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Research Article

Dynamic Design Quality Evaluation of Power Enterprise Digital System Based on Fuzzy Information Axiom

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With the deepening of digital transformation and upgrading of power grid enterprises, the digital system evaluation method of power grid enterprises based on experts' subjective experience has been unable to meet the management needs of modern enterprises. In this paper, a method based on fuzzy information axiom for dynamic design quality evaluation of digital system in electric power enterprises is proposed. Firstly, the electric power enterprise digital system dynamic design quality comprehensive evaluation index system is set up from three aspects, which are achievement degree of target business function, logical relation rationality, and technical economy of physical model. Secondly, the quantitative and qualitative index values are processed by using the information calculation formula of minimum information axiom and fuzzy membership function. And then best-worst method and antientropy weight method are used to form the comprehensive evaluation model. Finally, the feasibility and effectiveness of the design scheme are verified by an example of dynamic design of digital system in power enterprise.

1. Introduction

With the vigorous development of the digital economy and our country's vigorous promotion of the "Internet +" and green energy revolution development strategies, as well as the change of global market players, power companies are making full use of cloud computing, big data, mobile Internet, artificial intelligence, Internet of Things, and other information technologies, actively exploring the energy Internet, green energy substitution, and assisting the development the model of the digital strategic transformation of power companies. In 2020, China's power grid enterprises have increased their investment in the direction of digital transformation, and increased their investment in power grid digital platform, energy big data center, power big data application, power Internet of things, etc. in 2020, China's digital power grid investment exceeded 110 billion yuan, and the investment scale is expected to reach 158 billion yuan by 2025 [1]. At present, facing the technical and economic evaluation needs of multiscene and complex application, multidimensional comprehensive evaluation and quantitative control dynamic evaluation of digital construction, the traditional postevaluation method based on expert subjective evaluation, and manual method cannot meet the management requirements of modern enterprises and meet the needs of digital development under the new situation. Based on this background, this paper establishes the electric power enterprise digital system dynamic design quality comprehensive evaluation index system, and evaluates the digital design schemes based on comprehensive evaluation model of subjective and objective combination.

The paper is organized as follows. The second part serves as a literature review. The third part introduces the establishment of the index system. The fourth part sets up the evaluation model of digital system dynamic design quality. The fifth part analyzes the examples. Finally, the eighth part offers conclusion.

Table 1: Research on digital system design quality.

Author	Evaluation content	Indexes/dimensions	Method/model
Fang [1]	Design quality of software systems	Control area, coupling degree, degree of condensation	AHP method
Ma et al. [2]	Software quality	Operability, modifiability, and adaptability	Fuzzy theory
Enríquez et al. [3]	Software quality	Concepts, design, production, support/use, general	QuEF methodology
Corbin et al. [4]	Software design	Systems engineering, software development, test, quality assurance, configuration management, data management, process group	Empirical analysis
Jing et al. [5]	Software quality	Metering, communication, freezing, event recording, load curve, reliability	Analytic hierarchy process
Liu [6]	Software quality	Software operation, software modification, software transfer	Grey fixed weight clustering
Li et al. [7]	Software quality	Response time, database size, accuracy, language number, special clicks, dead links, update time and format	Fuzzy triangular number fuzzy neural network
Yue and Zhang [8]	Software quality	Maintainability, reliability, reusability	Improved TOPSIS method
Jianli et al. [9]	Software quality	Functionality, reliability, ease of use and portability	Hesitant fuzzy sets and multiattribute decision making
Yu et al. [10]	Software quality	Functionality, reliability, ease of use, efficiency, maintainability, portability	Generalized intuitionistic fuzzy hybrid weighted averaging
Zhou et al. [11]	Software quality	Functionality, reliability, ease of use, efficiency, maintainability, portability	Improved vague set method
Yue [12]	Software quality	Efficiency, reliability, functionality, maintainability	Entropy
Bao and Liu [13]	Software quality	General attributes, domain attributes, application attributes	Expert method
Akay et al. [14]	Conceptual design evaluation of adhesive tape dispenser	Not about software or digital system	Fuzzy information axiom

2. Literature Review

The quality of digital system design is the key to realizing the effective integration of the underlying driving energy technology and digital technology, prompting a comprehensive transformation of traditional power generation methods to new power systems, promoting the flexible configuration of energy supply and demand, and driving the steady growth of digital emerging strategic industries. To ensure the quality of digital system design, many scholars have carried out relevant research on design quality evaluation. The specific literature is shown in Table 1.

From Table 1 we can find that there are few studies on digital system design quality evaluation of power grid. Therefore, we summarize the software quality evaluation methods related to digital design. We find that AHP, Entropy, and Fuzzy evaluation are the main methods of comprehensive evaluation. The evaluation indexes are mainly set up from functions, defects, process, and performance. The above quality evaluation system cannot fully reflect the dynamic formation of design quality. Especially, the rapid iteration of the current power production mode, organization mode, power dispatch form, function positioning, etc., makes the dynamic characteristics of the related power digital system in the design link more significant, that is, while the power enterprise digital system is in the design process, based on the ever-changing internal and external demand information, the conceptual design, logical design, and functional design are dynamically adjusted, supplemented, and improved. For example, based on the software engineering system life cycle, the literature [15–17] defines the life cycle process of digital system construction, clarifies the phase characteristics and internal and external influence factors of the system construction process, and analyzes the impact of standardized design on digital systems, the importance of the construction stage, and its design quality evaluation must run through the whole process of dynamic design. The literature [18–21] stipulated and standardized the information architecture of electric power enterprises and strengthened the overall design of data element model (conceptual model, logical model, physical model), technical process (development activity), and visualization design requirements of the project process (enable process). It clarified the relationship between subject domains (business domain, application domain, data domain, and technology domain) and the dynamic path of data cross-domain reuse. However, the existing design quality evaluation methods fail to design the evaluation index system in the iterative process of dynamic design. Its specificity, the reliability, and practicability need to be further improved.

