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Ann integrated three-dimensional model on financing risk evaluation for PPP power plant projects based on WSR

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ABSTRACT

This article starts from the risky factors that influence the smooth running of PPP power plant project financing, such as insufficient income, changes in interest rates and so on. On the basis of previous studies, we develop an integrated three-dimensional model for financing risk evaluation of PPP power plant projects based on the WSR systems methodology, so that its "past", "present" and "future" are organically combined. Verifications in case studies show that this model effectively solves the evaluation problems for PPP financing risk and it can make risk control better.

KEYWORDS

Project financing risk; WSR; PPP; Comprehensive evaluation research.

INTRODUCTION

In recent years, China's electric energy demand grows continuously and rapidly. The investment of electric power construction is the basic for protecting electrical energy supply, but the reform of electric power system has made power market undergone great changes, which will undoubtedly increase the uncertainty of power plant investment and financing risk, as well as bring many new risks for the power plant investment and financing. At present, concerning PPP project financing risk, scholars have simple analyses of the project financing risk factors[1], and have studies on project financing risk identification[2], PPP project financing risk share[3,4], and also integrated dynamic risk management[5]. Scholars' researches are more focused on one aspect of the PPP project financing risk, but the process is long and complex, and has many participates, the whole process of project finance is a systematic and closely linked process, so there is a need for a more integrated approach to solve the problem of project financing risk evaluation. With the help of the WSR system methodology, an integrated three-dimensional risk evaluation model of PPP power plant project financing based on Wuli-Shili-Renli rationale (WSR) is proposed in this paper.

The WSR methodology is a kind of Oriental system method and it was proposed jointly by Chinese scholars Gu Jifa and Zhu Zhichang in the British Hull University in 1994. So far it has been preliminarily applied in the management science, system science and many other fields, and has been highly recognized by many experts[6].

Its main content, "Wuli" refers to the basic laws and mechanisms involved in the material movement process. Usually natural science knowledge is used to answer "what is the matter". "Wuli" needs the truth, and researches into the objective reality. "Shili" mainly refers to the laws in doing things, is meant to solve problems such as how to arrange equipments, materials, personnel. It usually uses operation research and management science knowledge to answer "how to do". "Renli" refers to using humanities and social science knowledge to answer "how should be done "and" how best to do"[6]. See Figure 1.

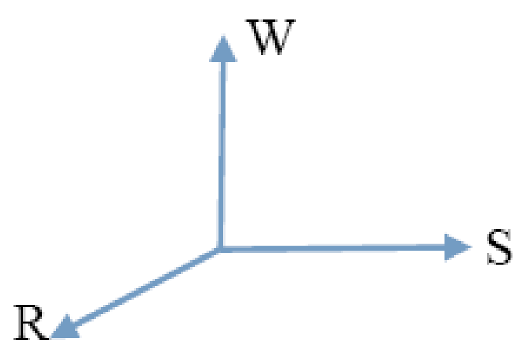

Figure 1 : WSR methodology

Project financing is the dynamic unification of the material world, system organization and people. The implementation process of project financing should include those three aspects and their relationships, namely consider "Wuli", "Shili" and "Renli" synthetically, so as to obtain satisfactory comprehensive and deeper understanding on project financing risk, in order to take appropriate strategy[7]. Since WSR methodology can consider the various intricacies inherent "mechanism" factors, it puts forward a new idea and method for dealing with complex system issues, so it is scientific and reasonable that such methodology be used in the study of comprehensive evaluation of the project financing risk.

THE THREE-DIMENSIONAL PPP PROJECT FINANCING RISK MODEL OF POWER PLANT

PPP power plant project financing risk

PPP, namely public-private partnership abbreviation, usually translated as "public-private partnership/joint venture", generally refers to the partnership established between public and private sectors to provide public goods or services, and narrowly can be understood as a general term of project financing in a series of ways, including BOT, DBFO etc. The narrow concept of PPP emphasizes more the ownership (stock) of the government in the project, as well as risk-sharing and benefit sharing in the process of cooperation with enterprises[8]. In the context of the power system reform, PPP power plant project financing is facing a lot of complex and uncertain risk factors. The success of the project depends largely on the quality of risk management. Therefore, it appears that scientific risk management is particularly important.

