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Research on Risk Assessment of PowerGrid Enterprise Asset Management Based on the Life Cycle Cost Management Theory

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I. Introduction

France's Fayol was the first person to introduce the risk management ideainto the business fields of production and management. After the Industrial Revolution, it was recorded in the book, *Administration Industrielle Et Générale*,writtenby Fayol, which laid a foundation for the development of Risk Management Theory. In the United States, Risk Management Theory developed relatively earlier. Due to the world economic crisis from 1929 to 1933, many large and medium-sized enterprises and banks in the United States went bankrupt and the economy recessed profoundly. And the economic crisisreflected the flaws in internal control mechanisms of enterprises. Therefore, many enterprises have established their own insurance departments since then, which are responsible for the audit management in the process of undertaking projects.

The thoughtstowardsRisk

Management Theory can be divided into two schools: the pure risk one and the corporate overall risk one. The pure risk school is represented by the United States. And the school focuses on the corporate static risk management and links it to insurance. It is believed that the risk management is to identify and analyze the pure risks of threatening enterprises, and consider the minimum cost between theinsurance and risk self-preservation so as to make risk management decisions. And it is the theoretical basis of the insurance risk management. The corporate overall risk school concerns all corporate risks that include static risks (the pure riskshold by the pure risk school) and dynamic risks (mainly referring to the speculative risks of enterprises, which are with uncertainty). The school believes that the purpose of risk management decision-making is to minimize the pure risksandmeanwhile maximize the income of speculative risks [1].

Risk identification is the basis of risk management in the process of risk management. It refers to the identification of which risks will affect the occurrence of an event, and then records their characteristics as a document.Currently,the frequently-used risk identification technologies include brainstorming, checklist analysis, questionnaire and interview, Delphi Method, nominal group techniques and Causality Diagram, system dynamics, influence diagram analysis and other graphic techniques [2]. In recent years, Support Vector Machines (SVM), triangular fuzzy numbers, the analysis based on SWOT, and Hierarchical Holographic Modelings(HHM)[3] have also been gradually applied to the risk identification. As for the research on the source and type of asset assessment risk, Xu Haicheng (2002) proposes that asset assessment risks should be divided into the predictable risks, the known risks, and the unpredictable risks. And he conducts risk researches on whether the risk is predictable [4].Pan Xuemo (2000) divides the risks that asset assessment organizations may face when accepting business into the legislative risks, the management risks, the practicing risks and the results' using risks, and puts forward corresponding countermeasures to regulate the industrydevelopment[5].Wang Xiudong, Wang Shuzhen, and Zhao Banghong (2002) believe that the analysis of the factors causing risks comes from three perspectives: the internal control mechanism of theassessment agency, the evaluation personnelquality, and the establishment of the evaluation law. And they mainly illustrate the issues that should be paid attention to by asset assessment agencies and appraisers in the process of undertaking businesses[6]. Cheng Yangchun (2004) divides asset appraisal risks into two types: the internal risks and the external ones. Internal risks are mostly caused by assessment agencies and the assessment industry personnel, and the reasons for the risks are subjective. And external risks mostly come from objective factors. And he emphasizes the external risks can not be ignored [7]. Yang Zhihai (2005) believes that the studies of asset appraisal risks can be divided into two parts, the studies towards the objective factors from externality, and the studies towards the subjective factors of the professional quality of appraisal organizations and asset appraisal staff[8]. Liu Yong (2006) mainly focuses on the legal responsibility of asset assessment as for the source of assets assessment risks, and comes up with some important issues for evaluating theliability of asset assessment law[9]. Yang Jian(2012)'s studytowards the sources of asset assessmentrisks focuses on the imperfection of the legal system and the assessment personnel. It is proposed to speed up and improve the construction of related laws and regulations on asset assessment, set up a unified industry supervision mechanism, and establish expert advisory committees for the asset assessment, and etc[10] . Wang Jiegang (2000) analyzes the pricing risk, the project risk, the quantity risk, and the quality risk in assessment, and then proposes solutions[11].·Wang Haisu, Wen Hao, and Zhang Shiru (2002) emphasize that the risk prevention should run through every process of asset evaluation, from the search for information, then the analysis and judgment, and to the revelation, and then build up a complete prevention system. And they propose that the risk management system should include the risk identification, the risk estimation, the risk assessment, the risk control and the risk effectiveness evaluation [12]. Liu Rongxian, Zhao Banghong, and Qiao Hong (2004) employthe risk management and control principles to establish the risk control modeling, and take corresponding risk management measures to control risks in the preparation phase, implementation phase, and examination phase of the asset evaluation business[13]. Liu Yan, Song Jian (2005) apply the multi-level fuzzy mathematics comprehensive evaluation method to the asset evaluation risk management process for the first time[14].Han Xiaodong (2007) classifies the risks of asset assessment into four categories: the environmental assessmentrisks, the risks of assessing practices, the associated risks and the risks of assessing operation. Furthermore, the associated risks are further divided into four categories: the risk of jointly committing to take large-scale projects, the risk of using other people's assessment results, the basic information provided by the assessed departments, and the local government’s intervention. He suggests establishingthe asset assessmentrisk’s management mechanism, which includesthe risk prediction, the risk control and the risk supervision[15].

Life Cycle Asset Management (LCAM) is the development of Life Cycle Cost(LCC) [17], LCAM is put forward through the application of LCC to the asset management. LCAM is a management method and concept that pursues the lowest life cycle cost. The concept fully considers the entire processes from the programming and planning, the procurement and construction,to the decommissioning disposal under the premise of satisfying efficiency, effectiveness and safety[18].In terms of the researches towards LCAM, Takata makesprograms according to the long-term plan, the medium-term plan, the stage plan, and the current plan of the asset management[19]. Ahmed divides the asset life cycle into four parts: the asset performance evaluation phase, the asset strategy development phase, the network design and planning phase, and the construction phase. These four parts are not separated from one another, but are continuously cycled, refined, and combined into an integrated process[20]. Meng Xianhai (2007) and Cai Ling (2006) conduct in-depth researches on the asset lifecycle programming andplanning. Based on the life cycle cost management theory, they propose a quantitative analysis modeling for the preliminary planning of project assets, which provides the theoretical support and practical foundation for the smooth implementation of the planning and programming work of

LCAM[20] [21].

II. Life Cycle Asset Theory

From the standpoint of equipment reliability, the traditional equipment management refers to the maintenance and operation management of the equipment in service. The traditional equipment management reflects the material movement status of the equipment in such processes as the equipment installation, usage, maintenance, and replacement and etc. For power enterprises, the asset management mainly focuses on fixed assets, projects under construction and engineering assets, including devices that are easier to identify the life cycle, such as substations, transformers, circuit breakers, and lines. With the objective of optimizing the economic efficiency of assets, and making the technical performance of assets meet the requirements, corresponding asset decisions (such as the new construction, renovation, maintenance, replacement, and etc.) are made. The asset management is actually the comprehensive management of equipment including the equipment technology management and the financial management. It starts from the economy of the entire operation of the company and manages the activities of the entire life cycle of the asset, which reflects the movement state of the asset value, including a series of content such as the equipment purchase, investment, maintenance, and decommissioning.

Modern equipment life cycle management includes not only the concept of equipment management, but also the concept of asset management, and also contains the management of both the physical state of equipment and the asset value changes. Therefore, the equipment life cycle management should start from not only the reliability of equipment but also the economic performance of enterprise. It includes the overall equipment and asset management processes from the programming and planning, the purchase and installation, the operation and maintenance, to the decommissioning disposal. And the asset management aims at optimizing the economic efficiency of assets. When the technical performance of assets meets the requirements, corresponding asset decisions (such as the new construction, renovation, maintenance and replacement, and etc.) are made. The asset management actually equals the equipment integrated management including the equipment's technical management and the financial management.

Based on the long-term economic benefits of the company, LCAM is to carry out overall management towards the entire processes of the equipment usage,including programming,planning, manufacturing, purchasing, installing, commissioning, operating, maintaining and transforming, up-dating and discarding through a series of technical and economic organizationmeasures. And guaranteeing the safety performance of the power grid, it is a kind of management concept that controls the expenses incurred in the whole processes and then minimizes the life cycle cost. Its core content is how to consistently formulate and implement the most valuable decisions of the corporate asset's usage and maintenance within the equipment cycle. LCAM has five characteristics:

(1) The pursuit of the most economical life cycle cost;

(2) The comprehensive management and study from three aspects: technology, economy, and management;

(3) The application of the technologies of Reliability Engineering and Maintainability Engineering;

(4) The scope of management extends to the full life cycle of the equipment, that is, the management towards the equipment in all processes;

(5) The attention towards the feedback management of various information.

Therefore, on the basis of the successful experience of traditional equipment management, LCAM absorbs the essence of modern management theories (the system theory, control theory, information theory, and decision theory), and comprehensively applies modern new technologies (failure studies, Reliability Engineering, Maintainability Engineering, and equipment diagnostics) to manage equipment scientifically and efficiently.

III. The Construction of Asset Management Risk Index System

According to the company's asset management processes, risk sourcesare identified, and then a risk index system is constructed based on the risk sources, which relates to not onlythe indexes of each process of the company's asset management, but also the static and dynamicindexes, and the qualitativeand quantitative indexes.