In summary, based on the software system engineering theory and enterprise architecture (TOGAF) [22] standard perspective, this paper takes data as the core evaluation element of the design quality of digital systems, takes the characteristics of the agile development cycle of digital systems as the dynamic evaluation mechanism, and introduces the information axiom [23, 24] in the modernized design theory, provides a new solution path for the multi-attribute decision-making problem of complex systems by

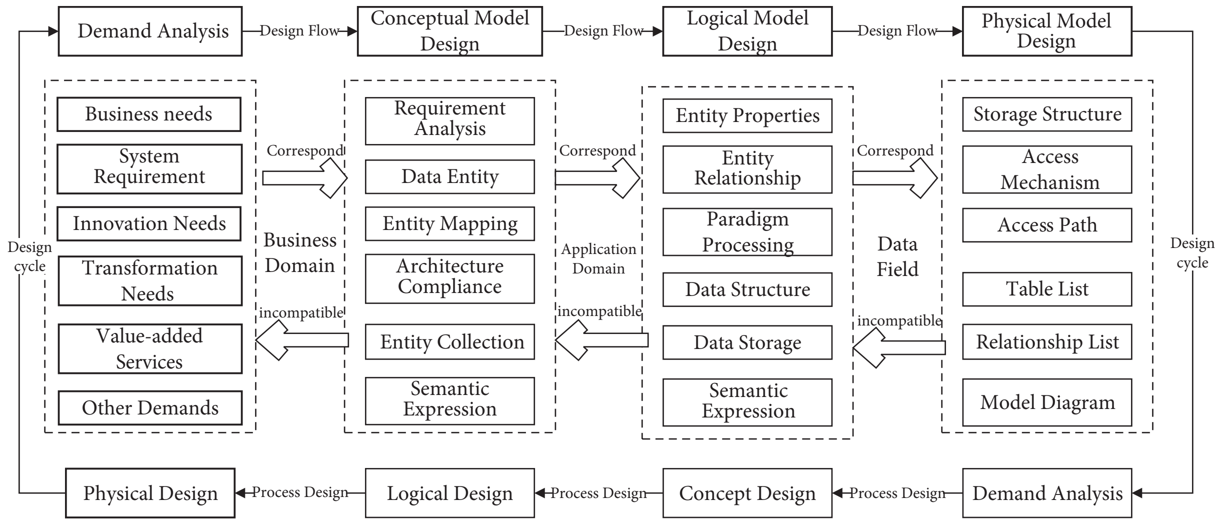

Figure 1: Characteristics of digital system dynamic design flow.

integrating the size of the information of each index, and completes the overall evaluation of the quality of the dynamic design of the digital system of the electric power enterprise. At the same time, due to the network characteristics, scale characteristics, functional diversity, and other characteristics of the digital system of electric power enterprises, the system has complexity and uncertainty in the design process, which causes a certain degree of human interference and inaccuracy in the design index evaluation information. In the process of digital project design quality evaluation, some indicators are difficult to quantify. Fuzzy evaluation is an effective way to solve this problem. The fuzzy evaluation method was founded by Professor Zadeh, an American scientist, in the 1960s. It is an evaluation model and method designed for the fuzziness of a large number of economic phenomena in reality. It has been constantly evolving by relevant experts in application practice. And it has been tested that which has the characteristics of clear results and strong systematicness. It can better solve the fuzzy and difficult to quantify problems and is suitable for solving all kinds of uncertain problems [25]. In this paper, how to eliminate the subjectivity of evaluation and give full play to the objective advantages of the fuzzy information axiom method is also the focus of this article.

3. Dynamic Design Quality Index System of Power Enterprise Digital System

3.1. The Dynamic Design Characteristics of the Digital System of the Electric Power Enterprise. The dynamic design of power enterprise digital system is based on the characteristics of digital system life cycle, and gives full play to the role of data as the core production factor. According to the strategic direction of enterprise digital development and the new operation and management mode, unify and solidify the entity, attribute and their relationship, introduce the standardized enterprise data model, strengthen the design of digital system data model, through periodic iteration, improve all business concepts and logical rules involved in the process of enterprise operation and management, and build an enterprise level digital system under the new power system. The dynamic design of the digital system of the electric power enterprise specifically includes three levels: conceptual data model design, logical data model design, and physical data model design. They rely on and interact with each other, with design modularity, cross-domain closed-loop reuse of data, and multilevel design collaboration features. Characteristics of dynamic design process of digital system are shown in Figure 1.

3.2. Dynamic Design Quality Evaluation Index System. According to the characteristics of dynamic design process in each stage of digital system, this paper establishes the quality evaluation index system of digital system dynamic design of power grid enterprises, as shown in Figure 2.

3.2.1. Quality Indexes and Measurement Method of Conceptual Design. Conceptual design is mainly used to describe the conceptual structure of things, including subject domain, entity, object, class, domain, generalization, aggregation, combination, dependency, and other specific design contents. Conceptual design is the communication bridge between requirements analysts and database designers. The evaluation indicators of conceptual design quality mainly involve business compliance, business architecture compliance, CIM model compliance, and data entity accuracy. The specific indicators are as follows.

(1) Compliance with Business Requirements. Mapping business requirements to business purposes is one task of conceptual design, which formulates business goals to meet certain user behaviors. This indicator is used to measure the degree to which the conceptual data model satisfies the business information required by the user's behavior. The calculation formula for the compliance degree of the business requirements is as follows:

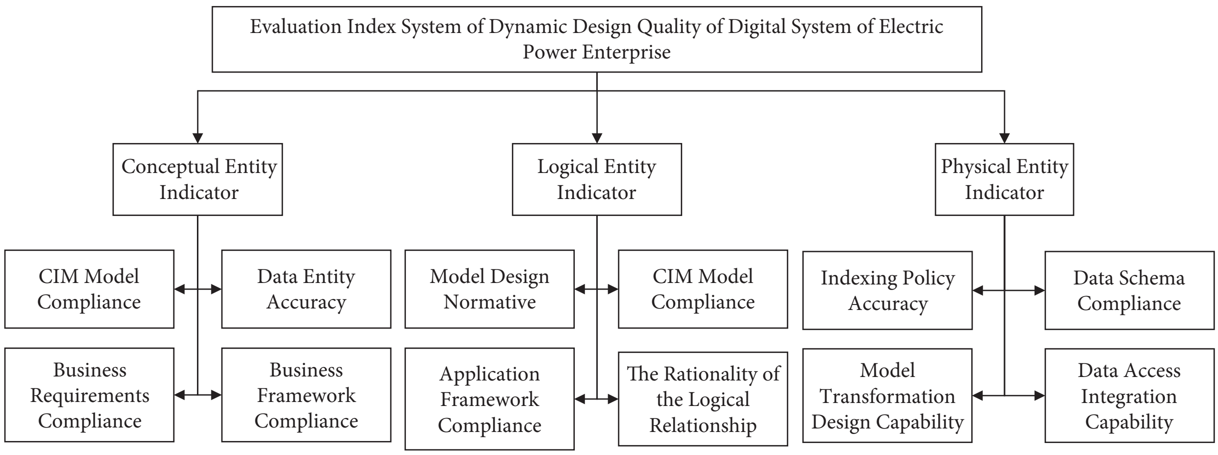

Figure 2: Digital system dynamic design quality evaluation index system.

$$C_1 = \left(\frac{1}{N_1}\sum_{i=1}^{N_1} C_i\right) \times 100\%, \tag{1}$$

where C_1 is the degree of compliance with business requirements; N_1 is the number of business requirements in the digital system; C_i is the state of demand satisfaction. If the demand is met in the digital system, $C_i = 1$, if partially met, $C_i < 1$, if not met, $C_i = 0$.

