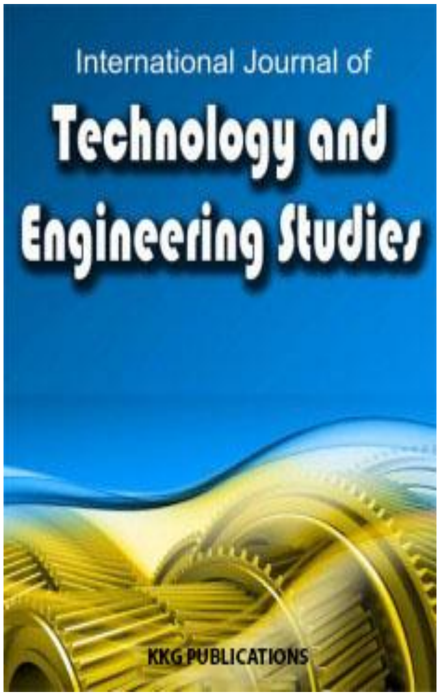

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Project Risk Management Based on WBS-RBS-OBS and ANP -with the Aerospace Industry as Example

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PROJECT RISK MANAGEMENT BASED ON WBS-RBS-OBS AND ANP - WITH THE AEROSPACE INDUSTRY AS EXAMPLE

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Abstract. With the rapid development of science, projects have increasingly become complicated. Due to the availability of resources, the changing environment, and other factors, projects have become large and complicated, and corresponding single project management has gradually tended to multi-project management. Optimal time duration, minimum cost, and best quality are the expected results of project management. However, there are many uncertainties and risks under large project management, which usually result in huge losses and social impact. Therefore, project risk management is increasingly important. Previous studies on project risk management only focused on the application of a combined matrix of WBS and RBS, while ignoring that risk decisions and actions are often decided by people and organizations. Aiming at project risk management from three aspects, WBS, OBS, and RBS, this paper solves the problem of traditional risk management control, conducts comprehensive evaluation through ANP, and determines risk weight and ranking in the quantization method, in order to render risk identification more perfectly, and help decision makers to make objective and effective management decisions and distribute resources under the multi-project mode. Finally, this paper presents an application of an actual case of the aerospace industry, analyzes and solves the project risk management problems in order to verify the usability of such a method, and offers follow-up suggestions.

INTRODUCTION

Research Background and Motives

With the rapid development of science, about 90% of projects are developed in a multi-project environment. Enterprises need the breakdown and integration of characteristic and complicated project groups under a series of restrictions of limited resources to finally serve the overall corporate interests.

In large projects, due to technical restrictions, the participation of many stakeholders, long construction duration, and uncertain cost and quality, projects are often exposed to uncertain circumstances, and through the application of risk management, the project life cycle can be effectively managed. However, subjective risk perception is likely to result in the risk that project objectives are not realized. There are many development tools and technologies of risk identification, risk analysis, and risk response; however, a comprehensive risk management method in traditional project management is rarely seen [1]. Therefore, project risk management requires a set of systematic decision analysis frameworks to help manager's ability to analyze the importance of decision criteria and determine their priority, in order to input corresponding resources and evaluate proper decision making schemes. The aerospace industry is an industry integrating many industrial technologies, and is featured by highly technical integration, wide industrial association, and high added value, rendering the aerospace industry a topic that cannot be ignored in project risk management.

Based on the above problem and the WBS-RBS-OBS model, this paper conducts risk identification and quantitatively analyzes the risks through ANP in order to help decision makers make more effective decisions in "project risk management".

Research Purpose

In a large and complicated project, there are often uncertainties in technology, economy, natural and social environments, and these uncertainties are likely to cause the risks of huge economic losses and social impacts; therefore, project

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risk management is related to the success of a project. Aiming at project risk management, a set of methods is developed herein, which can effectively identify the risks in large projects and provide objective analysis, thus, helping managers to plan and make decisions more effectively. The purpose of this paper is shown, as follows:

1. Establish an objective risk management system based on actual conditions:

Develop large project risk management identification, measurement, calculation, and ranking methods, and establish a reliable expert systematization module for large project risk management, in order to specifically apply team discussions and brainstorming results to risk management according to local conditions.

2. Develop a model of comprehensive project risk identification:

Regarding the occurrence of project risks, the people, matters, and things involved often play important roles. This paper presents a risk identification model, which comprehensively considers all important factors, to achieve the effective project risk management.

Provide risk ranking analysis procedures for simple project operations: Based on the current situation of project environment risk, through expert experience and knowledge, analyze the risk degree, and then, through software calculation and integration of expert opinions, understand the ranking of risks influencing the project, in order to provide objective decision data to managers.

LITERATURE REVIEW

Project Management

In an era of rapid scientific development, the popularization of networks and computers, the rapid development of multimedia, and increasingly developed information transfers, the global environment is rapidly changing, various industries are rapidly developing and expanding, and products and servers are sold to international markets. To meet different customer demands, there are more and more customized products, and at this time, corporate values and business models change correspondingly. In such a fiercely competitive environment, enterprises must face irregular and impermanent budget and time limitations, resulting in the traditional management modes of enterprises with fixed systems, organization, procedures, and resource capabilities, and thus, are unable to flexibly respond to issues. However, “project management” technology, with interdisciplinary integration, rapid change, and integration, has become an important contemporary management mode.