3.1 Risks Indexes in the Programming and Planning Process

The programming and planning stage includes the grid programming process, the project approval process, the investment planning process, and the preliminary designing process. The concerned sources of risks are the planning policies' risk source, the planning technology risk source, the planning environment's risk source, the budget risk source, the investment plan execution's risk source and the design work management system's risk source.

(1) The planning policies' risk source. It contains the tax policies' risk and the land policies' risk, among which tax policies' risk index ispercapita tax amount and land policies' risk indexisthe land policies' influence, including the land using policies and the compensation policies towards land acquisition.

(2) The planning technical risk source. It contains the risk of equipment advancement and the environmental risk of equipment. And the risk index of equipment advancement is the rate of smart substations, and the environmental risk index of equipment is the growthrate of the grid-connected generation of clean energy.

(3) The planning environment's risk source. It contains the risk of uncertainty in electricity prices, the risk of uncertainty in on-grid energy, and therisk of uncertainty in the supply and demand of regions. Among them, the risk index of uncertainty in electricity price is the average transmission and distribution price; the risk index of uncertainty in on-grid energy on the grid is the growth rate of consuming capacity; and the risk index of uncertainty in regional supply and demandis the growth rate of cross-regional poweroutput .

(4) The budget risk source. It contains the risk of uncertainty in benefitand the risk of budget execution. The benefit uncertainty's risk indexes are the main business' profit rate and the returnon net assets, while the budget execution risk index includes the budget implementation's deviation rate.

(5) The risk source of investment plans' execution. It contains the risk of construction cost and the risk of plan adjustment. The construction cost's risk index is the cost of power transmission and distribution per kWh, and theplan adjustment's risk index is the rate of preliminary schemes' adjustment.

(6) The risk source of design work management system. It contains the risk of bid management and the risk of the compatibilitydegree withlocal plans. The design management's risk indexesare the design progress (thecompletion degreeofprojects) and the rationality of bid segmentation. And additionally the risk indexof the compatibility with local plans is also included.

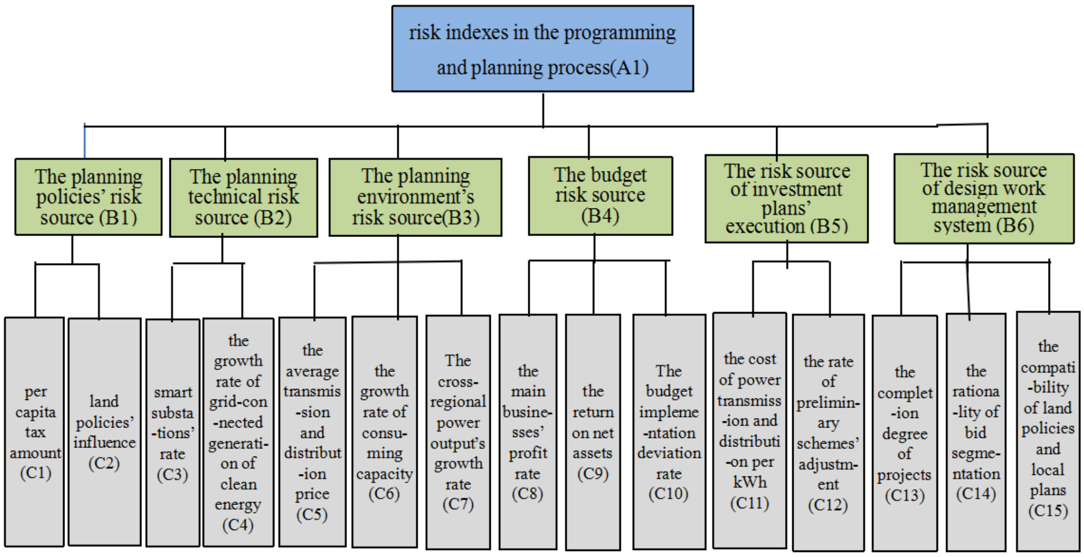

Figure 3-5 Risk Indexes in the Programming and Planning Process

3.2 Risk Indexes in the Procurement and ConstructionProcess

The procurement and construction phase includes the tender management process and the project construction process. Among them, the risk sources of the tender management process include the bidders' risk source and the bidding subjects' risk source; the risk sourcesin the construction process include the construction preparation's risk source and the civil construction's risk source.

(1) The bidders' risk source. It includes the risks of corporate strengthand corporate integrity. The corporate strength's risk index includes the implementation rate of material procurement standard; the corporate integrity's risk indexes include the timeliness rate of contract signings and the completion rate of material procurement plans.

(2) The bidding subjects' risk source. It includes the quality risk and the damaging risk of the subjects. And the quality risk index is the equipment lifeand thedamaging risk index includes the equipment availability coefficient.

(3) The construction preparation's risk source. It includes the risk of the extension of construction duration and the risk of unqualified construction duration. And the risk indexesare the timely completion rate of projects and the deviation rate of the completionof comprehensive plan indexes.

(4) The civil construction's risk source. It includes the construction safety's risk and the construction environment's risk, in which the constructionsafety's risk index is the total number of personal safety incidents, and the construction environment's risk index is the natural risks in construction sites.

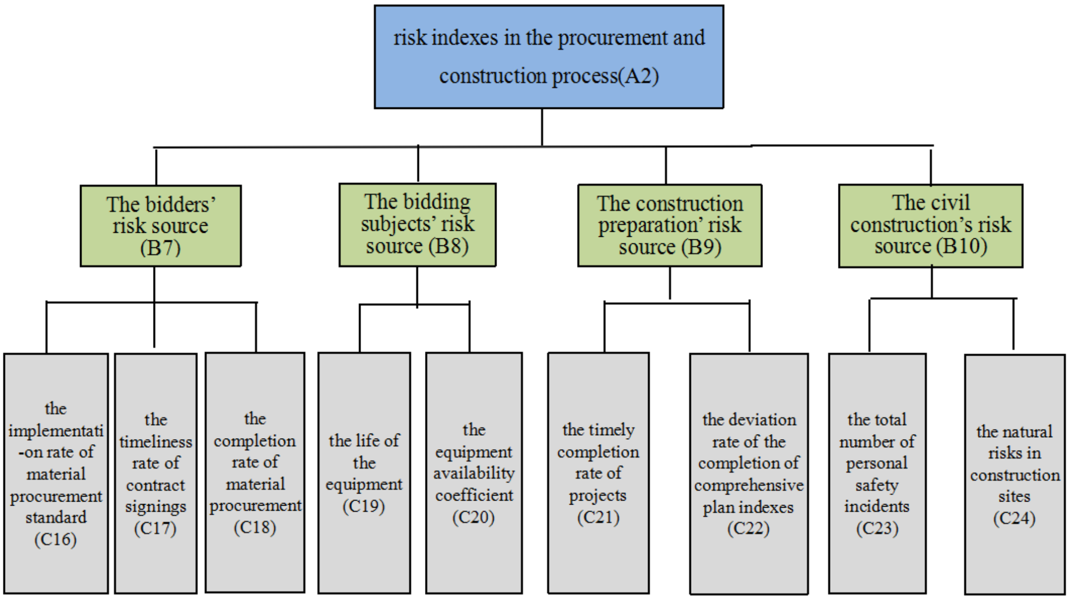

Figure 3-6 Risk Indexes in the Procurement and Construction Process

3.3 Risk Indexes in the Operation and MaintenanceProcess

The phase of operation and maintenance includes the operating and overhauling process and the spare parts' management process. The risksources for the operating and overhauling processinclude the equipment operation's risk source and the line maintenance's risk source, while the risk sources for the spare parts' management process include the risk source ofreserved facilities and the risk source of the spare parts' fixed demand.

(1) The equipment operating risk source. It includes the operational security risk, and its risk indexesare the total number of equipmentsafety incidents, the cost of operating and maintaining grid assets per 10,000 yuan, and the outage rate of equipment failures.

(2) The line maintenance's risk source. It includes the maintenance cost's risk and the transmission lines' risk. Among them, the maintenance cost's risk index is the total value of maintenance costs; the transmission line's risk indexes include the line tripping rate and the outage rate of power system breakdown.

(3) The reserved facilities' risk source. It includes the qualified rate of reserved facilities and the talent equivalent density.

(4) The spare parts' risk source. It includes the inventory turnover rate of spare parts and the transferringspeed of spare parts.