(2) Business Architecture Compliance. Measure whether the conceptual description of the name, attributes, and model relationships of the conceptual data model is clear and readable, that is, concisely reflect the semantics of the object, reflect the relationship and position of the object in the system, and facilitate the comparison with the business architecture design standards, so as to judge the compliance of the standardized design module. The calculation formula is as follows:

$$C_2 = \left(\frac{1}{N_{F2}}\sum_{i=1}^{N_{F2}} C_{Fi} + \frac{1}{N_{D2}}\sum_{i=1}^{N_{D2}} C_{Di}\right)/2 \times 100\%, \tag{2}$$

where C_2 is the concept expressing business architecture compliance; N_{F2} is the number of key business activities; C_{Fi} is the business capability comment status, if there is a comment, then $C_{Fi} = 1$, otherwise $C_{Fi} = 0$; N_{D2} represents the number of business processes, C_{Di} represents the legibility of object naming, if the legibility is met, then $C_{Di} = 1$, otherwise $C_{Di} = 0$.

(3) CIM Model Compliance. Measure the percentage of the conceptual data model contained in a digital system that belongs to the unified data model of the enterprise. The calculation formula is as follows:

$$C_3 = \left(\frac{1}{N_3}\sum_{i=1}^{N_3} C_{3i}\right) \times 100\%, \tag{3}$$

where C_3 is the standardized module adoption rate; N_3 is the number of modules in the digital system; C_{3i} is the adoption of standardized modules, if standardized modules are used then $C_{3i} = 1$, otherwise $C_{3i} = 0$.

(4) Accuracy of Data Entities. Calculate the accuracy of business subject analysis of power enterprise digital system in the conceptual design stage. The calculation formula is as follows:

$$C_4 = \left(\frac{1}{N_4}\sum_{i=1}^{N_4} C_{4i}\right) \times 100\%, \tag{4}$$

where C_4 is the accuracy of the data entity; N_4 is the number of topics; C_i is the accuracy of the topic domain, if the topic domain is accurate then $C_{4i} = 1$, otherwise $C_{4i} = 0$.

3.2.2. Logical Design Quality Indicators and Measurement Methods. Logic design is the further decomposition and refinement of conceptual design, describing entities, attributes and entity relationships, and mainly solving detailed business problems. The design generally follows the "third paradigm," which makes the logic of the digital system clearer, enhances compatibility, and reduces partial iterative update difficulties. The specific evaluation indicators are as follows.

(1) Normative Design Model. The standardization of the logic structure of power enterprise digital system is to overcome the problems of redundancy and abnormality in the logic structure. It is evaluated in terms of the number of redundant points, the number of abnormal points, the degree of satisfaction of the "third normal form," and the degree of compliance with the unified model of the digital system. The calculation formula is as follows:

$$L_1 = \left(1 - \left(\frac{1}{M_1}\sum_{i=1}^{M_1} r_i + \frac{1}{M_1}\sum_{i=1}^{M_1} A_i + \frac{1}{M_1}\sum_{i=1}^{M_1} T_i + \frac{1}{M_1}\sum_{i=1}^{M_1} u_i\right)/4\right) \times 100\%, \tag{5}$$

where M_1 represents the number of logical structure points, r_i represents the number of redundancy points, A_i represents the number of anomaly points, T_i represents the degree to which the "third paradigm" is satisfied, and u_i represents the unified model of the digital system.

(2) Application Architecture Compliance. The object-oriented design method is adopted to measure the accuracy of the entities, attributes and entity relationships of the logical data model in complying with the application architecture design standards, and to assess whether the semantics of the object and the description of the relationship and position of the object in the system are clear and readable, so as to judge the compliance of the standardized design module. The calculation formula is as follows:

$$L_2 = \left(\frac{1}{N_{F2}}\sum_{i=1}^{N_{F2}} C_{Fi} + \frac{1}{N_{D2}}\sum_{i=1}^{N_{D2}} C_{Di}\right)/2 \times 100\%, \quad (6)$$

where L_2 is the logical expression of application architecture compliance; N_{F2} is the number of key applications; C_{Fi} is the comment status of the application, if there is a comment $C_{Fi} = 1$, otherwise $C_{Fi} = 0$; N_{D2} represents the number of associated applications, C_{Di} means the legibility of the object name, if the legibility is met, then $C_{Di} = 1$, otherwise $C_{Di} = 0$.

(3) Adoption Rate of Standardized Modules. Measure the percentage of the logical data model contained in a digital system that belongs to the unified data model of the enterprise. The calculation formula is as follows:

$$L_3 = \left(\frac{1}{N_{L3}}\sum_{i=1}^{N_{L3}} C_{L3i}\right) \times 100\%, \quad (7)$$

where L_3 is the adoption rate of standardized modules; N_{L3} is the number of digital system modules; C_{L3i} is the case of using standardized modules, if standardized modules are used then $C_{L3i} = 1$, otherwise $C_{L3i} = 0$.

(4) Rationality of Logical Relationship. The rationality of business logic relationship refers to the clear hierarchical structure and smooth transmission path between digital system businesses. The calculation formula is as follows:

$$L_4 = \left(\frac{1}{M_H}\sum_{i=1}^{M_H} H_i + \frac{1}{M_R}\sum_{i=1}^{M_R} R_i\right)/2 \times 100\%, \quad (8)$$

where M_H represents the number of levels, H_i means the degree of clarity of each level, if it is clear, $H_i = 1$, otherwise $H_i = 0$; M_R means the number of paths, R_i means the smoothness of the path, if there is no obstruction, $R_i = 1$, otherwise $R_i = 0$.