Three-dimensional characteristics of PPP power plant project financing risk

There are numerous risk factors in the process of power plant project financing and project financing risk changes over time (the "past", "now", "future"). How to evaluate occurrences of risks about some objects (or systems) dynamically, objectively and scientifically during the project financing is a regular and important work in the risk management.

The uncertainty of project financing risk not only includes uncertainty of time and place, but also includes uncertainty of occurrence degree. How to evaluate these risks objectively and accurately? A certain risk factor not only depends on the circumstances of the risk happening now, but also depends on the impact of the risks arose in the past, and also the possible impacts of future. To integrate this idea into the whole process of risk assessment, it is necessary to build a new comprehensive evaluation method, so that the evaluation results can reflect the impact of the project financing risk throughout the whole project operation process.

Aiming to solve the above kind of comprehensive evaluation problem considering both the past and future impact of risks, this paper propose a "three-dimensional" comprehensive evaluation method integrating the "past", "now" and "future"[9].

COMPREHENSIVE THREE-DIMENSIONAL EVALUATION MODEL OF FINANCING RISK FOR PPP POWER PLANT PROJECTS BASED ON WSR

The establishment of evaluation index

It is easy that the following several kinds of risks of PPP power plant project financing appeared in the process of operation: environmental damage; changes in Fuel supply and price; power demand fluctuations; insufficient charges or income; changes in interest rates; the increase in finance costs; facilities ownership; labor disputes; the enforceability of the guarantee; contract disputes, arbitration, applicable law; operators lack of ability; government's restrictions on profits and prices; contractor defaults; violation of financing contract and so on. The emergence of these risks greatly hinders the smooth progress of PPP project financing. To manage these risks, cluster analysis is performed, and these 14 categories of questions were grouped into three categories through WSR "Renli system", "Shili system", "Wuli system ", as shown in Figure 2.

Because the whole cycle of PPP power plant project financing starting from the beginning of preparation to the smooth operation of the project is relatively long, along with changes in the external environment, these 14 categories of risks will also change over time, thereby causing the probability and impact of these risks change at different stages. Given space limitations, describe the risk factor "Insufficient charges or income" briefly. Occurrence probability of such an indicator is very small in the early stage of project financing (i. e. in "the past" of current operating projects). Pre-project financing has not been put into operation, and thus can not get the appropriate benefits. But once the project is completed and put into operation, the goodness of revenue will have a crucial impact on the success of the project, therefore assessing and control of less income risk will be a very important task. Form the interim of project operation (i. e. in "the present" of the project), until late of the project (i. e. the "future" of project), the impact of this indicator will gradually increase.

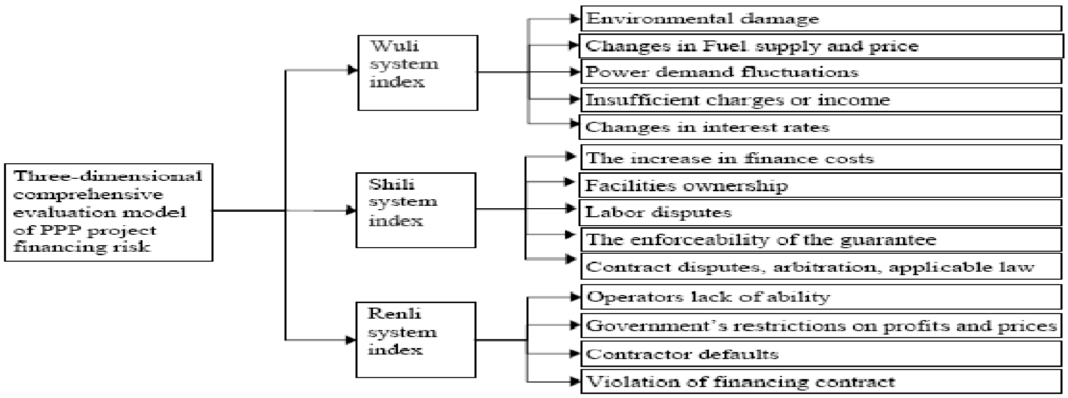

Figure 2 : Index system on PPP power plant project financing risk of three-dimensional integrated evaluation model based on WSR

The evaluation of project financing risk at different stages is a difficult problem. Through on-the-spot investigation and expert consultation, this paper gives the standard reference value of risk evaluation in different stages of the project financing process, as shown in TABLE 1. In the following, the three-dimensional evaluation model of PPP power plant project financing risk based on WSR can be built.