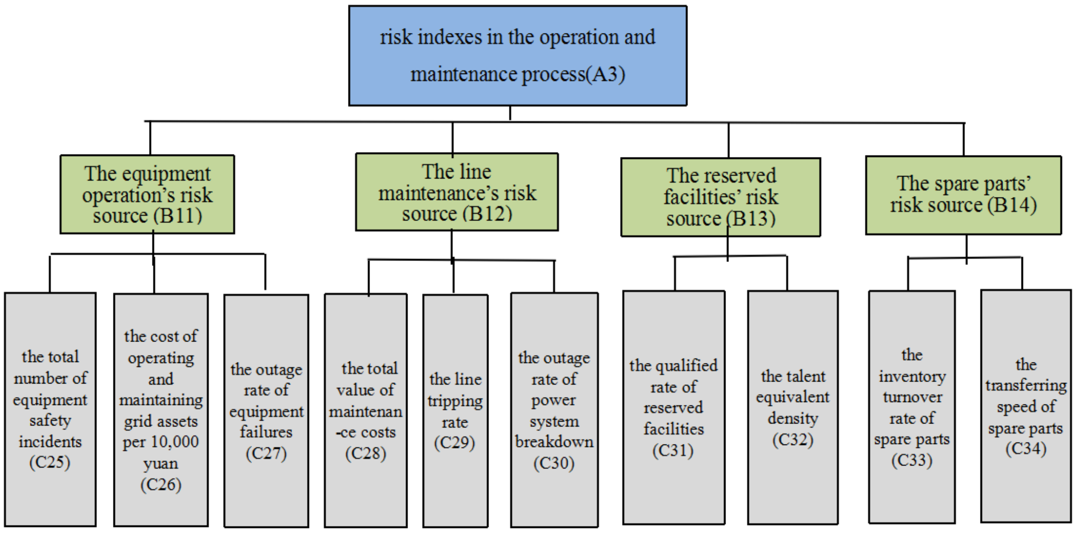

Figure 3-7 Risk Indexes in the Operation and Maintenance Process

3.4 Risk Indexes in the Decommissioning and Disposal Process

The decommissioning and disposal stage includes the technological renovation process and the disposal process ofdecommissioned assets. The risk sources of the technological transformation process include the risk source of feasibility studies towards technological renovation and the risk source of technological compatibility; the risk sources of decommissioned assets' disposal process include the risk source of the decommissioned equipment'sstatus assessment and the risk source of decommissioned assets' disposal management.

The unsafe condition of equipment is one of the direct causes of production accidents. Therefore, we must find ways to increase the overall safety of the equipment, so as to improve the safety of the company. In enterprises' production, the use of advanced and highly automated equipment and the elimination of outdated equipment can change the insecurity of equipment. A series of processes such as purchasing, using, fixing, maintaining, decommissioning, processing, as well as the equipment's operation status can reflect the equipment's security risks.

(1) The risk source of feasibility studiestowards technological renovation. The main risk indexes of it include the completion rate of technological reforming projects and the rate of the highly qualified technological renovation projects.

(2) The risk source of technological compatibility. It includes thecompatibilityrisk of the primary equipmentand the compatibilityrisk of the secondary equipment. The compatible primary devices include UHV, conventional energy, clean energy, energy storage devices, etc. The compatible secondary devices include protection devices, measurement devices, control devices, communication devices, software, and etc.

(3) The risk source of assessing retired equipment's status. The main risk indexes include the average life of decommissioned circuit breakers and the average life of decommissioned transformers.

(4) The risk source of retired assets' disposal and management. The risk indexes include the depreciation rate of fixed assets and the newnessrate of retired assets.

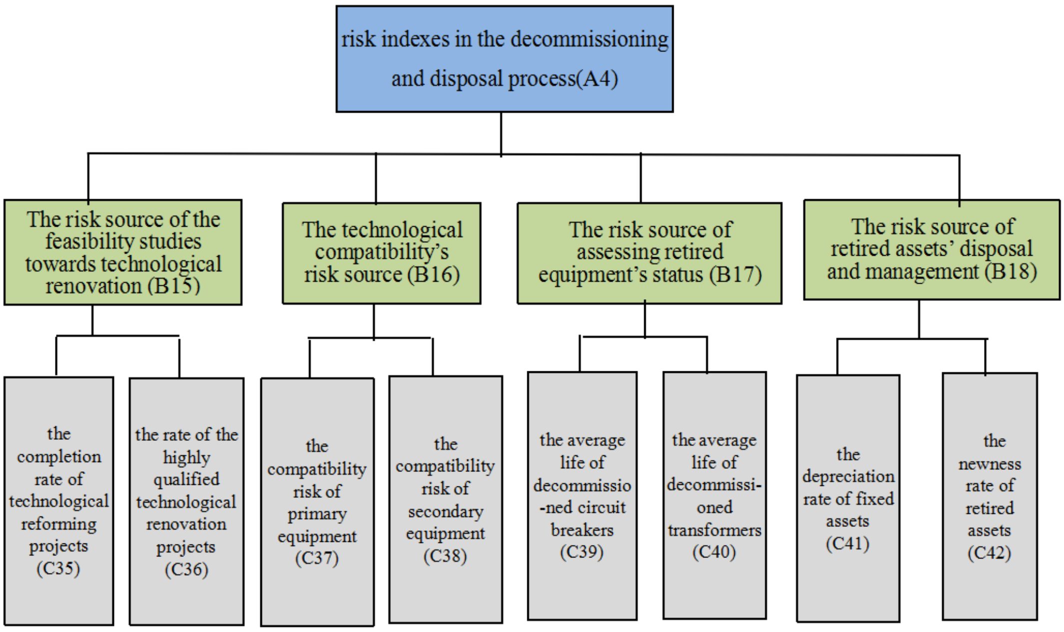

Figure 3-8 Risk Indexes in the Decommissioning and Disposal Process

Table 3-1 The Risk Index System of the Corporate Asset Management

The Processes	Risk Sources	Risk Indexes
the programming and planning process A_1	the planning policies' risk source B_1	percapita tax amountC_1
		land policies' influenceC_2
	the planning technical risk sourceB_2	the rate of smart substationsC_3
		the growthrate of the grid-connected generation of clean energyC_4
	the planning environment's risk sourceB_3	the average transmission and distribution priceC_5
		the growth rate of consuming capacityC_6
		the growth rate of cross-regional poweroutputC_7
	the budget risk sourceB_4	the main businesses' profit rate C_8
		the returnon net assetsC_9
		the budget implementation deviation rateC_{10}
	the risk source of investment plans' executionB_5	the cost of power transmission and distribution per kWh C_{11}
		the rate of preliminary schemes' adjustment C_{12}
	the risk source of the design work management systemB_6	the completion degreeof projects C_{13}
		the rationality of the bid segmentationC_{14}
		the compatibility of land policies and local plans C_{15}
the procurement and construction process A_2	the bidders' risk sourceB_7	the implementation rate of material procurement standardC_{16}
		the timeliness rate of contract signings C_{17}
		the completion rate of material procurement plansC_{18}
	the bidding subjects' risk sourceB_8	the equipmentlifeC_{19}
		the equipment availability coefficient C_{20}

	the construction preparation's risk sourceB_9	the timely completion rate of projects C_{21}
		the deviation rate of the completionof comprehensive plan indexesC_{22}
	the civil construction's risk sourceB_{10}	the total number of personal safety incidentsC_{23}
		the natural risks in construction sites C_{24}
the operation and maintenance process A_3	the equipment operation's risk sourceB_{11}	the total number of equipmentsafety incidentsC_{25}
		the cost of operating and maintaining grid assets per 10,000 yuanC_{26}
		the outage rate of equipment failuresC_{27}
	the line maintenance's risk sourceB_{12}	the total value of maintenance costsC_{28}
		the line tripping rateC_{29}
		the outage rate of power system breakdownC_{30}
	the reserved facilities' risk sourceB_{13}	the qualified rate of reserved facilitiesC_{31}
		the talent equivalent densityC_{32}
	the spare parts' risk sourceB_{14}	the inventory turnover rate of spare partsC_{33}
		the transferringspeed of spare partsC_{34}
the decommissi-oning and disposal process A_4	the risk source of the feasibility studiestowards technological renovation B_{15}	the completion rate of technological reforming projects C_{35}
		the rate of the highly qualified technological renovation projectsC_{36}
	the technological compatibility risk sourceB_{16}	the compatibilityrisk of the primary equipmentC_{37}
		the compatibilityrisk of the secondary equipmentC_{38}
	the risk source of assessing retired equipment statusB_{17}	the average life ofdecommissioned circuit breakers C_{39}
		the average life ofdecommissioned transformers C_{40}
	the risk source of retired assets' disposal and managementB_{18}	the depreciation rate of fixed assetsC_{41}
		the newnessrate of retired assetsC_{42}

IV. The Asset Management'sRisk Assessment ModelBased on the Matter-element Extension

4.1 Matter-element Extension Analysis Method

1). Matter-element

The matter$N$ has the characteristic c, and $v$is the value of c. Then an ordered triad,$R=(N, c, v)$, consisting of N, c, and v, is used as the basic element for describing the matter$N$, simply called "matter-element".

The matter N has many characteristics, which can be described by n characteristics, $c_1, c_2, \cdots, c_n$ and corresponding values, $v_1, v_2, \cdots, v_n$. Thus, the resultant matter R is an n-dimensional matter-element, denoted as:

$$R=(N,C,V)=\begin{bmatrix} R_1 \\ R_2 \\ \vdots \\ R_n \end{bmatrix}=\begin{bmatrix} N & c_1 & v_1 \\ & c_2 & v_2 \\ & \vdots & \vdots \\ & c_n & v_n \end{bmatrix} \quad (1)$$

In the formula, $R_i=(N_i,C_i,V_i)$ present the sub-elements of R; $C=[c_1,c_2,\ldots,c_n]$ represent the eigenvector; $V=[v_1,v_2,\ldots,v_n]$ represent the values of $C=[c_1,c_2,\ldots,c_n]$.