3.2.3. Physical Design Quality Indicators and Measurement Methods. Physical design is based on logical design, taking into account various specific technical realization factors, and designing digital system structure to provide the most detailed design for the digital system development. The quality of the design at this stage is determined by the system transformation capability, data processing capability, data application analysis capability, model stability, and data reuse degree.

(1) Model Conversion Design Ability. To measure the ability to be automatically transformed into a physical data model through a logical data model, this indicator is measured by the development experience of each logical module.

$$P_1 = \frac{1}{K_1}\sum_{i}^{K_1} TA_i, \quad (9)$$

where P_1 represents the model conversion design capability, K_1 represents the number of function points of the physical data model, and TA_i means the automatic function point conversion capability. If there is similar development experience, then $TA_i = 1$, otherwise $TA_i = 0$.

(2) Data Structure Compliance. According to the basic elements required for the initial design and the relationship between related elements, measure the accuracy of the storage structure, record the sequence and access mechanism of the physical data model in compliance with the data architecture design standards, so as to determine the compliance of the standardized design module, and the formula is as follows:

$$P_2 = \left(\frac{1}{N_{P2}}\sum_{i=1}^{N_{P2}} C_{Pi} + \frac{1}{N_{S2}}\sum_{i=1}^{N_{S2}} C_{Si}\right)/2 \times 100\%, \quad (10)$$

where P_2 is the compliance degree of the physical representation data structure; N_{P2} is the number of physical data models; C_{Pi} is the comment situation, if there is comment $C_{Pi} = 1$; otherwise $C_{Pi} = 0$; N_{S2} means the number of standard physical data models used, C_{Si} means the integrity of the physical data model used, if it satisfies $C_{Si} = 1$, otherwise $C_{Si} = 0$.

(3) Data Access Integration Capability. This indicator reflects the ability of digital systems to integrate different data sources, supporting both traditional data and big data platforms and supporting both structured data and unstructured data access. The specific calculation formula is as follows:

$$P_3 = \frac{1}{K_3}\sum_{i}^{K_3} DA_i, \quad (11)$$

where P_3 represents the data access integration capability, K_3 represents the type of data, DA_i represents the data access integration capability. If it can be accessed effectively, $DA_i = 1$, otherwise $DA_i = 0$.

(4) Accuracy of Indexing Strategy. Measure the physical design stage to improve the data access speed of database tables by creating indexes, and improve the accuracy of queries through strategy settings and algorithms.

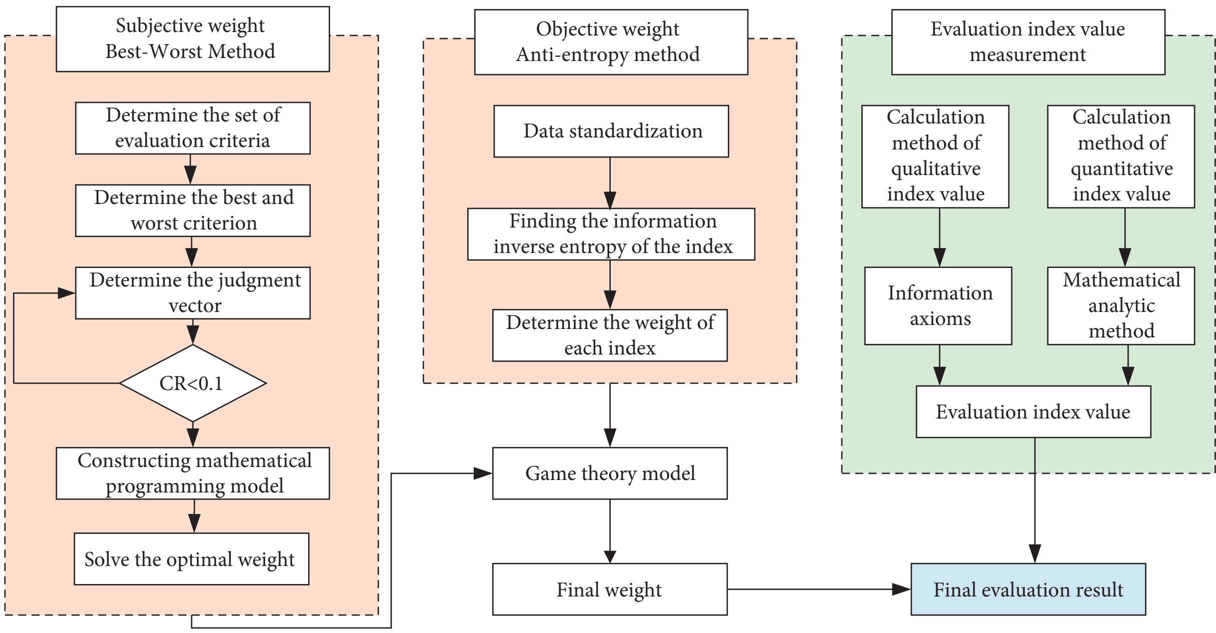

Figure 3: Digital system dynamic design quality evaluation model roadmap.

4. Dynamic Design Quality Evaluation Model of Power Enterprise Digital System

In the dynamic design process of digital system of power grid enterprises, digital experts play an important role in determining the index weight and estimating the index value. In this paper, BWM method is introduced to determine the subjective weight of evaluation indexes, and the antientropy weight method is selected to overcome the influence of inconsistent opinions of evaluation experts on the evaluation results of design quality. Information axiom method can more systematically and scientifically obtain the evaluation value of evaluation experts on indicators. The specific technical route of the evaluation model is shown in Figure 3.

4.1. Calculation Method of Index Weight

4.1.1. BWM Method. The BWM method was proposed by Rezaei in 2015 [26], according to the experience and actual needs of the project, the expert (decision-maker) selects the criteria other than the best (most important) and the worst (least important), and then compares the optimal criteria with other indicators in turn, and the other indicators with the worst criteria in turn. After comparing each indicator with the best (worst) indicator, an integer value of 1~9 reflecting the relative advantages and disadvantages will be formed. Finally, the BWM solution can be transformed into a mathematical programming problem, and the result calculation can be realized by lingo software. The specific operation steps are as follows [27–30].

(1) Determine the set of evaluation criteria

Experts (decision makers) discuss and determine the influencing factors of multicriteria decision-making problems to be studied, and then determine the set of evaluation criteria $\{c_1, c_2, \cdots, c_n\}$.

