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Problems of Management

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Original article

Establishment of indicator system for risk assessment of Sino-Russian interstate projects based on fuzzy analytic hierarchy process

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Abstract. Sino-Russian interstate projects are generally with the characteristics of large scale, long duration, high technical content, and multiple participants. In the process of project implementation, it will inevitably be affected by many objective conditions such as economy, management, and technology, resulting in certain risks and uncertainties. Therefore, the key factor to improve interstate project management is to control and reduce project risk from the whole life-cycle of the project. Through literature and case analysis, the evaluation indicators suitable for Sino-Russian interstate projects are reasonably selected. Further, through certain methodology, a comprehensive evaluation of risk indicators and guidance for project management is the purpose. The author uses expert interview, brainstorming, and questionnaires to further organize the risk list. The formation of the hierarchical structure and the construction of the risk factor hierarchical model is the first step and important foundation of the Fuzzy Analytic Hierarchy Process (FAHP) method. The article describes the establishment process of this risk factor hierarchical model in detail. It lays the foundation for the subsequent fuzzy complementary judgment matrix and risk factor importance ranking. The final results provide scientific references for Sino-Russian interstate project management.

Keywords: project management, risk management, risk factor hierarchical model, Analytic Hierarchy Process, Fuzzy Analytic Hierarchy Process

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Проблемы управления

Научная статья

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Создание системы индикаторов для оценки рисков китайско-российских межгосударственных проектов на основе нечеткого аналитического иерархического процесса

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Аннотация. Китайско-российские межгосударственные проекты, как правило, характеризуются крупными масштабами, большой продолжительностью, высокой технической насыщенностью и множеством участников. В процессе реализации проекта на него неизбежно будут влиять многие объективные условия, такие как экономика, управление, технологии, что приведет к определенным рискам и неопределенности. Поэтому ключевым фактором совершенствования управления межгосударственными проектами является контроль

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и снижение проектных рисков на протяжении всего жизненного цикла проекта. На основе анализа литературы и конкретных примеров обоснованно выбраны показатели оценки, подходящие для китайско-российских межгосударственных проектов. Далее с помощью определенной методологии проводится комплексная оценка показателей риска и разрабатывается руководство по управлению проектом. Для дальнейшей систематизации списка рисков автор использует экспертное интервью, мозговой штурм и анкетирование. Формирование иерархической структуры и построение иерархической модели факторов риска является первым шагом и важной основой метода нечеткого аналитического иерархического процесса (FAHP). В статье подробно описывается процесс создания иерархической модели факторов риска. Она закладывает основу для последующей нечеткой матрицы дополнительных суждений и ранжирования важности факторов риска. Итоговые результаты представляют собой научные рекомендации для управления китайско-российскими межгосударственными проектами.

Ключевые слова: управление проектами, управление рисками, иерархическая модель факторов риска, аналитический иерархический процесс, нечеткий аналитический иерархический процесс

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Introduction

The risk of Sino-Russian interstate project is a complex system with risk indicators similar to hierarchical relationship. The Analytic Hierarchy Process (AHP) a commonly used evaluation method by relevant scholars. It is one of the most popular multi-criteria decision-making methods for assessing, prioritizing, ranking, and evaluating decision alternatives, originally developed by T.L. Saaty [1]. In AHP method, the factors related to decision making are categorized to form a hierarchy. The number of levels in the hierarchy indicates the complexity of the problem.

The AHP has been applied by many scholars in different types of projects. Scholars S. Panchal et al. [2] established the AHP model to analyze the risk factors of National Highway 5 in the infrastructure project. The results can guide the planning of road construction and maintenance operations. The authors, Amos Darko et al. [3] detail the use of AHP tool in the field of construction management decision making during the period 2004-2014 through a literature review methodology. The authors found that almost all applications of the AHP in the field of risk management involve combining the AHP with other techniques.