TABLE 1 : Value of a reference standard of evaluation index

			Environmental damage			Changes in Fuel Supply and price			Power demand fluctuations			Insufficient charges or income		
			past	**now**	**future**	**past**	**now**	**future**	**past**	**now**	**future**	**past**	**now**	**future**
Little impact			1	1	2	0	1	2	0	1	2	1	2	2
Less impact			3	3	4	0	3	4	0	3	4	3	4	4
General effect			5	5	6	0	5	6	0	5	6	5	6	6
Greater impact			7	7	8	0	7	8	0	7	8	7	8	8
Very large impact			9	9	10	0	9	10	0	9	10	9	10	10
Changes in interest rates			**The increase in finance costs**			**Facilities ownership**			**Labor disputes**			**The enforceability of the guarantee**		
past	**now**	**future**	**past**	**now**	**future**	**past**	**now**	**future**	**past**	**now**	**future**	**past**	**now**	**future**
1	2	2	2	1	0	1	1	1	1	2	1	0	1	2
3	4	4	4	3	2	3	3	3	3	4	3	2	3	4
5	6	6	6	5	4	5	5	5	5	6	5	4	5	6
7	8	8	8	7	6	7	7	7	7	8	7	6	7	8
9	10	10	10	9	8	9	9	9	9	10	9	8	9	10
Contract disputes, arbitration, applicable law			**Operators lack of ability**			**Government's restrictions on profits and prices**			**Contractor defaults**			**Violation of financing contract**		
past	**now**	**future**	**past**	**now**	**future**	**past**	**now**	**future**	**past**	**now**	**future**	**past**	**now**	**future**
1	1	1	0	2	1	0	2	2	2	0	0	2	1	1
3	3	3	0	4	3	0	4	4	4	0	0	4	3	3
5	5	5	0	6	5	0	6	6	6	0	0	6	5	5
7	7	7	0	8	7	0	8	8	8	0	0	8	7	7

9	9	9	0	10	9	0	10	10	10	0	0	10	9	9

According to the actual condition and purpose of the object for evaluation, *m* evaluation indices were selected and respectively recorded as $x_1, x_2,..., x_m$. According to the effect sizes of evaluation index x_i, a corresponding basis point h_i ($i=1, 2,..., m$) is proposed. Assume the raw data of evaluation$\{x_{ij}\}$($i=1, 2,..., n;j=1, 2,..., m$) has been collected. They form a basis for the following discussion.

The general methods and steps for evaluation[9]

For a comprehensive evaluation of three different periods "past" "now" "future", it is necessary to establish an evaluation index system for the corresponding period. Without loss of generality, evaluation indices of different groups can be used in each period, recorded as $x_1, x_2,..., x_{mk}$ (k=1, 2, 3). Correspondingly one has $\{r_{ij}\}$ (i=1, 2,..., $n;j$=1, 2,..., $m_k;k$=1, 2, 3).

Evaluation of the effect of "the past" to s_i

In the time interval [K_0, K_{0+T-1}] the comprehensive dynamic evaluation function is taken as

$$u_i(k)=\sum_{j=1}^{m_1} w_j(k)r_{ij}(k), k=k_0, k_{0+1},..., k_{0+T-1} \tag{1}$$

In the formula, $w_j(k)$ is the weight function. For an arbitrary k one has $w_j(k)\geq 0$ and $\Sigma w_j(k)=1$. $u_i(k)$ means the comprehensive evaluation value of the running status and influence of s_i in moment k. $r_{ij}(k)$ is the evaluation value of S_i about the evaluation index x_j at moment k. T is a given positive integer.