(2) Determine the best criterion and the worst criterion

In the criterion set $\{c_1, c_2, \cdots, c_n\}$, the optimal criterion C_B and the worst criterion C_W are determined. The optimal criterion is the relatively most important criterion determined by experts (decision makers) according to their experience, cognition, and actual needs of engineering, which has the most prominent impact on the decision-making results; Similarly, the worst criterion is the criterion that is relatively least important and has the least impact on the decision-making results. If experts (decision makers) believe that there is more than one optimal (worst) criterion, they can choose one of these optimal (worst) indexes without affecting the calculation results.

(3) Compare the preference between the optimal criteria and all criteria, and construct the judgment vector $A_B = (a_{B1}, a_{B2}, \cdots, a_{Bn})$.

The expert (decision maker) compares the optimal criteria with other criteria one by one, determines the preference degree of the optimal criteria relative to other criteria, scores its preference degree with 1–9, and successively constructs the comparison vector $A_B = (\mathrm{a}_{B1}, a_{B2}, \cdots, a_{Bn})$ based on the optimal criteria, where a_{Bi} represents the preference degree of the optimal criteria B compared with the criteria i, and it is easy to know that $A_{BB} = 1$. It should be noted that the scale scoring method of 1–9 actually has the same meaning as that of AHP. The degree and meaning of each scale are very similar. The biggest difference is that the comparison vector set constructed by BWM with 1–9 scale is an integer, while the judgment matrix constructed by AHP with 1–9 scale is composed of fraction. The preference scoring table of experts (decision makers) based on the optimal criteria is shown in Table 2.

(4) Compare the preference between all criteria and the worst criterion, and construct the judgment vector $A_W = (a_{1W}, a_{2W}, \cdots, a_{nW})$.

The expert (decision maker) compares the worst criteria with other criteria one by one, determines the preference degree of the worst criteria relative to other criteria, scores its preference degree with 1–9, and successively constructs a comparison vector $\mathrm{A_W} = (\mathrm{a_{1W}}, \mathrm{a_{2W}}, \cdots, \mathrm{a_{nW}})^T$ based on the worst criteria, where a represents the preference degree of criterion i compared with the worst criterion W, and it is easy to know that $A_{WW} = 1$. The preference scoring table of experts (decision makers) based on the worst criteria is shown in Table 3.

(5) Constructing mathematical programming problem, solve the optimal weight (w_1^*, w_2^*, $\cdots$, w_n^*).

Criterion preference comparison is the comparison of criterion weights, so the optimal weight should meet the following conditions: the weight W of any criterion j is ^j_w.

$$\frac{w_B}{w_j} = a_{Bj}, \frac{w_j}{w_w} = a_{jw}. \tag{12}$$

Therefore, in order to determine the optimal weight, the following mathematical programming problem can be constructed:

$$\begin{aligned} &\min \max_j \left\{ \left| \frac{w_B}{w_j} - a_{Bj} \right|, \left| \frac{w_j}{w_w} - a_{jw} \right| \right\} \\ &\text{s.t.} \\ &\sum_j w_j = 1 \\ &w_j \geq 0. \end{aligned} \tag{13}$$

where the objective function is to minimize the largest one of $|W_B/W_j - a_{Bj}|$ and $|W_j/W_w - a_{jw}|$ among all j.

For the convenience of solution, mathematical programming can be transformed into the following problems:

$$\begin{aligned} &\min \xi \\ &\text{s.t.} \\ &\left| \frac{w_B}{w_j} - a_{Bj} \right| \leq \xi, \text{for all } j \\ &\left| \frac{w_j}{w_w} - a_{jw} \right| \leq \xi, \text{for all } j \\ &\sum_j w_j = 1 \\ &w_j \geq 0, \text{for all } j. \end{aligned} \tag{14}$$

Table 2: Optimal preference scoring criteria.

	c_1	c_2	$\cdots$	c_n
C_B	a_{B1}	a_{B2}	$\cdots$	a_{Bn}

Table 3: Worst preference scoring criteria.

	c_1	c_2	$\cdots$	c_n
C_W	a_{1W}	a_{2W}	$\cdots$	a_{nW}

The optimal weight $W_1(w_1^*, w_2^*, \cdots, w_n^*)$ based on BWM can be obtained by solving the mathematical programming.

4.1.2. Antientropy Method. According to the basic principle of information theory, information is a measure of the degree of system order, and entropy is a measure of the degree of system disorder. If the system may be in many different states, and the probability of each state is $p_i (i = 1, 2, \ldots, m)$, the entropy of the system is defined as

$$E = -\sum_{i=1}^{n} P_i ln P_i, \tag{15}$$

where $0 \leq P_i \leq 1$; $\sum_{i=1}^{n} P_i = 1$.

In the digital project evaluation of power grid enterprises, the closer the evaluation experts score on a certain index, it shows that the score consistency is strong, and the index should be given a high weight, otherwise a low weight. Therefore, the antientropy weight method is used to calculate the index weight. This method is based on the idea that the greater the difference of the index, the greater the antientropy. The antientropy calculation formulas are constructed, as shown in the following.

$$\begin{aligned} h_i' &= -\sum_{i=1}^{n} P_i ln (1 - P_i) \\ w_i' &= h_i' / \sum_{i=1}^{n} h_i', \end{aligned} \tag{16}$$

where h_i' express the antientropy of the index i, w_i' express the weight of the index i, and so we can get the weights W_2 of the indexes system.

4.1.3. Combined Weighting Method Based on Game Theory. The idea of game theory is used to seek agreement or compromise between weights W_1 and W_2 in order to obtain the most satisfactory weight. Let the comprehensive weight value composed of any linear combination of W_1 and W_2 be W. The calculation formula is as follows:

$$W = \lambda_1 W_1^T + \lambda_2 W_2^T, \tag{17}$$

where λ_1 and λ_2 are the linear combination coefficients, which all over zero.