With the introduction of ordinary fuzzy sets in research by Zadeh [4], it became popular in almost all branches of science. Researchers have expanded e.g. Type-2 fuzzy sets (T2FS) [5], Intuitionistic fuzzy sets [6], Spherical fuzzy sets [7] and so on. Scholars Hing Kai C. et al [8], compared in detail the classical AHP method with the triangular fuzzy hierarchy analysis (FAHP) in practice. They infer that FAHP is not actually a superior method to classical AHP. Complex FAHP method is not necessarily better than simple one.

Therefore, in this study, the author uses the FAHP method, which is a combination of classical AHP and the theory of fuzzy mathematics, to analyze and evaluate the data.

Fuzzy Hierarchy Analysis Process and key steps

In the AHP, researcher divides the decision goal for project decision-making into the highest, middle and lowest levels according to their interrelationships, and draws a diagram of the hierarchical model. The highest level refers to the objectives of project decision-making. The middle level refers to the criteria, factors to be considered in decision-making. The lowest level refers to the alternatives in decision-making. Factors at the same level are subordinate to or have an influence on factors at the higher level. At the same time, they dominate or are influenced by the factors at the lower level. Hierarchy model as shown in the Figure 1.

The main purpose of the AHP is to break down the problem into smaller components. By diluting the problem, the decision maker can focus on a limited number of items. AHP is a computational technique used for decision making. It is designed to make decisions as a team. It involves ranking the decision elements and then comparing the clustered pairs. This provides weights for each element in the hierarchy. The AHP procedure is shown in Figure 2.

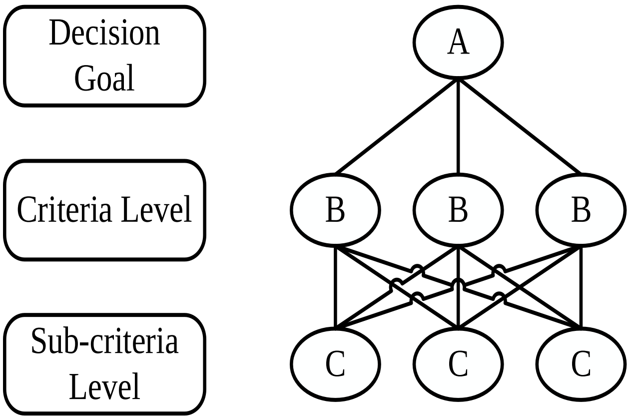

Figure 1. Hierarchy model diagram [9]

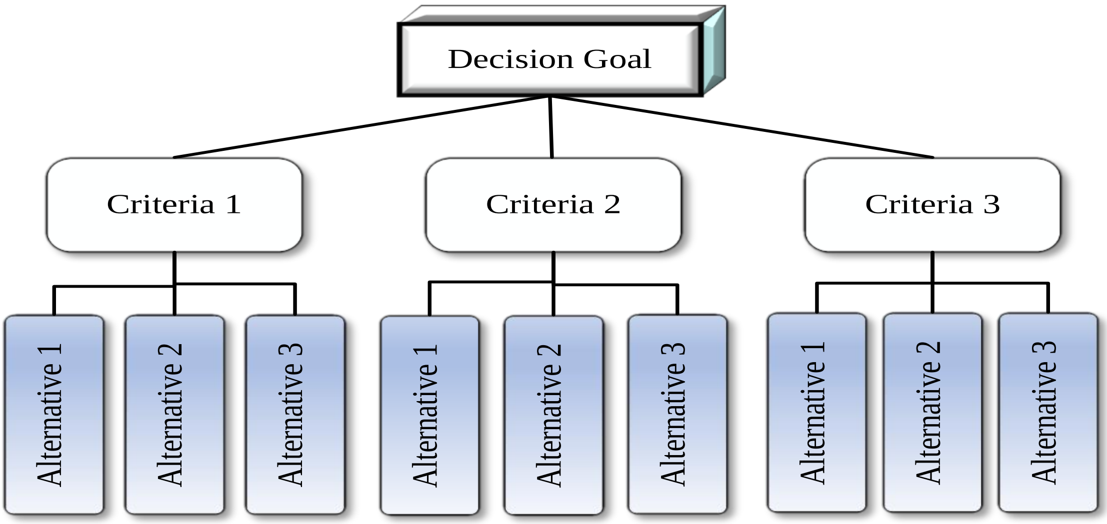

Figure 2. AHP procedure diagram [10]