The overall operation level of system s_i in time interval [K_0, K_{0+T-1}] can be expressed as

$$y_i^{(1)}=\sum_{k=k_0}^{k_0+T-1}\sum_{j=1}^{m_1} w_j(k)r_{ij}(k), i=1,2,...,n \tag{2}$$

Evaluation of s_i on "status quo"

For a given time T that represents the "status quo", in order to distinguish the running status of systems $S_1, S_2,... S_n$ as much as possible, the weight coefficients μ_j can be determined by the "open class" method. Then the "status quo" of s_i at moment k=T can be expressed by

$$y_i^{(2)}=\sum_{j=1}^{m_2}\mu_j r_{ij}(T), i=1,2,...,n \tag{3}$$

Evaluation of s_i on "development trend"

Let N be a suitable given constant. In the time interval (T, T+N), if the expected average value $\overline{x_{ij}}$ or $\overline{r_{ij}}(j=1,2,...,m_3)$ about evaluation index x_j can be obtained, then the future development trend of s_i can be expressed by

$$y_i^{(3)}=\sum_{j=1}^{m_3}\rho_j\overline{r_{ij}}, i=1,2,...,n \tag{4}$$

In the above formula, ρ_j is the corresponding weight coefficient (ρ_j may be different from μ_j).

Comprehensive evaluation of s_i on "three-dimensional"

The comprehensive "three-dimensional" evaluation value of system s_i integrating "past, " "now"and "future" as one body can be represented by

$$\mathbf{y_i} = \sum_{j=1}^{3} \lambda_j (y_i^{(j)} - y^{*(j)})^2, i = 1,2,...,n \qquad \textbf{(5)}$$

In the above formula, $y^{*(j)}$ is the desired (or known) value of $y_i^{(j)}$, or it holds that $y^{*(j)} = \max_{1 \le i \le n} \{y^j{}_i\} (j = 1,2,3)$, λ_1, λ_2, λ_3 are the weight coefficients given in advance.

Then, sorting or classifying the value of y_i according to the ascending order, the purpose of comprehensive "three-dimensional" value for systems s_1, s_2,... s_n can be achieved.

ANAPPLICATION CASE

Now gather information of four power plants A, B, C and D using PPP project financing model to construct and operate projects. There happened some problems in the operation by 2012. Some project financing risks that were not well controlled impacted effective operation of the project. Now evaluate these four projects using the comprehensive evaluation method based on WSR.

This paper uses the expert scoring method. Twenty experts were invited to make assessments on 14 indicators involving three categories: the past, the present and the future. Combining with the standard reference values at different stages of the project (TABLE 1), evaluation values of the indices are obtained, as shown in TABLE 2.

TABLE 2 : Evaluation values of evaluation index of project

	x_{w1}			x_{w2}			x_{w3}			x_{w4}		
	$\hat{r}$	r	$\tilde{r}$	$\hat{r}$	r	$\tilde{r}$	$\hat{r}$	r	$\tilde{r}$	$\hat{r}$	r	$\tilde{r}$
Project A	2. 7	4. 0	3. 3	3. 0	4. 6	5. 0	3. 4	2. 9	2. 1	2. 4	4. 3	5. 4
Project B	3. 2	2. 9	3. 4	3. 7	2. 0	4. 2	3. 1	2. 2	3. 5	2. 1	3. 0	4. 6
Project C	1. 9	2. 5	4. 9	2. 6	3. 8	2. 2	3. 9	4. 8	3. 6	2. 3	3. 1	3. 6
Project D	2. 6	3. 9	3. 0	4. 1	5. 4	4. 7	5. 0	4. 2	5. 3	1. 4	4. 4	5. 9

x_{w5}			x_{s1}			x_{s2}			x_{s3}			x_{s4}		
$\hat{r}$	r	$\tilde{r}$	$\hat{r}$	r	$\tilde{r}$	$\hat{r}$	r	$\tilde{r}$	$\hat{r}$	r	$\tilde{r}$	$\hat{r}$	r	$\tilde{r}$
1. 8	4. 5	3. 3	2. 2	6. 2	4. 8	4. 3	3. 3	1. 3	3. 6	6. 6	5. 2	3. 6	3. 9	6. 4
2. 2	5. 5	3. 8	3. 2	5. 7	4. 1	3. 7	2. 4	4. 4	3. 1	2. 1	2. 5	2. 6	4. 8	3. 7
2. 0	3. 4	3. 1	1. 5	4. 0	2. 0	1. 4	3. 7	3. 5	1. 6	4. 7	3. 4	3. 5	4. 6	5. 8
1. 7	3. 0	2. 6	1. 9	5. 1	2. 3	5. 6	4. 2	3. 0	2. 0	2. 4	1. 4	1. 4	1. 8	2. 9