(1) Determine the objective function

Through the above formula, the problem of combined weighting is transformed into the change of coefficients λ, so as to minimize the range between the comprehensive weight W and the weights W_1 and W_2. The calculation formula is as follows:

$$\min\left(\|W^T - W_1^T\|^2 + \|W^T - W_2^T\|^2\right) = \min\left(\|\lambda_1 W_1^T + \lambda_2 W_2^T - W_1^T\|^2 + \|\lambda_1 W_1^T + \lambda_2 W_2^T - W_2^T\|^2\right). \quad (18)$$

(2) Solving objective function

According to the properties of differential matrix, the first derivative condition of formula (18) optimization is

$$\begin{aligned} \lambda_1 W_1 W_1^T + \lambda_2 W_1 W_2^T &= W_1 W_1^T, \\ \lambda_1 W_2 W_1^T + \lambda_2 W_2 W_2^T &= W_2 W_2^T. \end{aligned} \quad (19)$$

(3) Calculate weight combination coefficient

The linear coefficient obtained after normalization is processed as follows:

$$\lambda_k^* = \frac{\lambda_k}{\lambda_1 + \lambda_2}, \quad k = 1, 2. \quad (20)$$

Final combination weights of the indexes system are $\overset{*}{W}$, which are calculated by the following formula:

$$W^* = \lambda_1^* W_1^T + \lambda_2^* W_2^T. \quad (21)$$

4.2. Index Value Measurement Method

4.2.1. The Establishment of Information Axioms. The information axiom method can obtain the evaluation value of the evaluation experts in a more systematic and scientific manner. After the axioms of information are proposed, they are widely used in the fields of design plan evaluation, advanced manufacturing system selection, and control decision-making. The basic idea of this method is that the overall amount of information is the smallest is the best.

(1) Conversion of Language Forms. Use fuzzy mathematics to convert qualitative language phrase descriptions into quantitative values. The conversion formula is shown as follows:

$$\widetilde{l}_q = \left(l_p^1, l_p^2, l_p^3\right) = \left[\max\left\{\frac{q-1}{t}, 0\right\}, \frac{q}{t}, \min\left\{\frac{q+1}{t}, 1\right\}\right], \quad q \in \{0, 1, \cdots, t\}. \quad (22)$$

In the formula, $\widetilde{l}_q$ represents the triangular fuzzy number, l_p^1, l_p^2, l_p^3 means the language phrase description, q means the number of reviews, and t means the number of reviews.

In this article, n experts will be organized to evaluate the qualitative index i, and the evaluation index will be evaluated according to the comment set [Very good (VH), good (H), fair (M), poor (L), very poor (VL)]. For evaluation, n experts obtain the evaluation result sequence $[v_{i,1}, v_{i,2}, \cdots, v_{i,n}]$ after completing the evaluation, and then use the triangular membership function (as shown in Figure 4) to transform the fuzzy evaluation result into a numerical sequence $[d_{i,1}, d_{i,2}, \cdots, d_{i,n}]$.

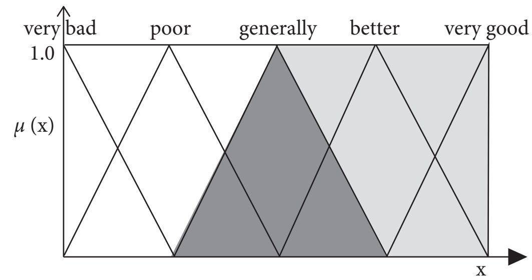

Figure 4: Range diagram of triangle membership function.

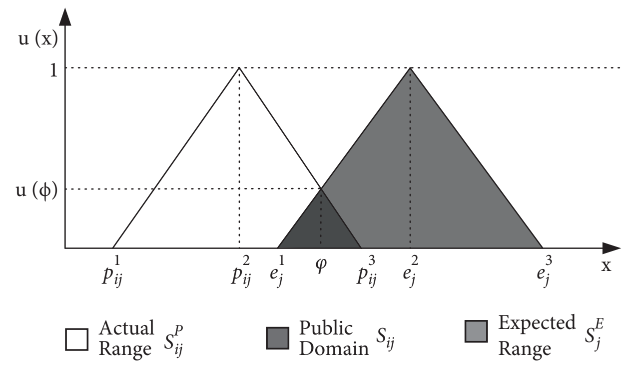

Figure 5: Extraction diagram of linguistic form index information.

According to formula (22), the membership degree for converting expert comment information into triangular fuzzy numbers $\widetilde{s}_j = (s_j^1, s_j^2, s_j^3)$ is defined as

$$u_j(x) = \begin{cases} \dfrac{x - s_j^1}{s_j^2 - s_j^1}, & s_j^1 \le x \le s_j^2, \\ \dfrac{s_j^3 - x}{s_j^3 - s_j^2}, & s_j^2 \le x \le s_j^3, \\ 0, & \text{else}. \end{cases} \quad (23)$$

The information value in the language form index is extracted through the intersection of the comments of the review experts, and the specific formula is as follows:

The S_j^E in Figure 5 shows the expected range, that is, the area enclosed by the expected information of the index $\widetilde{e}_j$ and the coordinate axis after the conversion. The expected range is expressed by the standard value of each index level.

$$S_j^E = \int_{-\infty}^{+\infty} u_j^E(x)dx = \int_{e_j^1}^{e_j^2} \frac{x - e_j^1}{e_j^2 - e_j^1} dx + \int_{e_j^2}^{e_j^3} \frac{e_j^3 - x}{e_j^3 - e_j^2} dx = \frac{e_j^3 - e_j^1}{2}. \quad (24)$$

In the same way, S_{ij}^P is the actual range, that is, the area enclosed by the converted evaluation information $\widetilde{p}_{ij}$ and the coordinate axis

$$S_{ij}^P = \int_{-\infty}^{+\infty} u_{ij}^P(x)dx = \int_{p_{ij}^1}^{p_{ij}^2} \frac{x - p_{ij}^1}{p_{ij}^2 - p_{ij}^1}dx + \int_{p_{ij}^2}^{p_{ij}^3} \frac{p_{ij}^3 - x}{p_{ij}^3 - p_{ij}^2}dx = \frac{p_{ij}^3 - p_{ij}^1}{2}. \tag{25}$$

where $i \in M, j \in N$, S_{ij} represents the common range, that is, the area S_j^E enclosed by the intersection of the expected range and the actual range S_{ij}^P, Here, when the index evaluation is higher than the decision maker's expectation, the public range is considered to be equal to the expected range. The calculation formula for the public range is as follows:

$$S_{ij} = \begin{cases} 0, & p_{ij}^3 \le e_j^1, \\ \int_{e_j^1}^{\phi} \frac{x - e_j^1}{e_j^2 - e_j^1}dx + \int_{\phi}^{p_{ij}^3} \frac{p_{ij}^3 - x}{p_{ij}^3 - p_{ij}^2}dx, & e_j^1 \le p_{ij}^3 \le e_j^3, \\ S_j^E, & p_{ij}^3 > e_j^3, \end{cases} \tag{26}$$

where ϕ represents the mapping on the x axis of the intersection points on the boundary between the expected range S_j^E and the actual range S_{ij}^P

$$\phi = \frac{e_j^2 p_{ij}^3 - e_j^1 p_{ij}^2}{e_j^2 - e_j^1 + p_{ij}^3 - p_{ij}^2}, \quad i \in M, j \in N. \tag{27}$$

