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STUDY ON THE DEVELOPMENT OF INTELLIGENT ASSISTANT EVALUATION SYSTEM FOR POWER GRID ENTERPRISES' OVERSEAS INVESTMENT

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ABSTRACT

Based on the comparison and induction of existing market investment evaluation methods at home and abroad as well as in-depth analysis of the elements and characteristics of the overseas power market regulatory environment (OPMRE), this paper constructed the OPMRE evaluation index system of six elements, containing policy stability, business risk, return on investment, asset growth, incentive strength and bilateral relations, and then the OPMRE evaluation model based on fuzzy comprehensive evaluation method was proposed. Finally, the corresponding intelligent assistant evaluation system was developed. The model and system were employed to evaluate the regulatory environment of six selected countries, and the results reveal that the evaluation model and system have strong practicability, which can generate the evaluation report quickly and automatically, indicating them has good realistic significance and practical value for the grid enterprises' overseas investment decisions.

KEYWORDS: power grid enterprises, overseas investment, fuzzy comprehensive evaluation, intelligent assistant evaluation system

INTRODUCTION

Chinese power grid enterprise have made great achievements in overseas investment business and acquired numbers of transmission and distribution assets in Philippines, Brazil, Portugal, Australia, Italy with over 100 billion yuan in size. Transmission and distribution assets are regulated assets in most countries due to the natural monopoly, while few studies focus on the regulatory environment assessment in overseas electric power investment, making it a great significance to investigate the methods as well as models and develop the appropriate intelligent assistant evaluation system on this field.

Generally, the economic regulation is widely used in power investment environment regulatory[1][2], and lots of scholars at home and abroad have carried out extensive research on the methods of overseas power investment environment assessment and the development of intelligent assistant evaluation system, which accumulate a wealth of research results, just as follows.Some researchers proposed kinds of methods to extract the assessment factors. For example, Farmer and Richman presented an investment assessment method named F-M matrix evaluation model, including three factors, namely elements needed in the business process, domestic environmental factors and international environmental factors [3]. Mitsubishi Investment Environment Evaluation Method is composed of four factors named economic activity level, geographical conditions, working conditions and reward systems [4]. Hot-Cold comparative analysis proposed by Litvak and Banting includes seven factors of political stability, market opportunities, economic growth achievement, cultural integration, legal obstacles, entity hinder, cultural and geographical differences [5]. Robert B. Stobaugh proposed scoring method that contains eight factors called capital repatriantion, foreign ownership allowed, discrimination and controls, currency stability, political stability, willingness to grant tariff protection, availability of local capital and annual inflation [6]. In addition, there are 11 factors in the multivariate evaluation method proposed by Min Jianshu called political environment, economic environment, financial environment and so on, and the key-factor evaluation method proposed by him divided investment motivation into reducing costs, expanding the local market, supply of raw materials, risk diversification and getting local production and management techniques [7].

Besides, many studies paid their attentions to comprehensive evaluation method and have made numerous outcomes. The characteristics of Analytic Hierarchy Process (AHP) was discussed in detail by He Yongxiu in literature [8], making investigators aware of the advantages and disadvantages of this approach. Zhang Biqiong and Tian Xiaoming introduced the comprehensive scoring method used in foreign direct investment environment evaluation [9], while Niu Dongxiao and Li Jinchao evaluated the electric power energy employing fuzzy comprehensive evaluation approach and obtained a satisfied result [10].

Also, many other ways were also applied in comprehensive evaluation. Du Xinle assessed the foreign investment environment using neural networks and intelligent algorithms, effectively resolving the absence of data for quantitative indicators, but lacking of empirical results [11]. The two similar methods, VIKOR and classic TOPSIS, which are both compromising algorithms approaching the ideal point, have been proposed in literatures [12] and [13]. It is distinct that the former can get the absolute best and satisfactory solution by setting a variety of decision-making ways, while the latter fails to achieve it.