The idea of the matter-element evaluation method can be fully illustrated below. First of all, according to the existing data, the levels of the evaluated objects are divided into several grades. And next the data range of each grade is given by the database or according to expert opinions. Then the indexes of the evaluated objectsareput into the collection of each grade to perform multiple index evaluation.The assessment results depend on the degree of correlation between the indexes and each collection.The greater the correlation degree is, the greater the degree of conformity is.

2). Evaluation Procedures

（1）The identification the matter-elements formed by the classical field, the segment field, and the to-be-identified objects.

$$R_j=(N_j,C_i,V_{ji})=\begin{bmatrix} N_j & c_1 & v_{j1} \\ & c_2 & v_{j2} \\ & \vdots & \vdots \\ & c_n & v_{jn} \end{bmatrix}=\begin{bmatrix} N_j & c_1 & \langle a_{j1},b_{j1}\rangle \\ & c_2 & \langle a_{j2},b_{j2}\rangle \\ & \vdots & \vdots \\ & c_n & \langle a_{jn},b_{jn}\rangle \end{bmatrix} \quad (2)$$

In the formula, N_j represents the divided*j* levels ;$c_1,c_2,\ldots,c_n$ represent the *n* different characteristics of N_j ; $v_{j1},v_{j2},\ldots,v_{jn}$ represent the value ranges of N_j in such aspects as $c_1,c_2,\ldots,c_n$, that is, the classical field. Let

$$R_p=(p,C_i,V_{pi})=\begin{bmatrix} p & c_1 & \langle a_{p1},b_{p1}\rangle \\ & c_2 & \langle a_{p2},b_{p2}\rangle \\ & \vdots & \vdots \\ & c_n & \langle a_{pn},b_{pn}\rangle \end{bmatrix} \quad (3)$$

In the formula, p represents the overall grades of theto-be-evaluated matters; $v_{p1},v_{p2},\ldots,v_{pn}$ represent respectively the valueranges of *p*in such aspects as $c_1,c_2,\ldots,c_n$, that is, the segment field of *p*. Let

$$R_0==\begin{bmatrix} p_0 & c_1 & v_1 \\ & c_2 & v_2 \\ & \vdots & \vdots \\ & c_n & v_n \end{bmatrix} \quad (4)$$

In the formula, p_0 indicates the to-be-evaluated matter-element; $v_1,v_2,\ldots,v_n$ represent respectively the specific data obtained from the tests towards p_0 in such aspects as $c_1, c_2, \ldots, c_n$.

（2）The normalization treatment

When the actual values ofevaluated indexes exceed the segment field range, the correlation degree function can't be calculated.And in this case, the performance evaluation towards the power generation cannot be carried out by the matter-element extension method.In order to overcome this limitation, in this section, the values of the classical field matter-elements and the to-be-evaluatedmatter-elementsaregoing to be normalized on the basis of the original matter-element extension method. They are divided by theright endpoint value b_{pi} of the segment field V_p, and then the new matter-element classical field and the new to-be-evaluated matter-element are obtained.The specific calculation is as follows:

$$R_j' = (N_j, C_i, V_{ji}') = \begin{bmatrix} N_j & c_1 & <\frac{a_{j1}}{b_{p1}}, \frac{b_{j1}}{b_{p1}}> \\ & c_2 & <\frac{a_{j2}}{b_{p2}}, \frac{b_{j2}}{b_{p2}}> \\ & \vdots & \vdots \\ & c_n & <\frac{a_{jn}}{b_{pn}}, \frac{b_{jn}}{b_{pn}}> \end{bmatrix} R_0' == \begin{bmatrix} p_0 & c_1 & v_1/b_{p1} \\ & c_2 & v_2/b_{p2} \\ & \vdots & \vdots \\ & c_n & v_n/b_{pn} \end{bmatrix} \quad (5)$$

(3) The calculation of correlation degree

Through the formula (5-21),the distance D between the new matter-element for appraising and the value range of the newclassical fieldis calculated.

$$D(v, V_{ji}') = \left| v - \frac{a+b}{2} \right| - \frac{b-a}{2} \quad (6)$$

In the formula, *v* represents the point value; *a* and *b* represent respectively the left endpoint value and the right endpoint value of the interval.

$$K_j(p_o) = 1 - \sum_{i=1}^{n} w_i D_{ij} \quad (7)$$

In the formula, w_i represents the index weight; $K_j(p_o)$ represents the overall correlative degree.

（4）The gradeassessment

If $K_j(p_o) = \max\{K_j(p_o)\} (j = 1, 2, \ldots, m)$, then the to-be-evaluated matter- element p_o belongs to*j*grade. Let

$$\bar{K}_j(p_o) = \frac{K_j(p_o) - \min K_j(p_o)}{\max K_j(p_o) - \min K_j(p_o)} \quad (8)$$

$$j^* = \frac{\sum_{j=1}^{m} j\bar{K}_j(p_o)}{\sum_{j=1}^{m} \bar{K}_j(p_o)} \quad (9)$$

In the formula, j^* represents the variable eigenvalue of the risk level. From the size of j^*, the degree to which the to-be-evaluated matter-element is biased toward the adjacent grade can be judged.

4.2 The StandardizationTreatment towardsRisk Indexes

In the asset management's risk assessment, the risk indexes are first standardized, and then people use the index weight distribution method to provide the basis for risk indexes' evaluation.

1). The uniformed treatment towards indexes

In general, among the indexes, $x_1, x_2, \ldots, x_m$, there may be four types: very large indexes, miniature indexes, intermediate indexes, and interval indexes. According to the different types, the index set $X = \{x_1, x_2, \ldots, x_m\}$ can be divided as follows:

$$X = \bigcup X_i \text{ ,and } X_i \bigcap X_j = \varnothing \quad (10)$$

Inthe formula, $X_i\,(i = 1,2,3,4)$ signifies the very large index set, the miniature index set, the intermediate index set, and the interval index set. For the convenience of discussion, this article will uniformly treat all types of indexes as extremely large indexes. The specific treatment methods are as follows:

（1）The uniformed treatment towards miniature indexes. As for the miniature index x, let

$$x^* = \frac{1}{x}, (x \neq 0) \quad (11)$$

（2）The uniformed treatment towards intermediate indexes. As for the intermediate index x, let

$$x^* = \begin{cases} \frac{2(x-m)}{M-m}, \left(m \le x < \frac{M+m}{2}\right) \\ \frac{2(M-x)}{M-m}, \left(\frac{M+m}{2} \le x < M\right) \end{cases} \quad (12)$$

In the formula, m is an allowable lower bound for the index x; M is an allowable upper bound for the index x.

（3）The uniformed treatment towards interval indexes

$$x^* = \begin{cases} 1 - \frac{q_1 - x}{\max\{q_1 - m, M - q_2\}}, (x < q_1) \\ 1 \qquad\qquad\qquad\qquad , x \in [q_1, q_2] \\ 1 - \frac{x - q_2}{\max\{q_1 - m, M - q_2\}}, (x > q_2) \end{cases} \quad (13)$$

In the formula, $[q_1, q_2]$ is the most stable interval; M and m are the allowable upper and lower bounds for $x$respectively.

2). The dimensionlesstreatment of quantitativeindexes

（1）Standard treatment method

$$x_{ij}{}^{*} = \frac{(x_{ij} - \overline{x}_j)}{s_j} \quad (14)$$

In the formula, x_{ij}^{*} is the standard observation value; $\overline{x}_j, s_j$ are respectively the sample mean and the sample mean square deviation for the j^{th} index's observation value.

（2） Extreme value treatment method

$$x_{ij}^{*} = \frac{x_{ij} - m_j}{M_j - m_j} \quad (15)$$

Inwhich, $M_j = \max_i \{x_{ij}\}, m_j = \min_i \{x_{ij}\}$。

（3）Normalization

$$x_{ij}^{*} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}} \quad (16)$$

The normalization method can be considered as a special case of the linear proportional method. Under the premise of $\sum_{i=1}^{n} x_{ij} > 0$, and when $x_{ij} > 0$, $x_{ij}^{*} \in (0,1)$ has no fixed maximum and minimum value, and $\sum_{i=1}^{n} x_{ij}^{*} = 1$.

（4）Linear proportional method

$$x_{ij}^{*} = \frac{x_{ij}}{x_j^{*}} \quad (17)$$

In the formula, x_{ij}^{*} can take the minimum, the maximumor the average value of the index. When x_j^{s} takes the minimum value of the index, the value range of x_{ij}^{*} is $[1, +\infty]$; when x_j^{s} takes the maximum value, the value range of x_{ij}^{*} is $[-\infty, 1]$; when x_j^{s} takes the average value, the value range of x_{ij}^{*} is $[-\infty, +\infty]$.