Finally, j calculate the amount of information I_j contained in the indicator, which is the degree to which the indicator does not meet the expectations, and the calculation formula is as follows:

$$I_j = \begin{cases} \infty, & p_{ij}^3 \le e_{ij}^1, \\ \log_2\left(\frac{S_{ij}^P}{S_{ij}}\right), & e_{ij}^1 < p_{ij}^3 \le e_{ij}^3, \\ 0, & e_{ij}^3 < p_{ij}^3, \end{cases} \tag{28}$$

According to formula (28), $I_j \in [0\ ,\ \infty)$ can be known. When $I_j = 0$, it means that the indicator is completely consistent with expectations. The larger the value, the greater the difference the experts expect. When $I_j = \infty$, the indicator has not reached expectations at all, and adjustments should be made.

(2) Index Information Extraction in the Form of Numerical Statistics. The amount of information (I) of indicators in the form of numerical statistics is calculated by the probability of meeting requirements and design standards. The specific formula is as follows:

Table 4: Design quality grade value of digital system.

Grade	Level 1	Level 2	Level 3
C1	0.7	0.8	0.95
C2	0.7	0.8	0.95
C3	0.7	0.8	0.95
C4	0.7	0.8	0.95
L1	0.7	0.8	0.95
L2	0.7	0.8	0.95
L3	0.7	0.8	0.95
L4	0.7	0.8	0.95
P1	0.7	0.8	0.95
P2	0.7	0.8	0.95
P3	0.7	0.8	0.95
P4	M	H	VH

$$I = -\log_2 p. \tag{29}$$

In the formula, p represents the probability of meeting system requirements and design standards. It is obtained by evaluation experts or statistical data processed in different ways.

4.2.2. Index Classification. With reference to the CMMI software quality management theory, combined with the life cycle characteristics of the software development process quality of power companies, according to the relevant design standards and engineering practices of the power company software engineering in the design phase, three quality levels and expectations are set for the software design quality as follows.

Level 1: The designed product has a basic standardized design process and quality control mechanism, and is based on and complies with a certain standardized model. Changes that occur can be tracked, and the accumulated experience can be used for the development of new projects.

Level 2: Design finished products based on and comply with enterprise-level information, architecture design specifications, and standardized models, which can effectively achieve quantitative quality control and can perform statistics and analysis on the accumulated data, but further refinement of the design is required to improve quality stability.

Level 3: On the basis of Level 2, the design product uses advanced theories and concepts and uses new technologies to continuously improve the design process. It can flexibly deploy and operate and maintain for the realization of business needs and subsequent changes that may occur to meet the needs of the enterprise and the overall layout requirements of the level information architecture.

The index values of each grade obtained through the expert scoring method are shown in Table 4.

4.3. Example Analysis. The digital system of electric power enterprises is the use of 5G, Internet of Things, cloud computing, big data analysis, artificial intelligence, and other emerging technologies to upgrade and transform traditional electric power enterprises. It is an effort to empower the

Table 5: Score table of digital system dynamic design quality evaluation index of provincial electric power enterprises.

Expert	C1	C2	C3	C4	L1	L2	L3	L4	P1	P2	P3	P4
E1	0.95	0.85	0.86	0.81	0.78	0.84	0.86	0.81	0.5	0.76	0.91	VH
E2	0.88	0.93	0.84	0.74	0.71	0.65	0.87	0.82	0.55	0.76	0.85	H
E3	0.99	0.93	0.78	0.67	0.76	0.84	0.8	0.81	0.51	0.78	0.89	M
E4	0.86	0.89	0.89	0.7	0.68	0.85	0.82	0.88	0.56	0.85	0.88	VH
E5	0.8	0.9	0.94	0.68	0.73	0.78	0.8	0.91	0.66	0.78	0.9	H
E6	0.87	0.86	0.85	0.65	0.67	0.85	0.75	0.93	0.66	0.81	0.88	VH
E7	0.9	0.86	0.8	0.7	0.68	0.73	0.89	0.87	0.61	0.85	0.93	H
E8	0.85	0.89	0.8	0.79	0.74	0.66	0.83	0.86	0.53	0.76	0.82	M
E9	0.85	0.93	0.84	0.74	0.73	0.8	0.8	0.82	0.59	0.76	0.89	VH
E10	0.91	0.9	0.87	0.65	0.63	0.7	0.87	0.83	0.65	0.86	0.89	VH
E11	0.8	0.89	0.78	0.71	0.72	0.84	0.76	0.9	0.66	0.77	0.95	H
E12	0.8	0.95	0.88	0.77	0.77	0.68	0.81	0.82	0.67	0.82	0.91	H
E13	0.93	0.9	0.86	0.84	0.64	0.8	0.89	0.83	0.58	0.85	0.83	VH
E14	1	0.94	0.88	0.69	0.66	0.78	0.84	0.86	0.6	0.85	0.81	VH
E15	0.89	0.91	0.85	0.85	0.75	0.84	0.82	0.84	0.51	0.79	0.89	VH
E16	0.83	0.89	0.93	0.78	0.76	0.82	0.88	0.88	0.7	0.79	0.83	H
E17	0.99	0.94	0.9	0.7	0.8	0.79	0.85	0.92	0.68	0.77	0.81	H
E18	0.95	0.91	0.85	0.69	0.63	0.66	0.88	0.87	0.55	0.85	0.87	M
E19	0.92	0.9	0.88	0.76	0.75	0.65	0.84	0.9	0.57	0.82	0.92	VH
E20	0.82	0.9	0.87	0.72	0.71	0.7	0.76	0.94	0.62	0.79	0.84	VH

Table 6: Information values of digital statistics indexes at different design quality levels.