Existing evidence shows that research work on expert systems is an important breakthrough in the development of artificial intelligence. Wang Yanan and Pan Quanwen introduced the basic structure and reasoning mechanism of expert system theoretically in their own research [14,15]. And satisfactory results were obtained through the application of intelligent assistant evaluation system in practice in Refs. [16] and [17].

The purpose of this study is to establish the assessment model of overseas investment for Chinese power grid enterprises and develop the related intelligent assistant evaluation system. In this paper, the fuzzy comprehensive evaluation method was employed and the process of developing the system was reported.

The remainder of this paper is organized as follows: Section 2 represents the methods and model this paper applied and section 3 reports the situation of system development. Section 4 shows the result of example application. Finally, we draw the conclusion in section 5.

EVALUATION MODEL AND METHODS

2.1 Evaluation Model

We divide overseas power investment regulatory environment factors into six categories including 27 indicators, of which there are 4 quantitative indicators and 23 qualitative indicators via investigating the existing investment evaluation system. The six categories we proposed are Political Stability, Business Risks, Return on Investment, Asset Growth, Incentive Strength and Bilateral Relationship. The specific indicators contained in each category are shown in Figure 1.

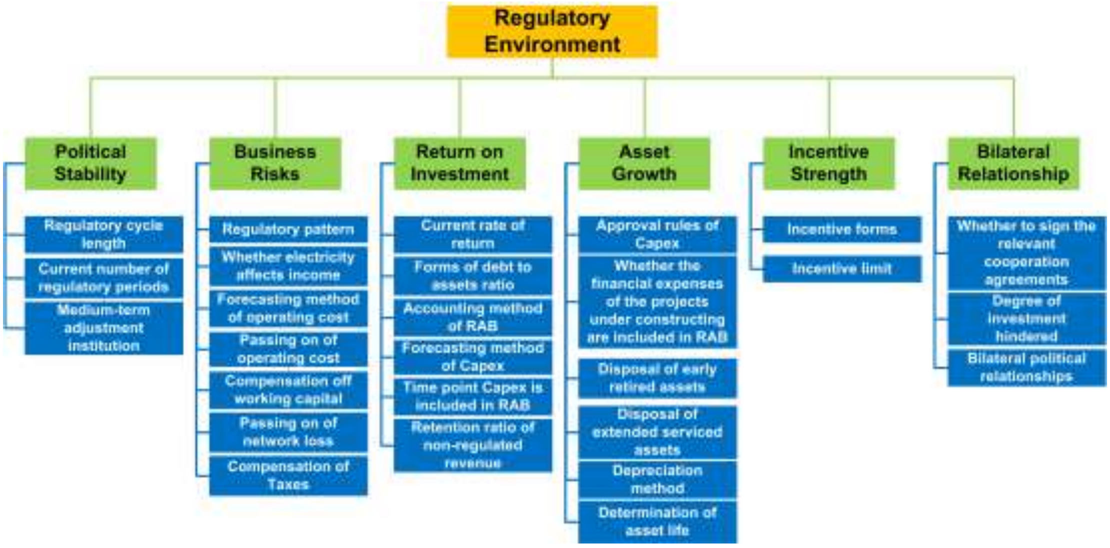

Figure 1 Constitution of Regulatory Environment Assessment System for Overseas Power Market

2.2 Evaluation Methods

2.2.1 Analytic Hierarchy Process (AHP)

AHP method is widely used to determine the weight of evaluation indicators, especially, when it comes to that there are qualitative indicators in the proposed indicator system. Comparison matrix plays a great role while applying AHP to get the weight value and the form of comparison matrix is given as below:

$$A = (a_{ij})_{n\times n} \quad (1)$$

where a_{ij} is the index i's degree of importance compared with index j, n is the order of the matrix which means the number of indicators. Normally, we determine the value of a_{ij} through 1-9 scaling method given in literature [9].

