Analysis and Evaluation on the Risks of the Construction Project

ANALYSES ET ÉVALUATION SUR LES RIQUES DU PROJET DE CONSTRUCTION

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Abstract: The thesis, starting from the characteristics of the construction project, deploys the combining method of normative and empirical research. According to integrated Risk Management Paradigm, the thesis sums up the overall framework of the construction project system and proposes the evaluation index system of the risk analysis based on the Analytic Hierarchy Process. In addition, the paper puts forward a comprehensive risk evaluation model and makes clear the relative importance of various risk factors. By so doing, it provides some thoughts for the construction projects' management and evaluation.
Key words: Construction Project; Risk Management; Risk Evaluation; Analytic Hierarchy Process

Résumé: A partir des caractéristiques du projet de construction, cette thèse utilise la méthode de combinaison de recherches normatives et de recherches empiriques. Selon le Paradigme de management de risques, cette thèse résume le cadre global du système de projet de construction et propose le système d'indexation de l'évaluation des analyses des riques, basé sur le Processus hiérarchique analytique. En plus, cet artcile met en avant un modèle d'évaluation de risques globaux et clarifie l'importance relative des différents facteurs de risque. En agissant de la sorte, il fournit quelques idées concernant la gestion et l'évaluation des projet de construction.
Mots-Clés: Projet de construction; Gestion des risques; évaluation des risques; Processus hiérarchique analytique

1. RESEARCH AT HOME AND ABROAD

Project risk management is an indispensable part of project management. As the new Economics and Management Science which has just emerged during the past 20 years, project risk management is based

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on economics, management science, behavioral science, operations research, probability and statistics, computer science, system theory, control theory, information theory and other disciplines, as well as modern engineering technologies. It also takes into account the particular conditions of modern construction projects and high-tech development projects, thus becoming a new fringe science of Economics and Management Science.

In terms of the published books and papers, the British scholar J • R • Turner devoted a chapter in his book *The Handbook of Project-based Management* to the project risk management. The most representative journal is Butterworth-Heinemann Ltd’s *International Journal of Project Management* from the United Kingdom. And it often publishes project risk management articles. Other magazines that often run articles on project risks are: Britain's *Project Appraisal*, America’s *Journal of Risk and Uncertainty*, *Risk Analysis*, *The Engineering Economist* and so on, and also other related magazines such as *Insurance: Mathematics and Economics*, *Decision Sciences*, *Management Science*, *Econometrics*, etc. The articles mainly focus on the technical development and improvement of the theoretical system, while some are application reports and feedbacks. In terms of software development and application, the software that has been developed are "Analytical Power Tools" developed by Palisade Corporation in the United States, the United Kingdom’s "Risk-Net" software, Norway’s "Dyn-Risk" software, and Finland’s " Riskman "software. In Western industrialized countries, the project risk management is relevant in many fields, ranging from national defense, aerospace and construction to medicine, chemical industry, mining, oil and other areas. In today's world, large-scale projects, without exception, apply project risk management. According to available statistics, the United States Washington metro, subway projects in London, Hong Kong and Singapore all have adopted the risk management techniques to ensure the success of the project.

Research on risk management in China starts from decision-making concerning project risks. And we have a late start. This is because China had practiced the highly centralized planned economy for a long time before China's reform and opening up. Under the planned economy, the state was the only investment body, and controlled prices of raw materials. Enterprises were not for profit and risks were borne by the state. Therefore, in a very long time, the construction projects of our country did not have risk management and we were way lagged behind the developed countries. When China introduced project management theory and methods at the end of the 70s, early 80s, we only introduced project management's basic theories, methods and procedures, not risk management. "Risk" was raised for the first time in 1980 by Zhou Shifu. From 1987 to 1996, at the national key scientific and technological project, "Major scientific and technological research of the Three Gorges project", sponsored by the National Science and Technology Commission, the Three Gorges Project risk research was adopted and was the first risk analysis and evaluation of large-scale project. So far, however, the majority of our research is about a particular risk, mainly focusing on project progress and cost control. In terms of software development and application, universities’ management colleges, colleges of computing technology, Menglong Science and Technology Co., Ltd. in Beijing, and Tongzhou computer Co., Ltd. (Sino-Japanese joint venture) in Dalian have all developed some software concerning the progress of project management, but they mainly use plan coordination technique and their research is not targeted at project risks. Project risk analysis has been adopted in projects in China, such as the Three Gorges Project, the Shanghai subway construction project, and Daya Bay Nuclear Power Plant project.