（5）Vector standardized method

$$x_{ij}^{*} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^{2}}} \quad (18)$$

The normalization method can be considered as a special case of the linear proportional method. When $x_{ij} > 0$, $x_{ij}^{*} \in (0,1)$ has no fixed maximum and minimum value, and $\sum_{i=1}^{n}\left(x_{ij}^{*}\right)^{2} = 1$.

(6) Efficiency coefficient method

$$x_{ij}^{*} = c + \frac{x_{ij} - m}{M_j - m_j} \times d \quad (19)$$

In the formula, M_j and m_j are respectively the satisfied value and the non-permitting valueof the index x_j; *c* and *d*are already given. The role of *c* is to "translate" the transformed value, while the effect of *d* is to "amplify" or "reduce" the transformed value, typically taking *c*=60, *d*=40.

3). The dimensionlesstreatment of qualitative indexes

It is often encountered that qualitative indexes appear in the evaluation system.In order to form an organic evaluation system withquantitative indexes, the qualitative indexes should be standardized. The commonly used and relatively simpler method is to firstly use the subjective weightmethod to score the different indexes' descriptions, and then standardize them by the corresponding standard functions according to the indexes' attributes. And the evaluation valuescan also be directly calculated based on subjective scores.

4.3 The Distribution Model of Risk Index Weight

Traditional calculating models for evaluating the index weightmainly include the subjective weight distribution model based on the function-driven principle and the objective weight distribution model based on the difference-driven principle. The two kinds of weight distribution models use a variety of specific methods.For example, the subjective weight distribution model adopts the occurrence statistics iterative method,the eigenvalue method, and the order relation method,while the objective weightdistribution model employsthe mean square difference method, the variation coefficient method, and the entropy method.

The subjective weighting method based on the function-drivenprinciple reflects the subjective judgment or intuition of appraisers, while the objective weightdistribution model, based on the difference-driven principle, uses the perfect mathematical theories and methods to calculate the weight. Thus, both havetheir own advantages.However, the comprehensive evaluation results of the subjective weight distribution model may be influenced by the subjective randomness of appraisers, and also the objective weight distribution modelignores the subjective information of appraisers.It is precisely because of the two kinds of problems that the conventional objective evaluation results often have some deviation from the real results. In order to overcome the above problems, this section proposes a weight distribution model based on Integrated Enduing Coefficients.The weight distribution model aims at minimizing the difference between the subjective and objective weightings. By optimizing the weighting coefficient, the final index weight is obtained, and the subjective information and the objective information of the evaluated index is better consolidated.

Suppose that through the ANP method, the subjective weight vector of the enterprise asset management's risk assessment index is, $w' = \left(w_1', w_2', \ldots, w_n'\right)^T$, and it satisfies the formula, $w_j' \in [0,1]$, $\sum_{j=1}^{n} w_j' = 1$; And by the entropy weight method, the objective weight vector of the enterprise asset management's risk assessment index is calculated as: $w'' = \left(w_1'', w_2'', \ldots, w_n''\right)^T$, and it satisfies the formula, $w_j'' \in [0,1]$, $\sum_{j=1}^{n} w_j'' = 1$; The final weight vector obtained by weighting the subjective weight vector and the objective weight vector is:

$$w = \alpha w' + \beta w'' \qquad (20)$$

In which α, β satisfy the formula, $\alpha, \beta > 0, \alpha + \beta = 1$.

In order to fully embody the subjective andobjective information in the alternative ranking, this paper starts from the weighted attribute values and establishes an optimization model of the coefficients α, β in the combined weight, taking into account the fact that the weighted attribute values determined by the subjective weight and the ones determined by the objective weight tend to be uniform. According to the formula (3-26), under the attribute u_j, the subjective weighted attribute value of scheme a_i is $r_{ij}\alpha w_j$, and the objective weighted attribute value is $r_{ij}\beta w_j'$.Thus the difference between the subjective and objective weighted attribute values is $r_{ij}\alpha w_j - r_{ij}\beta w_j'$. Therefore, it can be drawn out that the deviation degree of the subjective and objective decision information of program a_i is: $d_i = r_{ij}\alpha_j w_j - r_{ij}\beta_j w_j'$ (21)

Obviously, the smaller d_i is, the more consistent the subjective and objective decision-making information of the program is. Therefore, the optimization model can be constructed as follows:

$$\min D = \left(d_1, d_2, \ldots, d_m\right) \qquad (22)$$

This is apparently a multi-objective decision programming problem. Since there is fair competition among various programs and there is no preference,so the above-mentioned multi-objective programming model can be transformed into the equivalent single-objective programming models as follows by the linear weighted sum method.

$$\min Z = \sum_{i=1}^{m} d_i = \sum_{i=1}^{m}\sum_{j}^{n}\left(r_{ij}\alpha_j w_j - r_{ij}\beta_j w_j'\right) \qquad (23)$$

$$s.t.\alpha_j + \beta_j = 1\left(\alpha_j, \beta_j \geq 0\right) \qquad (24)$$

5. The Empirical Analysis of Corporate Asset Management's Risk Assessment

Through the analysis of the company's asset management risks, an index system for asset management's risk assessment of a grid company is constructed. According to the four processes, the programming and planning process, the procurement and construction process, the operation and maintenance process, and the decommissioning and disposal process, the whole index system has a total of 18 secondary indexes and 43 tertiary indexes. The risk sources and risk indexes are shown in Table 3-1.

5.1 The Determinationof the Index Weight Coefficient

According to the expert questionnaire and actual situationssuch as power grid's operation risks, the following index weights are obtained:

Table 5-1 The indexweights of risk sources'indexes in a grid company

the index	the index weight	the index	the index weight
B_1	$\omega_{B_1}=(0.3,0.7)$	B_{10}	$\omega_{B_{10}}=(0.3,0.7)$
B_2	$\omega_{B_2}=(0.4,0.6)$	B_{11}	$\omega_{B_{11}}=(0.35,0.25,0.4)$
B_3	$\omega_{B_3}=(0.4,0.4,0.2)$	B_{12}	$\omega_{B_{12}}=(0.3,0.3,0.4)$
B_4	$\omega_{B_4}=(0.35,0.35,0.3)$	B_{13}	$\omega_{B_{13}}=(0.65,0.35)$
B_5	$\omega_{B_5}=(0.6,0.4)$	B_{14}	$\omega_{B_{14}}=(0.5,0.5)$
B_6	$\omega_{B_6}=(0.4,0.3,0.3)$	B_{15}	$\omega_{B_{15}}=(0.55,0.45)$
B_7	$\omega_{B_7}=(0.333,0.334,0.333)$	B_{16}	$\omega_{B_{16}}=(0.5,0.5)$
B_8	$\omega_{B_8}=(0.5,0.5)$	B_{17}	$\omega_{B_{17}}=(0.5,0.5)$
B_9	$\omega_{B_9}=(0.6,0.4)$	B_{18}	$\omega_{B_{18}}=(0.4,0.6)$

Among them,the weights of the risk sources' indexesin the B-layer in the process respectively are:

$$\omega_{A_1}=(0.2,0.2,0.2,0.15,0.15,0.1)$$

$$\omega_{A_2}=(0.2,0.2,0.3,0.3)$$

$$\omega_{A_3}=(0.3,0.3,0.2,0.2)$$

$$\omega_{A_4}=(0.25,0.25,0.2,0.3)$$

In the risk assessment of corporate asset management, the weight of each process is: $\omega=(0.25,0.25,0.25,0.25)$

Then the weight of the layer C in the total target layers is:

$$\omega=\begin{pmatrix}0.015,0.035,0.02,0.03,0.02,0.02,0.01,0.013,0.013,0.011,0.023,0.015,0.01,0.0075,0.0075,\\0.017,0.017,0.017,0.025,0.025,0.045,0.03,0.0225,0.0525,0.026,0.019,0.03,0.0225,0.0225,\\0.03,0.032,0.017,0.025,0.025,0.034,0.028,0.031,0.031,0.025,0.025,0.03,0.045\end{pmatrix}$$

5.2 The Establishment of Risk Assessment Models

With reference to the historical data of a grid company's benchmarks, asset management's risk indexes of the company can be divided into five risk levels, as shown in the following table. Among them, N_1 represents the very high risk level ; N_2 represents the relatively high risk level ; N_3 represents the average risk level; N_4 represents the relatively low risk level ; N_5 represents the very low risk level. And the corresponding colors are red, orange, yellow, blue, and green. The higher the score is, the higher the level is, and the lower level the risk is at. At the same time, the relevant index data of a grid company is selected as a sample for an empirical analysis. The following figure shows the risk indexes' levels and the sample data.