The importance of each indicator in the criteria level is different from that of each indicator in the decision goal level. The importance of each indicator in the sub-criterion level is generally different from that of each indicator in the criteria level. Therefore, it is necessary to construct a judgment matrix by pairwise comparison between indicators. A pairwise comparison indicates the relative superiority measure between this level and its associated indicators with respect to the previous level. The results of the comparison of the superiority can be expressed in terms of an importance linguistic scale. This method of comparison is known as direct superiority comparison. In this study, the direct superiority comparison method was used.

The risk evaluation of the Sino-Russian interstate project involves more indicators; the hierarchical relationship is clear. However, most of the evaluation indicators are qualitative, and it is more difficult to quantify the indicators with specific numbers and formulas like economic evaluation indicators. It is necessary to establish a method to transform fuzzy information into definite information. The Fuzzy Analytic Hierarchy Process (FAHP) is an extension of the AHP to uncertainty and ambiguity problems, and is a quantitative method that can deal with uncertainty in complex problems [11]. Therefore, in this study, the author combines the theory of fuzzy mathematics with the AHP. The FAHP was used to evaluate the risk of the Sino-Russian interstate project.

The general idea is as follows: 1. The importance degree of pairwise judgment given by various experts is evaluated with fuzzy importance linguistic scale to form a fuzzy judgment matrix. 2. According to the fuzzy matrix properties and certain arithmetic methods, the weight vector of the fuzzy judgment matrix is calculated. Overall, the FAHP has the following advantages. It takes into account the relative importance of relationships between decision levels. It can handle imprecise and fuzzy language uncertainty and can effectively reflect fuzzy data [12].

The steps of Fuzzy Analytic Hierarchy Process (FAHP) are:

1. Hierarchy formation. Constructing the risk factor hierarchy model.

On the basis of project risk identification, the identified risk indicators are classified and stratified according to the rules of model construction to form a systematic organizational structure. According to the characteristics of risk indicators and the different ways of influencing projects, the following structural models can be developed.

a. Decision goal level. There is only one element that represents the project risk.

b. Criteria level. The most direct and major factors affecting project risk are generally used as a measurement criteria.

c. Sub-criteria level. Refers to the specific risks of the project. Because of the large number of risk indicators, it can be categorized into multiple levels based on affiliation.

2. Pairwise comparisons. Constructing a fuzzy complementary judgment matrix.

The domain expert is asked to complete pairwise comparison of indicators at each level of the hierarchy. Considering the decision-making objectives, the relative importance of each of the two criteria is compared at the second level of the hierarchy.

3. Ranking of indicators in order of combined importance.

Based on the above calculation steps, the relative importance of the lower level indicators relative to the higher level indicators can be obtained.

The process of modeling the structure of the risk assessment indicator system for Sino-Russian interstate project

The accuracy of the risk evaluation system is related to the effectiveness of the risk control. Therefore, it is particularly important to establish a scientific and reasonable evaluation indicator system. Based on extensive literature analysis, case analysis. Combined with the characteristics of Sino-Russian interstate projects, the author summarizes the initial list of risk identification for Sino-Russian interstate project. As shown in Table 1.

Table 1. The initial list of risk identification for Sino-Russian interstate project [13]

Risk category	Risk factor
Behavioral Risk	Owner intervention risk Subcontractor’s risk Consulting supervision risk Supplier's risk Designer's risk
Management Risk	Material procurement risk Technical standards risk Managing technology risk Safe operation risk
Process Risk	Bidding decision risk Contract risk Completion test risk
External Risk	Government approval risk Political instability risk International relation risk Government intervention risk Social security risk Cultural difference Geographical condition Natural force majeure Exchange rate risk Market competition risk Inflation risk Industry access risk Interest rate risk Law and regulation risk

In order to ensure the scientific, reasonable, and comprehensive establishment of the evaluation indicator system. On the basis of the initial list, the author uses expert interview and brainstorming methods to summarize, optimize, and categorize the indicators. The interview panel was drawn from a variety of professional fields, with experience in construction and management of interstate projects, and was able to identify risks from a multi-objective dimension. The composition of the interview panel was in accordance with statistical principles. Through interviews, risk factors of the same type were consolidated, factors that did not need to be considered were deleted, and factors that had not been considered were added. The author has identified risk evaluation indicators and risk factor meaning for the Sino-Russian interstate project. As shown in Table 2.