From the above summary of domestic and foreign research, we can conclude that: as for the project risk management, in terms of theoretical research and practical applications, China still has a long way to go to catch up with the Western developed countries. We are still in the introduction, absorption and digestion stage. In order to narrow the gap with other countries as soon as possible and strive to make breakthroughs and innovation, we should make full use of modern management techniques, improve the level of enterprise risk management, and learn the advanced practices and experience of developed countries. At the same time, it is necessary to consider China's national conditions, set up relevant systems, standards and procedures for risk management, so as to integrate the three benchmarks of project management, namely "cost, quality and progress", and form a scientific and standardized risk management system.

2. CHARACTERISTICS OF THE CONSTRUCTION PROJECT RISKS

Characteristics of the project risks are determined by the nature of the projects. Compared with the production process of other products, construction projects have their unique features. Therefore, it is necessary to elaborate on and analysis the characteristics of construction projects.

2.1 Characteristics of Construction Projects

In general, the construction project's main features are: 1) construction project involve huge risks which are volatile and complex; 2) risks affect not part of the project or only for a period of time, but have a overall effect; 3) the parties involved in construction projects all have risks, but their risks are not the same and their ability to withstand risks differs; 4) construction projects have a fixed structure, but construction process is flexible; 5) projects only produce one property at a time, but the project types are various; 6) the construction teams are often temporarily involved in the project and their recruitment is open to the whole society; 7) on the construction site, the project's co-ordination, command and supervision are complicated. In the construction process, there are many unpredictable factors, so the construction project is a high-risk process. The sources of project risks are complex and the risk patterns are difficult to grasp. The engagement status of key parties of the construction projects is shown in Table 1.

Table 1. The engagement status of key parties of the construction projects

Involved parties	Feasibility study	Design	Construction	Final acceptance of construction
Construction unit	※	&	∮	※
Design unit	&	※	∮	∮
Contractors	∮	&	※	※
Subcontractor	∮	∮	※	&
Supervision units	∮	∮	※	&
Materials suppliers	∮	∮	※	∮

Notes： ※ key parties； &involved parties； ∮ not involved parties

2.2 Characteristics of the Construction Project Risks

The nature of construction projects determines the risk characteristics as follows:

- Wide risk sources. Construction project risks not only come from the external natural conditions (such as: fires, floods, typhoons), the social environment (such as: the economy, politics, laws and regulations), as well as the project's techniques, management level, and the quality of personnel, etc.
- The risk's long-term hidden effects. It takes time or some stages for certain construction

projects risks to inflict losses. For example, the risk of design errors may only be revealed at the final acceptance stage of even after being put into use.

- The risks change from time to time. The risks of construction projects are not static, but rather change with the passage of time or the different construction stages. the variability of project risks are mainly reflected in the changes of the nature of risk, the consequences, the emergence of new risks and the diminishing of risk factors. Therefore, in the actual operation of construction projects, there should be real-time monitoring of risk changes and an effective early warning system should be set up.

- Serious consequences. When construction projects' risk incurs losses, the losses are often severe. In addition, it may indirectly affect the socio-economic development, natural environment, as well as people's lives, etc.

- The complexity of risk management techniques. During the construction project risk management, the risk managers should not only have a deep understanding of the construction project itself, are familiar with risk management theory and methods, but also have knowledge concerning economics, policies, law, finance, or even math, computer science, etc.