Table 5-2 Risk Indexes' Levels and Sample Data

Index	per capita tax amount c_1	land policies' influence c_2	smart substation s'rate c_3	the grid-connected generation of clean energy's growthrate c_4	the average transmission anddistributio n pricec$_5$	consuming capacity's growth rate c_6
the standard value of a grid company's indexes	0.8844	0.6492	1	0.2371	0.6943	0.2509
very high risk level N_1	0-0.2	0-0.2	0-0.2	0-0.2	0-0.2	0-0.2
relatively high risk level N_2	0.2-0.4	0.2-0.4	0.2-0.4	0.2-0.4	0.2-0.4	0.2-0.4
average risk level N_3	0.4-0.6	0.4-0.6	0.4-0.6	0.4-0.6	0.4-0.6	0.4-0.6
relatively low risk level N_4	0.6-0.8	0.6-0.8	0.6-0.8	0.6-0.8	0.6-0.8	0.6-0.8
very low risk level N_5	0.8-1	0.8-1	0.8-1	0.8-1	0.8-1	0.8-1
Index	cross-regional power output growth ratec$_7$	the main businesses' profit rate c_8	the return onnet assetsc$_9$	the budget implementation deviation rate c_{10}	the cost of unit power transmission and distributionc$_{11}$	the rate of adjusting initial plans c_{12}
the standardvalue of a grid company's indexes	1	0.3224	0.951	0.991	1	0.8371
very high risk level N_1	0-0.2	0-0.2	0-0.2	0-0.2	0-0.2	0-0.2
relatively high risk level N_2	0.2-0.4	0.2-0.4	0.2-0.4	0.2-0.4	0.2-0.4	0.2-0.4
average risk level N_3	0.4-0.6	0.4-0.6	0.4-0.6	0.4-0.6	0.4-0.6	0.4-0.6

relatively low risk level N_4	0.6-0.8	0.6-0.8	0.6-0.8	0.6-0.8	0.6-0.8	0.6-0.8
very low risk level N_5	0.8-1	0.8-1	0.8-1	0.8-1	0.8-1	0.8-1
Index	projects' completion degree c_{13}	the bid segmenta ti-on's rationalit y c_{14}	conformit y degree with local planc$_{15}$	The implementation rate of material procurement standardc$_{16}$	the timeliness rate ofcontract signings c_{17}	The material procureme nt plans' completion ratec$_{18}$
the standard value of a grid company's indexes	0.9506	1	0.7316	1	1	0.8028
very high risk level N_1	0-0.2	0-0.2	0-0.2	0-0.2	0-0.2	0-0.2
relatively high risk level N_2	0.2-0.4	0.2-0.4	0.2-0.4	0.2-0.4	0.2-0.4	0.2-0.4
average risk level N_3	0.4-0.6	0.4-0.6	0.4-0.6	0.4-0.6	0.4-0.6	0.4-0.6
relatively low risk level N_4	0.6-0.8	0.6-0.8	0.6-0.8	0.6-0.8	0.6-0.8	0.6-0.8
very low risk level N_5	0.8-1	0.8-1	0.8-1	0.8-1	0.8-1	0.8-1
Index	The equipment life c_{19}	equipmen t availabilit -y coefficien tc$_{20}$	the timely completio n rate of projects c_{21}	the deviation rate of comprehensive plan indexes' completionc$_{22}$	the total number of personal safetyincidents c_{23}	the natural risks in constructio n sitesc$_{24}$
the standard value of a grid company's indexes	0.8204	0.7509	0.9519	0.3049	1	0.6937
very high risk level N_1	0-0.2	0-0.2	0-0.2	0-0.2	0-0.2	0-0.2
relatively high risk	0.2-0.4	0.2-0.4	0.2-0.4	0.2-0.4	0.2-0.4	0.2-0.4

level N_2						
average risk level N_3	0.4-0.6	0.4-0.6	0.4-0.6	0.4-0.6	0.4-0.6	0.4-0.6
relatively low risk level N_4	0.6-0.8	0.6-0.8	0.6-0.8	0.6-0.8	0.6-0.8	0.6-0.8
very low risk level N_5	0.8-1	0.8-1	0.8-1	0.8-1	0.8-1	0.8-1
Index	the total number of equipment safety incidents c_{25}	the cost of operating and maintaini n-g the grid assets per 10,000 yuan c_{26}	the outage rate of equipment failures c_{27}	the total value of maintenance costs c_{28}	the line tripping rate c_{29}	the outage rate of power system breakdown c_{30}
the standard value of a grid company's indexes	0.2857	1	0.9643	0.174	0.8881	0.5094
very high risk level N_1	0-0.2	0-0.2	0-0.2	0-0.2	0-0.2	0-0.2
relatively high risk level N_2	0.2-0.4	0.2-0.4	0.2-0.4	0.2-0.4	0.2-0.4	0.2-0.4
average risk level N_3	0.4-0.6	0.4-0.6	0.4-0.6	0.4-0.6	0.4-0.6	0.4-0.6
relatively low risk level N_4	0.6-0.8	0.6-0.8	0.6-0.8	0.6-0.8	0.6-0.8	0.6-0.8
very low risk level N_5	0.8-1	0.8-1	0.8-1	0.8-1	0.8-1	0.8-1
Index	the qualified rate of reserved facilities c_{31}	the talent equivalen t density c_{32}	the inventory turnover rate of spare parts c_{33}	the transferring speed of spare parts c_{34}	the completion rate of technical reforming projects c_{35}	the highly qualified rate of technical renovation projects c_{36}

the standard value of a grid company's indexes	0.9031	1	0.874	0.7912	0.9169	1
very high risk level N_1	0-0.2	0-0.2	0-0.2	0-0.2	0-0.2	0-0.2
relatively high risk level N_2	0.2-0.4	0.2-0.4	0.2-0.4	0.2-0.4	0.2-0.4	0.2-0.4
average risk level N_3	0.4-0.6	0.4-0.6	0.4-0.6	0.4-0.6	0.4-0.6	0.4-0.6
relatively low risk level N_4	0.6-0.8	0.6-0.8	0.6-0.8	0.6-0.8	0.6-0.8	0.6-0.8
very low risk level N_5	0.8-1	0.8-1	0.8-1	0.8-1	0.8-1	0.8-1
Index	the compatibilit-yrisk of primary equipment c_{37}	the compatibil-ityrisk of secondary equipment c_{38}	the average life ofdecommissioned circuit breakers c_{39}	the average life of decommissioned transformers c_{40}	the depreciation rate offixed assets c_{41}	the newness rate of retired assets c_{42}
the standardvalue of a grid company's indexes	0.9662	0.82	0.8918	1	0.8659	0.5805
very high risk level N_1	0-0.2	0-0.2	0-0.2	0-0.2	0-0.2	0-0.2
relatively high risk level N_2	0.2-0.4	0.2-0.4	0.2-0.4	0.2-0.4	0.2-0.4	0.2-0.4
average risk level N_3	0.4-0.6	0.4-0.6	0.4-0.6	0.4-0.6	0.4-0.6	0.4-0.6
relatively low risk level N_4	0.6-0.8	0.6-0.8	0.6-0.8	0.6-0.8	0.6-0.8	0.6-0.8
very low risk level N_5	0.8-1	0.8-1	0.8-1	0.8-1	0.8-1	0.8-1

(1) The establishment of the classical field. The classical field of quantitative indexes in the above evaluation index system is given by experts' experience, and is set from 0% to 100%. The classical field of each risk level is in this range. For example, the classical fieldof some very high risk level indexes such as C_1 and C_2 is from 0 to 20%.And the classical fieldof relatively high risk level indexes is from 20% to 40%, and so on. Through expert surveys, qualitative indexes use a 10-point scoring system to identify. After the unification, the miniatureindexes are converted into the very large ones. Then they are divided by 10, and theclassical fields of five risk levels are successivelyranked as 0-20%,20%-40%, 40%-60%, 60%-80%, 80%-100%.

(2) The establishment of the segment field. The segment field of each risk index is the sum of the classical field.

(3) The determination of the to-be-evaluated matter-elements. Through a fuzzy statistical analysis towards the questionnaireresults of the possibility of the occurrence of various risk indexes in a power grid enterprise' asset management risk assessment, the specific values of each index of the to-be-evaluated matter-elements are obtained.

In the matter-element model, each risk level's values of the classical field matter-elements, R_1, R_2, R_3, R_4, R_5,, the segment field matter-elements R_p,and the to-be-evaluated matter-elementsare as follows:

$$R_1 = \begin{bmatrix} N_1 & C_1 & (0, 20\%) \\ & C_2 & (0, 20\%) \\ & \cdots & \cdots \\ & C_{41} & (0, 20\%) \\ & C_{42} & (0, 20\%) \end{bmatrix}$$

$$R_2 = \begin{bmatrix} N_2 & C_1 & (20\%, 40\%) \\ & C_2 & (20\%, 40\%) \\ & \cdots & \cdots \\ & C_{41} & (20\%, 40\%) \\ & C_{42} & (20\%, 40\%) \end{bmatrix} \quad R_3 = \begin{bmatrix} N_3 & C_1 & (40\%, 60\%) \\ & C_2 & (40\%, 60\%) \\ & \cdots & \cdots \\ & C_{41} & (40\%, 60\%) \\ & C_{42} & (40\%, 60\%) \end{bmatrix}$$

$$R_4 = \begin{bmatrix} N_4 & C_1 & (60\%, 80\%) \\ & C_2 & (60\%, 80\%) \\ & \cdots & \cdots \\ & C_{41} & (60\%, 80\%) \\ & C_{42} & (60\%, 80\%) \end{bmatrix} \quad R_5 = \begin{bmatrix} N_5 & C_1 & (80\%, 100\%) \\ & C_2 & (80\%, 100\%) \\ & \cdots & \cdots \\ & C_{41} & (80\%, 100\%) \\ & C_{42} & (80\%, 100\%) \end{bmatrix}$$

$$R_p = \begin{bmatrix} p & C_1 & (0, 100\%) \\ & C_2 & (0, 100\%) \\ & \cdots & \cdots \\ & C_{41} & (0, 100\%) \\ & C_{42} & (0, 100\%) \end{bmatrix}$$

In the formula, R_1、R_2、R_3、R_4、R_5 represent the classical fields; N_1 represents the very high risk level; N_2 represents the relatively high risk level; N_3 shows that the risk level is at an average level; N_4 represents the relatively low risk level; N_5 represents the very low risk level; R_p represents the segment field.