The matrix we established usually have no complete consistency, revealing that the weights we calculated may be unreliable. Therefore, the test judging whether the matrix matches the consistency in a certain degree is necessary. The discriminant formula for consistency test is proposed by Saaty as follow:

$$CR = CI / RI \quad (2)$$

where CR is the consistency level, CI is the consistency index calculated by the following formula, RI is the mean random consistency index shown in Table 1.

$$CI = \frac{\lambda_{\max} - n}{n-1} \quad (3)$$

where, λ_{max} presents the maximum eigenvalue of the comparison matrix, n is the order of the matrix. The weight values can be obtained via calculating and normalizing the geometric mean of each element in row.

Table 1 Mean Random Consistency Index Value

Order	1	2	3	4	5	6	7	8	9	10	11
RI	0	0	0.51	0.89	1.12	1.25	1.35	1.42	1.46	1.49	1.52

The common measures to combine various exports' weights judgment are to average all exports' data in arithmetic mean or geometric mean, and this paper employs the later one to get the weight vector of all indicators named *W*.

2.2.2 Fuzzy Comprehensive Evaluation

Fuzzy comprehensive evaluation is a kind of comprehensive evaluation method based on fuzzy mathematics. This method transforms the qualitative evaluation into quantitative evaluation with the theory of membership degree in fuzzy mathematical, that is, making an overall evaluation for things or objects restricted by a variety of factors using fuzzy mathematics. It has a distinct result and strong systematicness, and can successfully solve the problems which are vague and difficult to quantify and match the solution to the problems with numbers of uncertainty.

Because the indicator system comprises quantitative and qualitative indicators, the membership is introduced in this paper to unify all indicators into a single membership matrix. We set the evaluation levels as below:

$$V = \{V_1, V_2, V_3, V_4, V_5\} = \{excellent, good, general, poor, worst\} \quad (4)$$

After all exports match the indicators with the evaluation level, we obtain the membership of index i and level j through the follow formula:

$$r_{ij} = m_{ij} / m \quad (5)$$

where r_{ij} is the membership of index i and level j, m_{ij} presents the number of the exports who deem that the index i belongs to evaluation level j, and m is the number of all exports. Hence, we combine the membership of all indicators to get the membership matrix called *R*.

After determining the weight vector *W* and the membership matrix *R* of all indicators, the result of fuzzy comprehensive evaluation can be received as follows according to the theory of fuzzy comprehensive evaluation:

$$B = WR = (b_1, b_2, ..., b_m), \quad m = 5 \quad (6)$$

where $b_j = \sum_{i=1}^{n} (w_i \times r_{ij})$, w_i represents the weight value of index i, m is the number of evaluation levels and n is the number of indicators.

Then, the weighted average operator will be used to quantify the result of fuzzy comprehensive evaluation through the following formula:

$$F = \sum_{j=1}^{m} b_j \times c_j, \quad m = 5 \quad (7)$$

where *F* presents the total fraction, c_j is the score endowed to level *j*. In this paper, we set c_j as below:

$$C = (c_1, c_2, c_3, c_4, c_5) = (100,80,60,40,20) \quad (8)$$

SYSTEM DEVELOPMENT

3.1 Principles of System Designing

According to the actual situation of Chinese grid enterprises and the objectives of overseas investment regulatory environment assessment, the design principles of the intelligent assistant evaluation system developed in this paper are determined to be secure, convenient and scalable.

(1) Secure principle

Security of system is an important part of the program design, and the security guarantees in program design include the following areas: network security, system security, business security and management security.

Network security refers to the security of the entire network system itself, including the effective isolation of unauthorized users, the protection against malicious network attacks, the guarantee to network availability and so on. System security represents the security of host systems (a variety of server systems, PC systems) in information system network, including the security of system login and operation as well as the protection for viruses and unauthorized access. Business security implicates not only the authenticity, reliability, integrity and non-repudiation of the online business activities but also the confidentiality and integrity of the information preserved and transported in the system. Management security refers to the organizational strategy on the management required or recommended by the platform.