Table 2. Risk evaluation indicator and the meaning of Sino-Russian interstate project[1]

Risk category	Risk factor	Meaning of indicator
Behavioral Risk	Owner's risk	The owner's audit scope is too large, excessive intervention in the project.
	Subcontractor's risk	Inadequate performance of subcontractors leading to delays. Moral hazard of subcontractor.
	Consulting supervision risk	The consulting supervisor is not familiar with the Chinese technical specification.
	Supplier's risk	Inadequate supplier delivery capacity, and moral hazard of supplier.
	Designer's risk	Unfamiliarity of the designer with international standards, moral hazard on the part of the designer.
Management Risk	Design management risk	Lack of clarity in the study of the owner's requirements, leading to deviations in the project design process resulting in failure to pass approval.
	Procurement management risk	Unreasonable procurement of materials due to lack of oversight.
	Technical standard risk	Chinese technical standards are difficult to be recognized by owner.
	Human resource risk	Inadequate management capacity of project manager.
	Security risk	Lack of safety operation training and emergency plan.
	Environmental risk	Lack of basic environmental awareness and failure to take appropriate environmental protection measures.
	Collection risk	Inadequate investigation of owners' ability to pay.
	Insurance risk	Failure to settle claim in a timely manner or difficulty in settling claim due to insurance processing error.
Process Risk	Project selection risk	Wrong bidding strategy, inadequate project research.
	Contract risk	Insufficient claim awareness and contractual deficiency.
	Completion test risk	Failure to meet completion standard at the time of project handover.
External Risk	Government approval risk	Complex and inefficient government approval process.
	International relation risk	Subject to economic sanction or military intervention.
	Policy change risk	The old policies have changed, and the government has issued new policies to have a negative impact on the project.
	Government intervention risk	Government corruption, delaying or denying project access, or forcing corporate technology transfer.
	Public security risk	Cases of terrorist attack or criminal offense.
	Cultural difference risk	Large differences in ideology, corporate culture, and language habits.

[1] Developed by author.

	Natural condition risk	Complex geographical and climatic condition.
	Exchange rate risk	Exchange rate fluctuation.
	Market competition risk	Malicious competition in the marketplace.
	Inflation risk	Fluctuating price and rising cost due to inflation.
	Industry access risk	Industry access restrictions and licensing differences against the contractor.
	Interest rate risk	Fluctuations in interest rate on contractor finance loan.
	Risk of inadequate legal system	Inadequate or unreasonable law and regulation.

Due to the degree of subjectivity in the evaluation of risk indicators for interstate engineering projects, the author strictly controls the data sources when selecting indicators. The author selects engineers who have participated in interstate engineering projects of varying scales, or associate professors or professors engaged in relevant international engineering project management teaching and research fields as the group of experts to be interviewed. The author invited 20 qualified experts to judge the degree of approval of the identified risk factor indicators of the Sino-Russian interstate project. The background information of the interviewed experts is shown in Table 3.