x_{s5}			x_{r1}			x_{r2}			x_{r3}			x_{r4}		
$\hat{r}$	r	$\tilde{r}$	$\hat{r}$	r	$\tilde{r}$	$\hat{r}$	r	$\tilde{r}$	$\hat{r}$	r	$\tilde{r}$	$\hat{r}$	r	$\tilde{r}$
1. 5	3. 0	6. 7	1. 7	6. 8	7. 0	1. 2	5. 6	7. 1	5. 8	3. 3	1. 4	6. 9	5. 2	3. 3
3. 0	2. 8	3. 9	2. 0	5. 5	6. 0	1. 9	4. 8	5. 9	4. 6	4. 2	1. 6	6. 8	4. 7	2. 2
2. 4	3. 6	4. 7	1. 9	5. 4	6. 7	2. 2	5. 1	6. 5	6. 2	4. 7	2. 1	6. 2	5. 3	3. 8
1. 4	2. 2	4. 2	2. 4	4. 9	5. 6	2. 3	4. 5	4. 7	4. 3	2. 7	1. 5	5. 9	3. 9	2. 0

The weight coefficients corresponding to the three periods are shown in TABLE 3.

TABLE 3 : The weight coefficient

x_{s5}		x_{w1}	x_{w2}	x_{w3}	x_{w4}	x_{w5}	x_{s1}	x_{s2}	x_{s3}	x_{s4}	x_{r1}	x_{r2}	x_{r3}	x_{r4}
0. 057	ω	0. 058	0. 06	0. 049	0. 1	0. 066	0. 103	0. 086	0. 057	0. 074	0. 045	0. 055	0. 11	0. 08
0. 065	μ	0. 059	0. 068	0. 057	0. 107	0. 065	0. 074	0. 061	0. 063	0. 054	0. 109	0. 069	0. 079	0. 07
0. 075	ρ	0. 076	0. 065	0. 062	0. 105	0. 062	0. 051	0. 072	0. 065	0. 063	0. 079	0. 08	0. 058	0. 087

Using this method, the projects A, B, C, D were comprehensively evaluated in each period of "past", "now" and "future". Because the purpose of a construction project is to realize investment returns, emphasizing the present and the future, and taking into account the "past", letλ_1=0. 2, λ_2=0. 3, λ_3=0. 5. The four projects A, B, C and D are evaluated using a comprehensive "three-dimensional" method. The values and rankings are listed in TABLE 4.

TABLE 4. Comprehensive evaluation value of projects

	x_{w1}	x_{w2}	x_{w3}	x_{w4}	x_{w5}	x_{s1}	x_{s2}	x_{s3}	x_{s4}	x_{s5}	x_{r1}	x_{r2}	x_{r3}	x_{r4}	Comprehensive evaluation value
A	0. 228	0. 292	0. 148	0. 470	0. 214	0. 305	0. 181	0. 335	0. 318	0. 327	0. 514	0. 413	0. 246	0. 363	4. 354
B	0. 218	0. 222	0. 177	0. 380	0. 254	0. 297	0. 266	0. 156	0. 233	0. 235	0. 435	0. 356	0. 247	0. 303	3. 778
C	0. 252	0. 180	0. 232	0. 335	0. 189	0. 171	0. 218	0. 218	0. 309	0. 274	0. 458	0. 390	0. 309	0. 376	3. 909
D	0. 213	0. 312	0. 285	0. 479	0. 162	0. 211	0. 281	0. 114	0. 141	0. 216	0. 403	0. 306	0. 202	0. 263	3. 589

From the above table, it can be seen that the overall investment and financing risk of Project A is relatively large, Project C and B followed by, and Project D has a relatively small risk.

CONCLUSIONS

Electric energy demand increases continuously in China and power plant constructions are critical in satisfying China's economic and social demands. In this paper, based on the summarizing of PPP power plant project financing risks, a comprehensive evaluation model for project financing risks based on WSR is established. It can make a holistic, effective and objective evaluation of the power plant project financing risk, which provides the premise for the further efficient control of risks and a guarantee for the smooth construction and operation of the project. However, the dynamic mechanisms and the comprehensive aging of this method, still need to be further studied.

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