3. THE MANAGEMENT SYSTEM FOR RISKS IN CONSTRUCTION PROJECTS

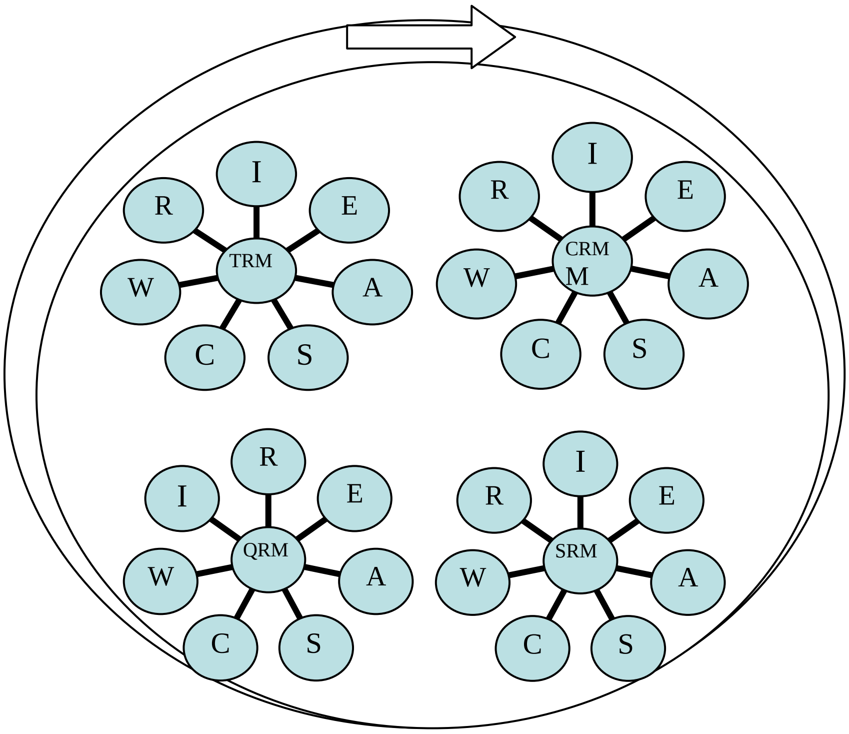
Generally speaking, risk management includes five components, namely, risk analysis, formulation of risk management and circumvention strategies, risk control, risk pre-warning and evaluation of the risk control results. Among the five, risk analysis is the basis of risk control and consists of three components: risk factor identification, risk estimation and risk evaluation. These components go through the whole process of the construction projects, constituting a circular structure. Horizontally, risk management of construction projects can be divided into four important aspects: cost risk management, project schedule risk management, quality risk management and safety risk management. Vertically, it can be divided according to the different stages the project is in, which include risk management in the project initiation stage, the feasibility study stage, the designing stage, the construction stage and completion and utilization stage.

Therefore, according to characteristics of construction projects and components of risk management, which are analyzed in the previous paragraphs, the risk management process of construction projects can be shown in graph1.

Symbols in the graph represent the following terms respectively:

I—risk identification,; E—risk estimation; A—risk evaluation; S—formulation of circumvention strategies; C—risk control; W—risk pre-warning; R—evaluation of the risk control results; TRM—schedule risk management; CRM—cost risk management; QRM—quality risk management; SRM—safety risk management.

In graph1, the four small circles represent the four important aspects of risk management of construction projects: cost, schedule, quality and safety. Each of the small circles, i.e. each important aspect of risk management consists of seven steps: risk factor identification, risk estimation, risk evaluation, formulation of risk management and circumvention strategies, risk control, risk pre-warning and evaluation of the risk control results. In addition, the four important aspects are also interrelated. The outer circle shows the periodic nature of the risk management of the construction projects, indicating that the risk management is continuous throughout the life cycle of the construction projects. Every stage includes some or all components of the four important aspects. The components and magnitude of the risks in the next stage, to some extent, depend on the management and control of this stage.



Graph1. Risk Management Process for Construction Projects

4. EVALUATION OF AHP IN CONSTRUCTION PROJECT RISKS

4.1 Basic Contents of AHP

Analytic Hierarchy Process (AHP), which is widely applied in construction, is a risk estimation method that combines qualitative analysis and quantitative analysis. It identifies the major risk factors in the target project by way of a hierarchy structure. Experts then decide the relative importance of the risk factors in the perspective of the amount of loss the risk may cause and the risk's probability of occurrence. On such basis, the experts will run a consistency check on the matrix. If the check is passed, the experts will calculate the relative importance of each risk factor and sequence all the factors accordingly. If not, they will repeat the above-mentioned procedure and revise their opinion until the check is passed.