Table 3. Background information of the interviewed expert[1]

Category	Options	Percentage	Category	Options	Percentage
Gender	Male	80%	Professional field / business responsibilities	Engineering technology	73%
	Female	20%		Project management	60%
Age	21-30	7%		Design consulting	13%
	31-40	27%		Finance	7%
	41-50	33%		Contract management	20%
	＞50	33%		Engineering cost	20%
Relevant years of work	1-5 years	0%		Regulation	7%
	6-10 years	33%		Market	13%
	11-20 years	33%		Other	13%
	More than 20 years	33%	Interested party	Project owner	28%
Types of projects participated in	Infrastructure (transportation/energy/water affair, etc.)	42%		Contractor	37%
	Industry (Petroleum/chemical, etc.)	32%		Subcontractor	12%
	Equipment/material manufacturing	9%		Designer	4%
	Building construction	5%		Consulting supervision	3%
	Other	12%		Supplier	6%
	/	/		Operator	0%
				Acceptance party	4%
				Other	6%

[1] Developed by author.

20 questionnaires were sent out and 20 were respond, with a response rate of 100%. Twenty experts were invited to score the 29 project risk indicators shown in Table 4, and the results were normalized and ranked. The indicator which normalized value is equal to or greater than 0,40 is selected as the key measure indicator of FAHP model [14]. The results obtained are shown in Table 4.

Table 4. Ranking of risk indicator
for Sino-Russian interstate project[1]

Number	Risk factor	Average value	Normalization	Ranking
1	Human resource risk	4.5714	1.0000	1
2	Contract risk	4.5714	1.0000	1
3	Designer's risk	4.4286	0.9130	3
4	Security risk	4.4286	0.9130	3
5	Consulting supervision risk	4.3571	0.8696	5
6	Environmental risk	4.3571	0.8696	5
7	Collection risk	4.3571	0.8696	5
8	Insurance risk	4.3571	0.8696	5
9	Subcontractor's risk	4.2857	0.8261	9
10	Project selection risk	4.2857	0.8261	9
11	Completion test risk	4.2857	0.8261	9
12	Government approval risk	4.2857	0.8261	9
13	Government intervention risk	4.2857	0.8261	9
14	Policy change risk	4.2143	0.7826	14
15	Public security risk	4.2143	0.7826	14
16	Supplier's risk	4.0714	0.6957	16
17	International relation risk	4.0714	0.6957	16
18	Risk of inadequate legal system	4.0000	0.6522	18
19	Inflation risk	3.7857	0.5217	19
20	Technical standard risk	3.7143	0.4783	20
21	Exchange rate risk	3.7143	0.4783	20
22	Industry access risk	3.5974	0.3987	22
23	Interest rate risk	3.5974	0.3987	22
24	Procurement management risk	3.5714	0.3913	24
25	Market competition risk	3.5714	0.3913	24
26	Cultural difference risk	3.5000	0.3478	26
27	Cultural difference risk	3.4758	0.2981	27
28	Natural condition risk	3.3571	0.2609	28
29	Owner's risk	2.9286	0.0000	29

As can be seen from Table 4, 21 risk factors have a normalized value of 0.40 or more and cover all four levels of project risk. According to the results, it is possible to establish a risk breakdown structure model of the Sino-Russian interstate project, as shown in Figure 3. Further, the screened 21 risk factor indicators were used as the FAHP model establish.

[1] Developed by author based on questionnaire.