5.3 The Calculation of the Indexes' CorrelationDegree

Since the index values of the asset management risk assessment of a grid company are within the scope of the classical field, the correlation degreecan be calculated directly.

Table 5-3 The correlation value of asset management'srisk levels in a grid company

The index	Very large $D_1(v_i)$	Relatively large $D_2(v_i)$	Average $D_3(v_i)$	Relatively small $D_4(v_i)$	Very small $D_5(v_i)$
C_1	0.6844	0.4844	0.2844	0.0844	-0.0844
C_2	0.4492	0.2492	0.0492	-0.0492	0.1508
C_3	0.8	0.6	0.4	0.2	0
C_4	0.0371	-0.0371	0.1629	0.3629	0.5629
C_5	0.4943	0.2943	0.0943	-0.0943	0.1057
C_6	0.0509	-0.0509	0.1491	0.3491	0.5491
C_7	0.8	0.6	0.4	0.2	0
C_8	0.1224	-0.0776	0.0776	0.2776	0.4776
C_9	0.751	0.551	0.351	0.151	-0.049
C_{10}	0.791	0.591	0.391	0.291	-0.009
C_{11}	0.8	0.6	0.4	0.2	0
C_{12}	0.6371	0.4371	0.2371	0.0371	-0.0371
C_{13}	0.7506	0.5506	0.3506	0.1506	-0.0494
C_{14}	0.8	0.6	0.4	0.2	0
C_{15}	0.5316	0.3316	0.1316	-0.0684	0.0684
C_{16}	0.8	0.6	0.4	0.2	0
C_{17}	0.8	0.6	0.4	0.2	0
C_{18}	0.6028	0.4028	0.2028	0.028	-0.028
C_{19}	0.6204	0.4204	0.2204	0.0204	-0.0204
C_{20}	0.5509	0.3509	0.1509	-0.0491	0.0491
C_{21}	0.7519	0.5519	0.3519	0.1519	-0.0481
C_{22}	0.1049	-0.0951	0.0951	0.2951	0.4951
C_{23}	0.8	0.6	0.4	0.2	0
C_{24}	0.4937	0.2937	0.0937	-0.0937	0.1063
C_{25}	0.0857	-0.0857	0.1143	0.3143	0.5143
C_{26}	0.8	0.6	0.4	0.2	0
C_{27}	0.7643	0.5643	0.3643	0.1643	-0.0357
C_{28}	-0.026	0.026	0.226	0.426	0.626
C_{29}	0.6881	0.4881	0.2881	0.0881	-0.0881

C_{30}	0.3094	0.1094	-0.0906	0.0906	0.2906
C_{31}	0.7031	0.5031	0.3031	0.1031	-0.0969
C_{32}	0.8	0.6	0.4	0.2	0
C_{33}	0.674	0.474	0.274	0.074	-0.074
C_{34}	0.5912	0.3912	0.1912	-0.0088	0.0088
C_{35}	0.7169	0.5169	0.3169	0.1169	-0.0831
C_{36}	0.8	0.6	0.4	0.2	0
C_{37}	0.7662	0.5662	0.3662	0.1662	-0.0338
C_{38}	0.62	0.42	0.22	0.02	-0.02
C_{39}	0.6918	0.4918	0.2918	0.0918	-0.0918
C_{40}	0.8	0.6	0.4	0.2	0
C_{41}	0.6659	0.4659	0.2659	0.0659	-0.0659
C_{42}	0.3805	0.1805	-0.0195	0.0195	0.2195

Through the calculation, the correlation degreeofthe grid company's asset management risk levels is:

$$K_1(p) = 1 - \sum_{i=1}^{42} \omega_i D_{ij} = 0.428$$

$$K_2(p) = 1 - \sum_{i=1}^{42} \omega_i D_{ij} = 0.616$$

$$K_3(p) = 1 - \sum_{i=1}^{42} \omega_i D_{ij} = 0.76$$

$$K_4(p) = 1 - \sum_{i=1}^{42} \omega_i D_{ij} = 0.875$$

$$K_5(p) = 1 - \sum_{i=1}^{42} \omega_i D_{ij} = 0.913$$

Because of $K_5(p) = \max K_j(p), j = (1,2,3,4,5)$, it can be drawn that a grid company's asset management risk level is low.

5.4 The Assessmentof the Level of Each Risk Source

At the same time, the above matter-element extension model is used to carry out risk assessment towards the risk sources in each process.And the evaluation results are displayed in the risk map with the risk assessment method. E.g:

(1) In the programming and planning process, the risk assessment towards the planning policies' risk source is made, and it can be concluded that the risk level is relatively low.

$$K_1(p_{B1}) = 1 - \sum_{i=1}^{2} \omega_i D_{ij} = 0.48024$$

$$K_2(p_{B2}) = 1 - \sum_{i=1}^{2} \omega_i D_{ij} = 0.68024$$

$$K_3(p_{B3}) = 1 - \sum_{i=1}^{2} \omega_i D_{ij} = 0.88024$$

$$K_4(p_{B4}) = 1 - \sum_{i=1}^{2} \omega_i D_{ij} = 1.00912$$

$$K_5(p_{B5}) = 1 - \sum_{i=1}^{2} \omega_i D_{ij} = 0.91976$$

（2）The risk assessment towards the planning technology risk source is made, and it can be concluded that the risk level is relatively high.

$$K_1(p_{B2}) = 1 - \sum_{i=3}^{4} \omega_i D_{ij} = 0.65774$$

$$K_2(p_{B2}) = 1 - \sum_{i=3}^{4} \omega_i D_{ij} = 0.78226$$

$$K_3(p_{B2}) = 1 - \sum_{i=3}^{4} \omega_i D_{ij} = 0.74226$$

$$K_4(p_{B2}) = 1 - \sum_{i=3}^{4} \omega_i D_{ij} = 0.70226$$

$$K_5(p_{B2}) = 1 - \sum_{i=3}^{4} \omega_i D_{ij} = 0.66226$$

（3）The risk assessment towards the planning environment risk source is made, and it can be concluded that the risk level is relatively low.

$$K_1(p_{B3}) = 0.6219 \qquad K_2(p_{B3}) = 0.7826 \qquad K_3(p_{B3}) = 0.8226 \qquad K_4(p_{B3}) = 0.8581$$

$$K_5(p_{B3}) = 0.73808$$

（4）The risk assessment towards the budget risk source is made, and it can be concluded that the risk level is very low.

$$K_1(p_{B4}) = 0.458\ K_2(p_{B4}) = 0.658\ K_3(p_{B4}) = 0.733\ K_4(p_{B4}) = 0.7629\ K_5(p_{B4}) = 0.8521$$

（5）The risk assessment towards the investment plan execution's risk source is made, and it can be concluded that the risk level is very low.

$$K_1(p_{B5}) = 0.2643 \qquad K_2(p_{B5}) = 0.4643 \qquad K_3(p_{B5}) = 0.6643 \qquad K_4(p_{B5}) = 0.8643$$

$$K_5(p_{B5}) = 1.0146$$

（6）The risk assessment towards the design work management system's risk source is made, and it can be concluded that the risk level is very low.

$K_1(p_{B6}) = 0.3003$ $K_2(p_{B6}) = 0.5003$ $K_3(p_{B6}) = 0.7003$ $K_4(p_{B6}) = 0.9003$

$K_5(p_{B6}) = 0.9992$

（7）The risk assessment towards the bidders' risk source is made, and it can be concluded that the risk level is very low.

$K_1(p_{B7}) = 0.2657$ $K_2(p_{B7}) = 0.4657$ $K_3(p_{B7}) = 0.6657$ $K_4(p_{B7}) = 0.8573$

$K_5(p_{B7}) = 1.0093$

（8）The risk assessment towards the bidding subjects' risk source is made, and it can be concluded that the risk level is relatively low.

$K_1(p_{B8}) = 0.4144$ $K_2(p_{B8}) = 0.6144$ $K_3(p_{B8}) = 0.8144$ $K_4(p_{B8}) = 1.0144$

$K_5(p_{B8}) = 0.9857$

(9) The risk assessment towards the construction preparation's risk source is made, and it can be concluded that the risk level is very low.

$K_1(p_{B9}) = 0.5069$ $K_2(p_{B9}) = 0.7069$ $K_3(p_{B9}) = 0.7508$ $K_4(p_{B9}) = 0.7908$

$K_5(p_{B9}) = 0.8308$

（10）The risk assessment towards the civil construction risk source is made, and it can be concluded that the risk level is relatively low.