(2) Convenient principle

The interface of the system is opened and standard, and it can provide the data import and export interfaces based on Restful Web API. Meanwhile, the system design fully considers the compatibility of the system, and all protocols employ the standard Web Service protocols in order to ensure the data interaction with existing systems. Besides, we apply the standard TCP/IP protocol to connect with the INTERNET, which can easily achieve the data communication with exiting system.

(3) Scalable principle

The system developed by us offers a variety of programs to ensure the reliability of the platform including designing numbers of technical means related to reliability and establishing strict management measures on security and reliability. In addition, we adopt plug-in design to make it convenient to expand the data interface and repository of system, which can support the dynamic maintenance and updating of the repository.

3.2 System Architecture and Selection of Platform for Development and Operation

With applying the MVC design pattern, the system is depended on Microsoft's .Net Framework technology, and the overall architecture employs B/S structure. The basic structure and the technology used in the system are shown in Figure 2, where the arrow refers to the direction of information flow and the content in parenthesis presents the specific development technology we used. The specific configuration parameters of the system are given in Table 2.

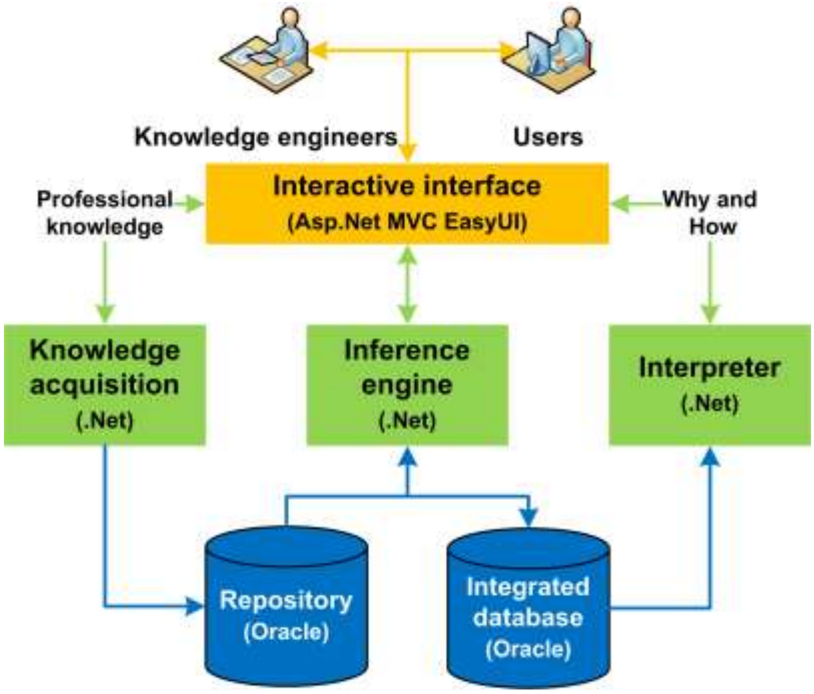

Figure 2 The Basic Structure and Technology of the System

Table 2 System Configuration Parameters

System Configuration	Related Parameters
Database	Oracle Database
Development Platform	Microsoft .Net 4.0
Web Development Framework	Asp.Net MVC 5.1
Development Language	C# 5.0
UI Framework	Twitter Bootstrap
Operating Platform	Windows，IIS

Figure 2 shows that the system consists of six major parts named repository, integrated database, knowledge acquisition, inference engine, interpreter and interactive interface. Firstly, repository is the collection of required knowledge for problem solving in the field, including basic facts, rules and other relevant information. Representation of knowledge can be varied, comprising framework, rules, semantic networks and so on. In this system, we can reprocess the existing research achievements of national regulatory environment and collate the regulatory elements into knowledge entries, which helps the repository compare the unified regulatory environment assessment elements among different countries horizontally. Moreover, the repository can analyze the characteristics of national regulatory environment and the impact of these characteristics on investment decisions. Users can change and perfect the knowledge in the repository to enhance the performance of the expert system, and we apply Oracle database to conserve the knowledge of repository within the export system.