4.2 Features of AHP

The features of AHP include: (1) loss expectation and estimation are manly based on the experts' subjective judgment; (2) the results of risk evaluation are indicated by the relative importance of factors in the project's risk factors system, so absolute indexes such as the amount of loss various risks may cause and the risk occurrence probability can not be reached.

4.3 Evaluation of the Hierarchy Analysis Method

Table2. Evaluating engineering change risks —a index system

Risk factors（$g_1,\dots,g_4$）	Sub-risk factors（$p_1,\dots,p_{23}$）	Evaluating Methods
Operation risk g_1	（1）geological conditions of the construction site and foundation conditions	Experts' estimates
	（2）supply of materials	
	（3）supply of equipments	
	（4）engineering change	
	（5）technical standards	
	（6）designing and construction	
Financial risk g_2	（1）changes in exchange rate	Experts' estimates
	（2）change in interest rate	
	（3）collateral	
	（4）liabilities	
	（5）tax	
	（6）inflation	
Strategic risk g_3	（1）strategic environment	Experts' estimates
	（2）strategic resources	
	（3）enterprise competitiveness	
	（4）enterprise leadership	
	（5）strategic position	
Management risk g_4	（1）competence of the designer	Experts' estimates
	（2）competence of the constructor	
	（3）competence of the contractor	
	（4）competence of the supervisor	
	（5）competence of the proprietor	
	（6）competence of the personnel in government functional bodies	

4.3.1 Building the Judgment Matrix

In order to compare the importance of each risk factor, four evaluation standards are selected, namely, operation risk, financial risk, strategic risk and management risk.

Assume that the real risks for the four evaluation standards are w_1 、 w_2 、 w_3 and w_4 respectively. Compare the four indexes two by two; you will reach the results in the table below:

Table3. Results of the Pairwise Comparisons between the Four Indexes

Importance of the risk	g_1	g_2	g_3	g_4
g_1	w_1 / w_1	w_1 / w_2	w_1 / w_3	w_1 / w_4
g_2	w_2 / w_1	w_2 / w_2	w_2 / w_3	w_2 / w_4
g_3	w_3 / w_1	w_3 / w_2	w_3 / w_3	w_3 / w_4
g_4	w_4 / w_1	w_4 / w_2	w_4 / w_3	w_4 / w_4

$$Ag = \begin{pmatrix} w_1/w_1 & w_1/w_2 & w_1/w_3 & w_1/w_4 \\ w_2/w_1 & w_2/w_2 & w_2/w_3 & w_2/w_4 \\ w_3/w_1 & w_3/w_2 & w_3/w_3 & w_3/w_4 \\ w_4/w_1 & w_4/w_2 & w_4/w_3 & w_4/w_4 \end{pmatrix} = \begin{pmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & a_{34} \\ a_{41} & a_{42} & a_{43} & a_{44} \end{pmatrix}$$

4.3.2 Calculating the Relative Importance

This step is to obtain the maximum latent root and the corresponding eigenvector of the matrix. An approximate solution is employed to obtain the root. The procedure is as follows:

1st. Following the rows in the matrix,

$$\mu_i = \sqrt[n]{\prod_j a_{ij}} \quad (i=1，2，3，4)$$

2nd. Normalize vector $\boldsymbol{\mu} = (\mu_1, \mu_2, \mu_3, \mu_4)^T$, eigenvector $\mathbf{w} = (w_i, w_2, w_3, w_4)^T$ is then obtained,

i.e. $w_i = \mu_i / \sum_{i=1}^{n} u_i \quad (i=1，2，3，4)$

e.g. $$Ag = \begin{pmatrix} 1 & 7 & 5 & 3 \\ \frac{1}{7} & 1 & \frac{1}{3} & \frac{1}{5} \\ \frac{1}{5} & 3 & 1 & \frac{1}{3} \\ \frac{1}{3} & 5 & 3 & 1 \end{pmatrix} \qquad \boldsymbol{\mu} = \begin{pmatrix} 3.201 \\ 0.312 \\ 1.189 \\ 1.495 \end{pmatrix} \qquad \mathbf{w} = \begin{pmatrix} 0.564 \\ 0.055 \\ 0.118 \\ 0.263 \end{pmatrix}$$