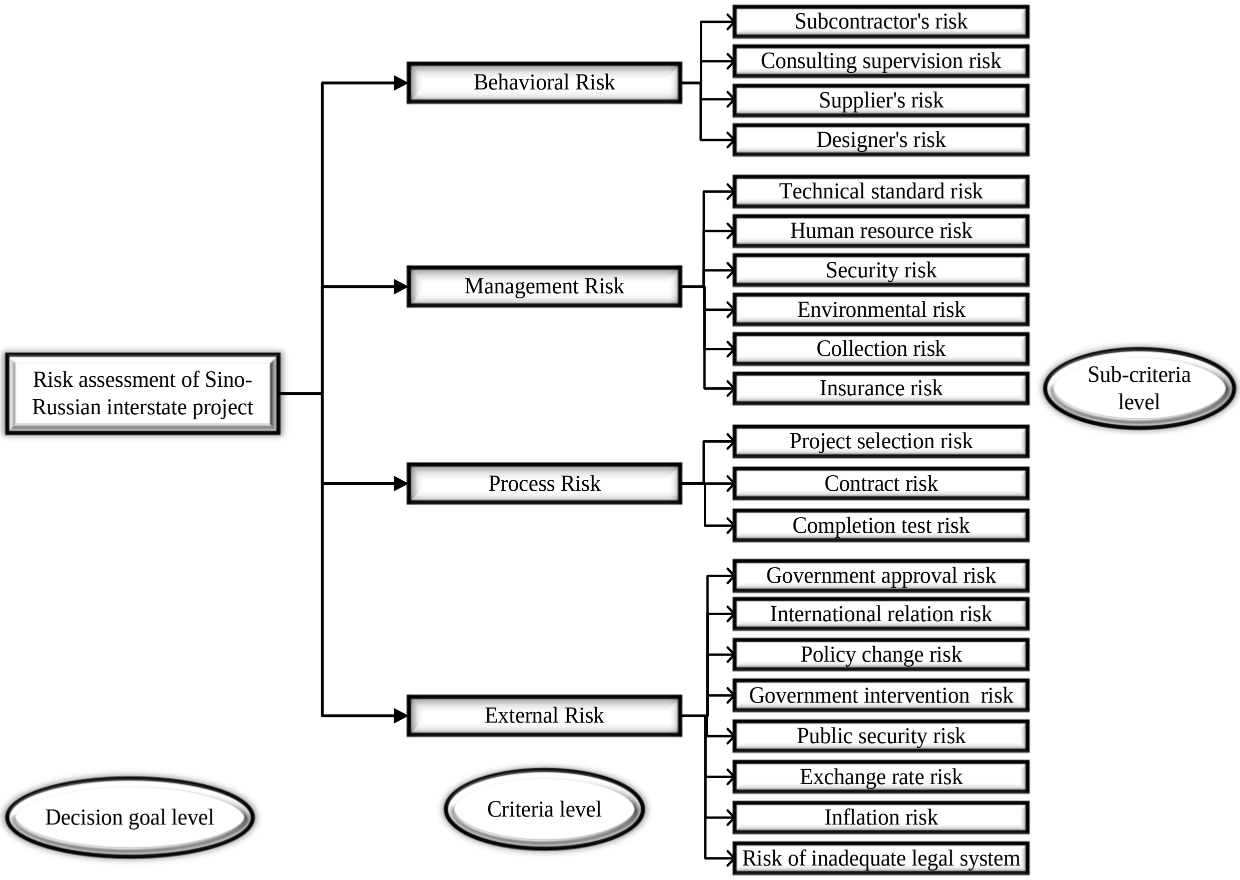

Figure 3. Risk assessment indicator system
of Sino-Russian interstate project[1]

Conclusion

The establishment of the model of Sino-Russian interstate project risk evaluation indicator system is the basis and the first step of the comprehensive evaluation system of Sino-Russian interstate project risk based on Fuzzy Analytic Hierarchy Process. The scientific evaluation indicator system can provide a basis for the data collection of the subsequent fuzzy judgment matrix, thus further promoting the scientific and rigorous nature of the study. Therefore, this study is of value to the research field of risk evaluation of Sino-Russian interstate project and provides a scientific increment.

Subsequently, the author will use the questionnaire method by pairwise compare the indicators at each level. Compare the relative importance of indicators at different levels on the basis of decision-making objectives. In the same level, pairwise compare the relative importance of two sub-criteria indicators. Based on the data of the comparison results, a fuzzy complementary judgment matrix of risk factors of the Sino-Russian interstate project will be established, and the judgment results will be quantified. Based on the above calculation steps, the relative importance of the lower level indicators relative to the higher level indicators can be obtained. Using the results as the basis for ranking the importance of the indicators, it is possible to determine the position of each indicator in the overall system of evaluation system. The author will complete all the steps of the entire Sino-Russian interstate project risk evaluation system in subsequent research.

Sino-Russian interstate project management is a research issue with strong practical significance. Strengthening the efficiency of project management from the perspective of risk control can provide improvement measures at all levels: scholars, enterprises, government, universities, and society.

[1] Developed by author.

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