Integrated database, also known as dynamic link library or working memory, is the collection of the current state reflecting problem solving, which is used to store all of the information and raw data generated and required for system operation, including the messages users entered, the intermediate results of reasoning, the recording of inference process and the like. The state composed by facts, propositions and relationships in the integrated database is the foundation used by inference engine to select knowledge as well as the sources adopted by interpreter to obtain inference path. We employ Oracle database or memory storage to complete the storage of the raw data in this export system.

Knowledge acquisition is responsible for establishing, modifying and expanding the repository, and is a major agency converting the expertise needed for kinds of problem solving from the mind of a human expert or other sources of knowledge into the repository. In this system, knowledge acquisition is completed in the set-up phase of export repository of the project and the knowledge content has already existed during the actual development process.

Inference engine, which is actually a program interpreting the knowledge, is the core executive body to solve the problem. Based on the semantic, inference engine can explain and execute the knowledge found with a certain tactics and record the results into the appropriate space of the dynamic library. It is an important feature that the inference engine program has nothing to do with the specific content of the repository, that is, the inference engine and repository are separated. The advantage of this design can be noted that we can modify the repository without changing the inference engine, but we have to realize that the pure form of reasoning may reduce the efficiency of problem solving. Because the system repository is relatively fixed, we combine inference engine and repository to develop the system, which can greatly improve the efficiency of problem solving. The main development language used for inference engine is *C#*.

Interpreter can make a statement for the solution process and answer questions of users which mainly are “Why” and “How”. Interpreter relates transparency of procedures and provides users with an understanding window about the system, which allows users to comprehend what the program is doing and how to do so. The interpreter is essential in many cases. For instance, to answer the question "why" we obtained certain conclusion, it typically takes system to backtrack the inference path saved in dynamic library, and translate it into natural language expressions users can accept. Interpreter employs *C#* language for development.

Interactive interface is deployed for users to communicate with system, through which users enter basic information and answer questions proposed by system. The reasoning results and related interpretations system output are also shown through the interactive interface. We adopt Asp.Net MVC framework binding Bootstrap EasyUI interface framework to complete the interactive interface.

3.3 Functional Design of System

3.3.1 Rapid Assessment for Regulatory Environment

The system is available to quantify the regulatory environment of target market into corresponding indicators through the built-in evaluation index system and weight inference engine. Then, we gain the final evaluation results via certain procedure algorithm calculating the basic data obtained through expert scoring. The specific evaluation process has been shown in Figure 3.

Figure 3 Flowchart of Rapid Assessment in System

In practice, the only work the evaluators need to do is to complete the corresponding operation following the system prompts. And then, the system will receive the evaluation results of regulatory environment of the target market rapidly by analyzing and processing the data obtained from weight and evaluation inference engine. The schematic diagrams of work processes of weight and evaluation interface machine are shown in figure 4 and 5 as below:

