can use BIM model to view, maintain and update during substation operation, and the application ability of BIM has been greatly improved. In view of the BIM application maturity evaluation has a great impact on the implementation of BIM technology, which is one of the preconditions for the realization of BIM value, it is very important to quantitatively judge the participants' BIM application ability. The evaluation of participants' model production ability, model cognition ability, project management ability and team cooperation ability can be converted to quantification by using LWD operator and LOWA operator. The owner can choose the most competitive contractor. Finally, it can effectively promote the comprehensive application ability of all participants, and the application of BIM technology in the electric power industry shows a spiral rising state, the whole process is highly integrated.

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