4.3.3 Consistency Check

Only when matrix Ag is fully consistent, equation $\lambda_{\max} = n$ is true. According to AHP, to check the consistency (compatibility) of the judgment matrix, the difference between $\lambda_{\max}$ and *n* can be used for the test. The consistency index is defined as follows:

$$CI = \frac{\lambda_{\max} - n}{n-1} ,$$

$\lambda_{\max}$ can be obtained through the equation below：

$$\lambda_{\max} = \frac{1}{n}\sum_i \left(\frac{(\mathbf{AW})_i}{w_i} \right)$$

In the above example： $\mathbf{AW} = \begin{pmatrix} 1 & 7 & 5 & 3 \\ \frac{1}{7} & 1 & \frac{1}{3} & \frac{1}{5} \\ \frac{1}{5} & 3 & 1 & \frac{1}{3} \\ \frac{1}{3} & 5 & 3 & 1 \end{pmatrix} \begin{pmatrix} 0.564 \\ 0.055 \\ 0.118 \\ 0.263 \end{pmatrix} = \begin{pmatrix} 1.893 \\ 0.723 \\ 0.484 \\ 1.080 \end{pmatrix}$

$$\lambda_{\max} = \frac{1}{4} \times \left(\frac{1.893}{0.564} + \frac{0.723}{0.055} + \frac{0.484}{0.118} + \frac{1.080}{0.263} \right) = 4.117$$

$$CI = \frac{4.117 - 4}{4-1} = 0.039$$

Obviously, the judgment error increases with *n*, that's why the influence of *n* needs to be considered when conducting the consistency check. A consistent random ratio $CR = \frac{CI}{RI}$ is introduced with RI being the average random consistency index. Table 4 shows average of 500 samples.

Table 4. The Average Random Consistency Index

order	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.51	1.54	1.54	1.56	1.57	1.59

When CR <0.1, the consistency of the judgment matrix is acceptable.

In the above example, $CR = \frac{0.039}{0.90}$ =0.043<0.1，which proves the consistency of the judgment matrix. The obtained eigenvector is representative of the preference and relative importance of the risk factors.

4.3.4 Calculating the Comprehensive Risk Importance

After gaining the relative importance of the factors at the same level, the comprehensive importance of factors at each level relative to the total can be calculated following a top-down order. In the above example, there are four factors g_1, g_2, g_3, g_4 on level *g*, with their relative importance being w_1, w_2, w_3, w_4. On the next level there are 23 child nodes from p_1 to p_{23}, their importance relative to g_j being v_{ij} (obtained in the same way as w_i), then the comprehensive importance of factor p_i on the level p is:

$$W_i' = \sum_j w_j v_{ij}$$

Table 5 shows the calculation process:

Table 5. Comprehensive Importance of the Risks in Construction Projects

	g_1	g_2	g_3	g_4	W_i'
	w_1	w_2	w_3	w_4	
p_1	v_{11}	v_{12}	v_{13}	v_{14}	$W_1' = \sum_j w_j v_{1j}$
p_2	v_{21}	v_{22}	v_{23}	v_{24}	$W_2' = \sum_j w_j v_{2j}$
…	…	…	…	…	…
p_{23}	v_{231}	v_{232}	v_{233} …	v_{234}	$W_{23}' = \sum_j w_j v_{23j}$

Through comparing the value of W_i', an order of the sub-risks' risk importance can be obtained. The bigger W_i' is, the higher degree of risk is contained in the corresponding risk factor.

5. CONCLUSION

The characteristics of construction projects determine that risks in construction involve factors of all aspects. To ensure smooth completion and cost-efficiency of the projects, effective risk management is necessary. As a key step in risk management, risk evaluation should be paid with sufficient attention. The rapid development of modern mathematics and computer technology equip the risk studies of construction projects a great number of evaluation methods, which, in addition to AHP, include fuzzy mathematics method, grey correlation analysis method, Program Evaluation and Review

Technique(PERT) and ***Monte Carlo*** method. The studies on risk identification and evaluation methods can provide decision-making support to project managers and help them to consciously control, reduce and shift risk so as to minimize the loss caused by the risks.

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