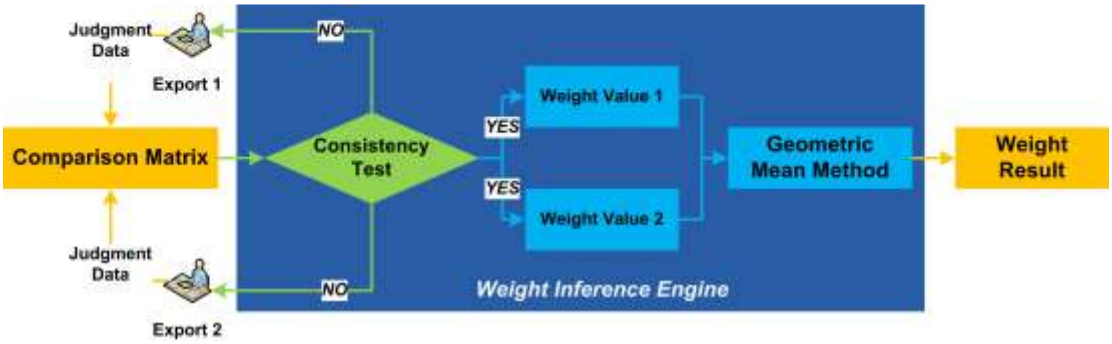

Figure 4 The Schematic Diagram of Working Processes of Weight Inference Engine

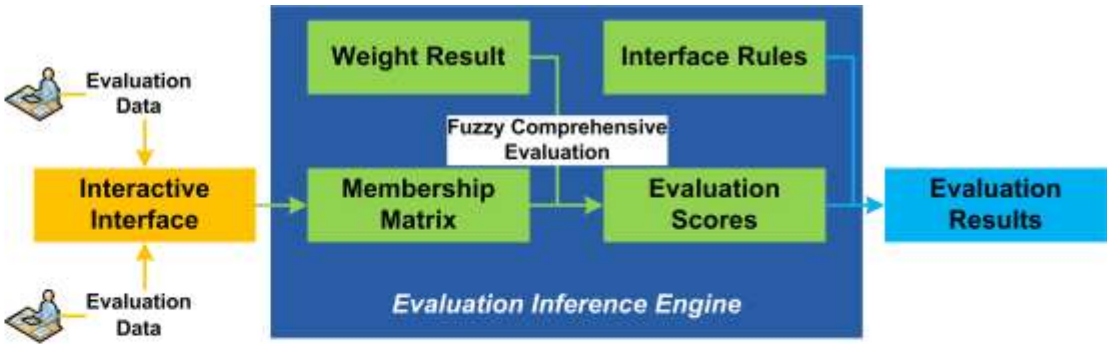

Figure 5 The Schematic Diagram of Working Processes of Evaluation Inference Engine

3.3.2 Swift Generation of Assessment Reports

Swift generation of assessment reports is a quite useful function for our export system, making the evaluators get rid of lots of tedious text entry work, which significantly improves the work efficiency of project evaluation staff. When it comes to evaluate in practice, we only need to accomplish the relational problem entry in the light of the directive of system, and then, the system will implant each entry to the corresponding section of assessment report according to the structure of the built-in assessment report template, enabling swift report generation. Figure 6 expresses the system flowchart of the operation.

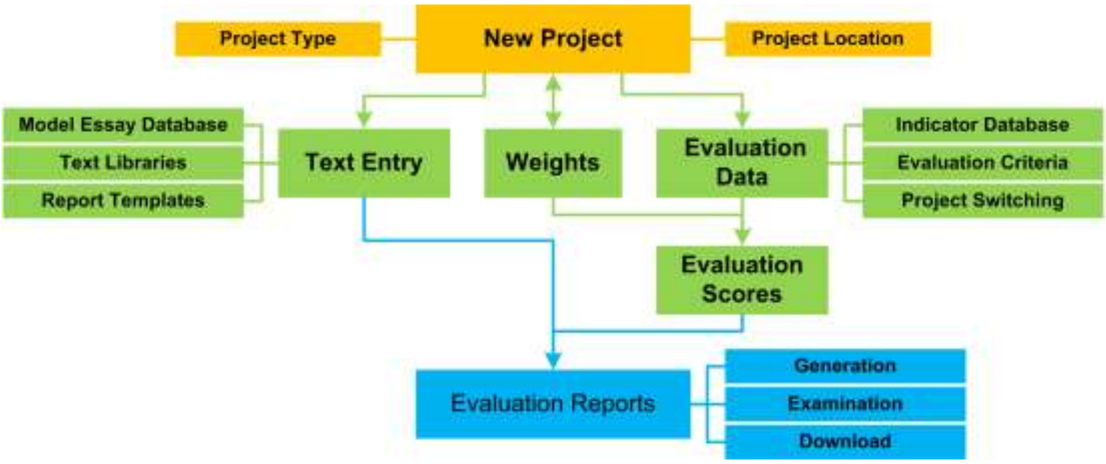

Figure 6 Flowchart of Evaluation Report Generation

3.3.3 Accumulation and Sharing for Knowledge

The export system provides the capabilities of knowledge accumulation and sharing to make it more flexible and scalable. Users can upload kinds of existing knowledge to the expert system repository in forms of documents, diagrams and videos in the long-running process. Meanwhile, users can choose whether to share the knowledge they uploaded. The approach to implement the accumulation and sharing of knowledge in the system has been shown in figure 7.