$K_1(p_{B10}) = 0.4144$ $K_2(p_{B10}) = 0.6144$ $K_3(p_{B10}) = 0.8144$ $K_4(p_{B10}) = 1.0056$

$K_5(p_{B10}) = 0.9256$

（11）The risk assessment towards the equipment operation risk sources is made, and it can be concluded that the risk level is very low.

$K_1(p_{B11}) = 0.4619$ $K_2(p_{B11}) = 0.6520$ $K_3(p_{B11}) = 0.7133$ $K_4(p_{B11}) = 0.7747$

$K_5(p_{B11}) = 0.8360$

（12）The risk assessment towards the line maintenance's risk source is made, and it can be concluded that the risk level is at an average level.

$K_1(p_{B12}) = 0.6776$ $K_2(p_{B12}) = 0.8020$ $K_3(p_{B12}) = 0.8820$ $K_4(p_{B12}) = 0.8095$

$K_5(p_{B12}) = 0.7224$

（13）The risk assessment towards the reserved facilities' risk source is made, and it can be concluded that the risk level is very low.

$K_1(p_{B13}) = 0.2620$ $K_2(p_{B13}) = 0.4620$ $K_3(p_{B13}) = 0.6620$ $K_4(p_{B13}) = 0.8620$

$K_5(p_{B13}) = 1.0620$

（14）The risk assessment towards the spare facilities' risk source is made, and it can be concluded that the risk level is very low.

$K_1(p_{B14}) = 0.3674$ $K_2(p_{B14}) = 0.5674$ $K_3(p_{B14}) = 0.7674$ $K_4(p_{B14}) = 0.9674$

$K_5(p_{B14}) = 1.0326$

（15）The risk assessment towards the technical feasibility studies' risk sources is made, and it can be concluded that the risk level is very low.

$K_1(p_{B15}) = 0.2456$ $K_2(p_{B15}) = 0.4456$ $K_3(p_{B15}) = 0.6456$ $K_4(p_{B15}) = 0.8456$

$K_5(p_{B14}) = 1.0456$

（16）The risk assessment towards the technical compatibility risk source is made, and it can be concluded that the risk level is very low.

$K_1(p_{B16}) = 0.3069$ $K_2(p_{B16}) = 0.5069$ $K_3(p_{B16}) = 0.7069$ $K_4(p_{B16}) = 0.9069$

$K_5(p_{B16}) = 1.0269$

（17）The risk assessment towards the retired equipment status assessment's risk source is made, and it can be concluded that the risk level is very low.

$K_1(p_{B17}) = 0.2541$ $K_2(p_{B17}) = 0.4541$ $K_3(p_{B17}) = 0.6541$ $K_4(p_{B17}) = 0.8541$

$K_5(p_{B17}) = 1.0459$

（18）The risk assessment towards the retired asset disposal management's risk source is made, and it can be concluded that the risk level is relatively low.

$K_1(p_{B18}) = 0.5053$ $K_2(p_{B18}) = 0.7053$ $K_3(p_{B18}) = 0.9053$ $K_4(p_{B18}) = 0.9619$

$K_5(p_{B18}) = 0.8947$

On the basis of the various risk sources, the risk of each process of the grid company is rated. As shown in the following table, the risk level of the programming and planning process is relatively low, and the risk level of the procurement and construction process is very low. And then the risk levels of the operation and maintenance process and the decommissioningand disposal process areboth very low.

Table 5-4 Risk Levels in Each Process of the Grid Company

The Risk Level	Very high	Relatively high	Average	Relatively low	Very low
Programming and Planning Process	0.49	0.667	0.7685	0.8482	0.8443
Procurement and Construction Process	0.4118	0.6118	0.7652	0.913	0.9293
Operation and Maintenance Process	0.4677	0.6421	0.7645	0.8411	0.8864
Decommissioning and Disposal Process	0.3408	0.5408	0.7408	0.8976	0.9955

5.5 The Demonstration ofRisk Levels at All Parts

The risk levels and the influence degree of the risk sources and the asset management processes of the grid company are respectively and visually displayed in the risk map, as shown in the figure.

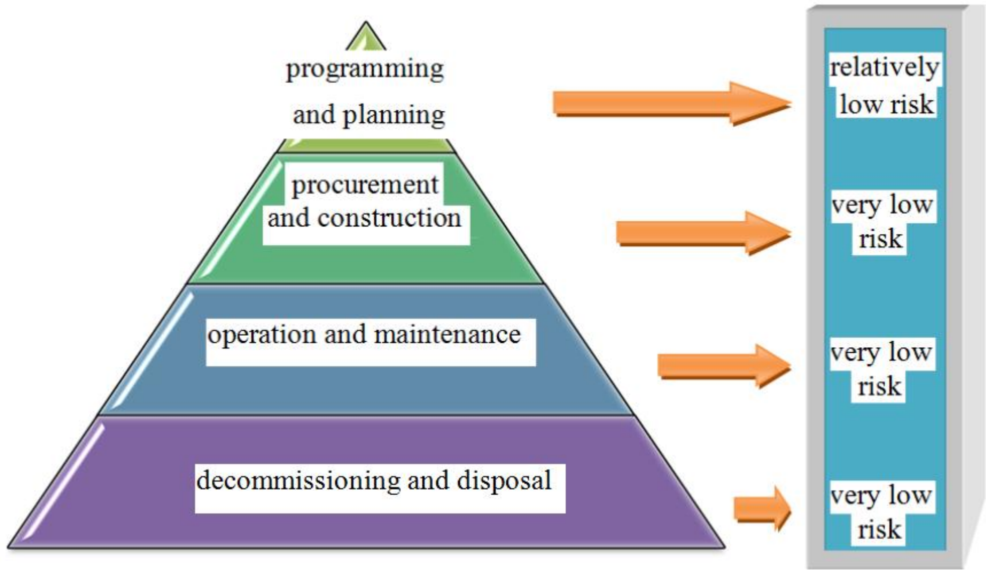

Figure 5-1 The Risk Levels of All Processes in the Grid Company

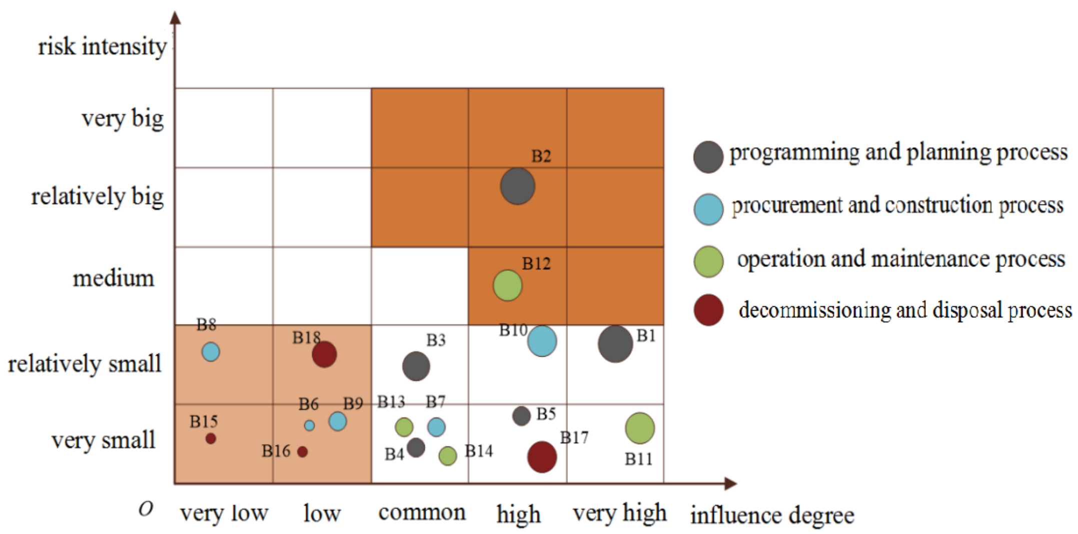

Figure 5-2 An example of a grid company's risk sources in a risk map

From the aboverisk map, it can be seen that the risk level of each process of the grid company is relatively low or very low, in which the programming andplanning process has a higher risk level than the other processes in the life cycle of asset management. And it is found in the risk assessment of risk sources thatthe risk intensity of the planning technology risk sourceis relatively big, which suggests that in assets' management, the company should do well preventive work to transfer or evade planning technology risks.

Conclusion

This article first elaborates the theory of asset life cycle and then applies it to the electric power field. Then based on this theory and starting from the long-term economic benefits of the company, by constructing a risk index system, this article carries out an analysis towards risk sources'indexes in a series of technical and economic organizational measures, and in the four processes, that is, the programming and planning process, the procurement and construction process, the operation and maintenance process. Finally, the asset managements risk's assessment model based on the matter-element extension theory is used to conduct an empirical analysis of the asset management risks in a grid company. Under the premise of ensuring the security performance of the grid, the risk indexes of each stage of the company are quantitatively analyzed, and the risk levels are divided at each part. The purpose is to help managers understand the company more clearly and directly, and also to prepare for prevention more efficiently so as to shift or evade the planning technology risks.

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