Grade	First level	Level 2	Level 3
C1	0.000	0.000	2.000
C2	0.000	0.000	4.322
C3	0.000	0.152	∞
C4	0.515	2.737	∞
L1	0.621	4.322	∞
L2	0.415	1.152	∞
L3	0.000	0.234	∞
L4	0.000	0.000	∞
P1	0.322	1.737	∞
P2	0.000	1.152	∞
P3	0.000	0.000	4.322

Table 7: Transformation of language phrases and trigonometric fuzzy numbers.

Language phrase	Triangular fuzzy number
VL	[0.00, 0.00, 0.25]
L	[0.00, 0.25, 0.50]
M	[0.25, 0.50, 0.75]
H	[0.50, 0.75, 1.00]
VH	[0.75, 1.00, 1.00]

construction of Digital China and build an internationally leading energy Internet with Chinese characteristics. The digital engine built by the enterprise. This article takes the dynamic design of the digital system of the provincial power enterprise as the analysis object, and hires 20 industry experts to statistically score the 12 indicators of the dynamic design. The specific scoring results are shown in Table 5.

First, according to formula (19), the information value of each numerical statistical form index under different design quality grade standards is calculated, as shown in Table 6.

Table 8: Digital system dynamic design quality evaluation information based on triangular fuzzy numbers.

Expert	P4
E1	[0.75, 1.00, 1.00]
E2	[0.50, 0.75, 1.00]
E3	[0.25, 0.50, 0.75]
E4	[0.75, 1.00, 1.00]
E5	[0.50, 0.75, 1.00]
E6	[0.75, 1.00, 1.00]
E7	[0.50, 0.75, 1.00]
E8	[0.25, 0.50, 0.75]
E9	[0.75, 1.00, 1.00]
E10	[0.75, 1.00, 1.00]
E11	[0.50, 0.75, 1.00]
E12	[0.50, 0.75, 1.00]
E13	[0.75, 1.00, 1.00]
E14	[0.75, 1.00, 1.00]
E15	[0.75, 1.00, 1.00]
E16	[0.50, 0.75, 1.00]
E17	[0.50, 0.75, 1.00]
E18	[0.25, 0.50, 0.75]
E19	[0.75, 1.00, 1.00]
E20	[0.75, 1.00, 1.00]

The five-level language form is transformed into triangular fuzzy numbers and the results are shown in Table 7.

The comment of index P4 is converted based on the triangular fuzzy number and the conversion result is shown in Table 8.

According to the design quality grade division value, the expected values of different grades of the index are calculated using formulas (14)–(18). The specific results are shown in Table 9.

The average value of the information value of the index at each level is calculated and the specific results are shown in Table 10.

Table 9: Evaluation index information value.

Expert	First level	Level 2	Level 3
E1	0	0	0
E2	0	0	2
E3	0	2	∞
E4	0	0	0
E5	0	0	2
E6	0	0	0
E7	0	0	2
E8	0	2	∞
E9	0	0	0
E10	0	0	0
E11	0	0	2
E12	0	0	2
E13	0	0	0
E14	0	0	0
E15	0	0	0
E16	0	0	2
E17	0	0	2
E18	0	2	∞
E19	0	0	0
E20	0	0	0

Table 10: Evaluation index P4' information values at different levels.

	P4 under 1st level	P4 under 2nd level	P4 under 3rd level
Information value	0	0.3	∞

Table 11: Index weight values.

Index	BWM	Antientropy	Combined weights
C1	0.363	0.083	0.223
C2	0.141	0.084	0.113
C3	0.106	0.084	0.095
C4	0.050	0.083	0.067
L1	0.041	0.082	0.061
L2	0.019	0.082	0.050
L3	0.033	0.084	0.058
L4	0.148	0.084	0.116
P1	0.017	0.084	0.051
P2	0.049	0.084	0.067
P3	0.010	0.083	0.047
P4	0.023	0.083	0.053

Using the BWM, antientropy method, and Game Theory to calculate the weight of each evaluation index is shown in Table 11.

Through calculation, the dynamic design quality of the power company's digital system is calculated to be 0.1096, 0.7143, and ∞, respectively. The probability of the system design quality reaching the first level is 92.69%, and the probability of reaching the second level is 60.95%. It does not meet the third level at all. Based on the comprehensive judgment, the design system is still at the first-level design level, and some design indicators have reached the second-level level.

5. Conclusion

Digital transformation is a new system engineering faced by enterprises. The digital construction of power grid enterprises is still in the stage of exploration and running in with the actual operation of enterprise organizational structure, digital system construction process, and technological innovation capability. From the perspective of software system engineering and power enterprise architecture standards, this paper integrates interdisciplinary, interdisciplinary and interdisciplinary technology and management knowledge theory systems, makes a structural analysis on the quality of digital cycle characteristics, model construction, design process and dynamic design in the process of power enterprise digital transformation, and puts forward a quality evaluation method of power enterprise digital system dynamic design based on fuzzy information axiom.

The index system in the evaluation method covers three aspects: business function achievement degree, logical relationship rationality, and physical model technical economy, with a total of twelve specific indicators. The index value measurement methods are mainly analytical method and fuzzy information axiom. The evaluation index division standard is set by the digital evaluation experts of power grid enterprises according to their work experience.

The weight calculation method in the evaluation method is obtained by using the game theory to deal with the subjective weight obtained by BWM and the objective weight obtained by the antientropy weight method. The combined weight calculation method realizes the principle of combining subjective and objective and helps to improve the reliability of the evaluation results.

Combined with the characteristics and current situation of the digital transformation of power grid enterprises, this paper carries out a numerical example analysis of the design quality evaluation of the digital system of power grid enterprises and proves the feasibility of the model.

In the future, with the further deepening of the transformation and development of power grid enterprises to energy Internet enterprises, the evaluation indicators will be further deepened. The indicator system will fully reflect the digital development trend of power grid enterprises and truly help the steady and healthy development of new power systems under the energy Internet.

Data Availability

This article study the dynamic design of the digital system of the provincial power enterprise as the analysis object and hires 20 industry experts to statistically score the 12 indicators of the dynamic design.

Conflicts of Interest

The authors declare no conflicts of interest.

Authors' Contributions

Xinping Wu contributed to the conception and design. Xinzhou Geng and Zhiyi Chen contributed to the index system design. Aidi Dong collected and interpreted the data. Jinchao Li contributed to the evaluation method design and computation. All authors drafted and revised the manuscript together and approved its final publication.

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