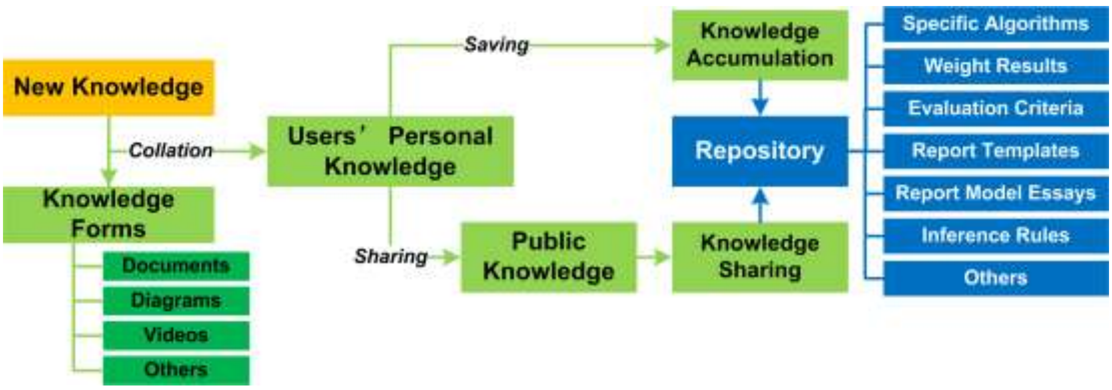

Figure 7 The Approach to Implement Knowledge Accumulation and Sharing in the System

APPLICATION EXAMPLES

The intelligent assistant evaluation system developed in this study has achieved initial practice outcome in Chinese power grid enterprises. To prove the reliability of the system in actual running process, we evaluated the regulatory environment of six countries (Portugal, Sweden, Italy, Philippines, Greece and Brazil) that have full representation in geographical distribution, economic level, social status and regulatory mechanism, considering the practical experience of Chinese power grid enterprises and the features of regulatory environment for investment in overseas power market.

There are totally 14 exports presenting their own weight determination result via our system, and then we averaged all exports' results with geometric mean method. Table 3 represents the weight results after performing the averaging process and the numbers in parentheses indicates the weight values corresponding to the categories.

Table 3 Index Weights of the Comprehensive Assessment System for Overseas Power Market Regulatory Environment

Categories	Indicators	Weight Values
Political Stability (0.0644)	Regulatory cycle length	0.0166
	Current number of regulatory periods	0.0239
	Medium-term adjustment institution	0.0239
Business Risks (0.3308)	Regulatory pattern	0.0434
	Whether electricity affects income	0.0395
	Forecasting method of operating cost	0.0431
	Passing on of operating cost	0.0501
	Compensation off working capital	0.0496
	Passing on of network loss	0.0548
	Compensation of Taxes	0.0501
Return on Investment (0.2593)	Current rate of return	0.0391
	Forms of debt to assets ratio	0.0421
	Accounting method of RAB	0.0428
	Forecasting method of Capex	0.0437
	Time point Capex is included in RAB	0.0468
	Retention ratio of non-regulated revenue	0.0449
Asset Growth (0.2597)	Approval rules of Capex	0.0407
	Whether the financial expenses of the projects under constructing are included in RAB	0.0466
	Disposal of early retired assets	0.0442
	Disposal of extended serviced assets	0.0480
	Depreciation method	0.0400
	Determination of asset life	0.0400
Incentive Strength (0.0202)	Incentive forms	0.0041
	Incentive limit	0.0161
Bilateral Relationship (0.0657)	Whether to sign the relevant cooperation agreements	0.0205
	Degree of investment hindered	0.0225
	Bilateral political relationships	0.0227

Simultaneously, with counting all exports' opinions about the affiliations between indicators and evaluation levels, we obtained the membership matrix of all indicators named *R* using the inference engine built in the system. Applying secondary fuzzy comprehensive evaluation method, the system reports the evaluation results of regulatory environment for each country, which are listed in Table 4.

Table 4 The Results of Fuzzy Comprehensive Evaluation for Six Typical Countries

Categories	Weights	Portugal	Sweden	Italy	Philippines	Greece	Brazil
Political Stability	0.0644	76	66	51	73	57	73
Business Risks	0.3307	97	94	83	91	85	50
Return on Investment	0.2593	75	76	78	75	70	74
Asset Growth	0.2597	80	84	83	76	70	53
Incentive Strength	0.0202	76	100	100	64	28	28
Bilateral Relationship	0.0657	86	60	74	39	74	100
Totally	1.0000	84.4	82.8	79.4	78.1	73.4	61

As shown in Table 4, Portugal and Sweden have higher composite scores while Greece and Brazil perform unsatisfactorily, which is consistent with the practical experience of Chinese power grid enterprises. To distinguish the difference in national regulatory environment more intuitively, our system provides the function of graphical demonstration. Figure 8 displays the evaluation results of regulatory environment in Italy and Sweden as the examples.

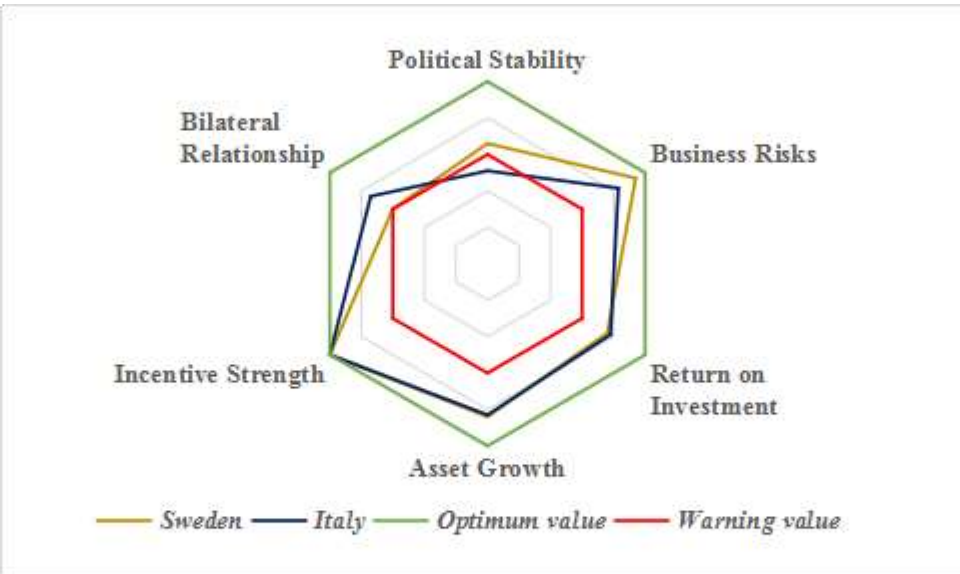

Figure 8 The Radar Chart for the Evaluation Results of Italy and Sweden

CONCLUSION

This paper explores the evaluation of regulatory environment on overseas investment for Chinese power grid enterprises using fuzzy comprehensive evaluation method and develops the corresponding intelligent assistant evaluation system. The regulatory environment in the power market of six countries has been assessed by adopting the system completed in this paper. It should be noted here that we do appreciate the fact that the evaluation model we established and the intelligent assistant evaluation system this study developed have strong practicability. Besides, the achievements of this paper can help Chinese power grid enterprises achieve rapid and effective assessment of the regulatory environment on investment in the overseas power market. Moreover, it is confirmed that the outcome of this study has an extensive application prospect.

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