Project management is to apply knowledge, skills, tools, and techniques to project activities in order to reach the project requirements. The realization of project management requires 5 project management procedures: the application and integration of starting, planning, implementing, monitoring, and supervising. Project management conducts effective management by using technologies and tools aimed at performance, cost, time, and scope, which are 4 limitation factors, in order to reach the expected targets and results.

In a time of developing technology, project management in different industries becomes more and more complicated. Of the 9 knowledge fields of project management, scholars have recently focused on the field of project risk management. Project risk management has become an important factor to determine the success of project management [2], [3]. According to [2] project risk management in project management shall be specially considered, as a safety evaluation project is likely to bring more risks to the users than other projects [4]. According to the research developed by [2], good project risk management can help contractors avoid unnecessary losses, reduce costs, and increase profit [2].

There are many risks existing in the early stages of a project, and early decisions are important to the realization of project targets in follow-up stages. This paper focused on the early project stage for a simple application of an effective risk analysis method [2].

Project Risk Management

In 2000, project risk management was defined by the Project Management Institute as a process to systematically identify, analyze, and respond to a project. It includes the maximization of occurrence probabilities and the results of incidents with positive influence on project targets, and the minimization of the occurrence probability and results of incidents with negative influence on project targets.

Previous experts and scholars adopted different methods for the risk management of large projects. The commonly used risk identification methods include WBS-RBS, the Delphi method, the flow chart method, Expert Survey, and Fault Tree Analysis; while risk analysis methods include AHP, ANP, the Monte Carlo method, Expert survey, and the grading method with sensitivity analysis [5], [6].

Work Breakdown Structure (WBS)

WBS was first put forward by the United States Department of Defense, and is a tool for scope management. It is a kind of project breakdown technology for the purpose of management and control [7]. The core idea of WBS is to decompose a complicated and systematic work into relatively simple and measurable work packages. WBS groups project elements with delivery results as a guide, and is an important basis for the development of project scope, schedule planning, cost budget, risk management plans, purchase management, etc.; in addition to being an important basis for the control of project changes, in order to realize management and control over an entire project. WBS is a method in which a project is decomposed into sub-projects, as based on different levels, while a sub-project is decomposed into smaller work units that are easier to manage. WBS is a structural tree, and the tree organization determines the entire scope of a project [8].

Risk Breakdown Structure (RBS)

After it was mentioned and applied in Hillson's [9] documents, RBS has frequently been used in risk management processes, and is taken as the standard and index of risk management.

In WBS, project risk sources are considered in order that managers can comprehensively understand the exposure of project risks, and this breakdown structure is called RBS, which is based on WBS, and defined by the Project Management College as "grouping with a project risk source as a guide for the organization and definition of a project". Each lower level represents the source of the detailed risk identification of the upper level project.

Organizational Breakdown Structure (OBS)

OBS specifies the relationship of an organization or individual with project management, which is frequently used in combination with WBS to specify the work content and responsibility of each organization or individual.

In the project process, organization and labor play important roles, thus, appropriateness in work and responsibility allocation is often related to the success or failure of a project. OBS individually narrates the content that the organization implements through project tasks and work packages [10]. The basic planning process of a project is to determine who will be responsible for project works, record the information, convey the information to the project team, and record distributed labor work packages in OBS [11]. It defines roles and responsibilities, and is linked to WBS. OBS is used to define the project, cost declaration, settlement, budget, and project control responsibility [12].

Analytic Network Process (ANP)

ANP was put forward by Saaty [13]. This method is based on AHP, in which the mutual influences between each factor and neighboring layer are considered, and it is a method applicable to the dependent hierarchical structure, as it fulfills the complicated situation of mutual influence and mutual feedback between hierarchies and elements [14]. It was suggested by Saaty [13] that AHP should be adopted to solve the problems of both dependent and independent alternative solutions and standards [15]. ANP mainly includes two parts, (1) control layer and (2) network layer [15], which constitute a typical ANP hierarchical structure, as shown in Figure 1.

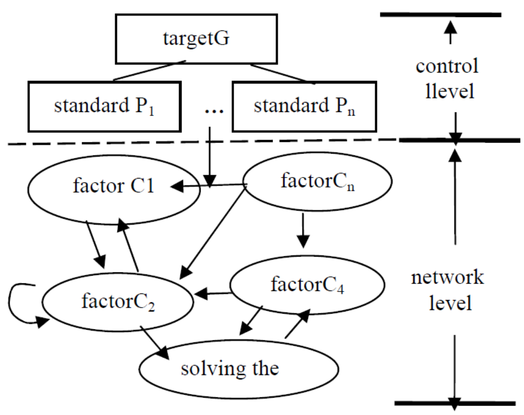


Fig. 1. ANP

RESEARCH METHOD

Research Structure, Method, and Process

Such research method is mainly divided into four parts, data collection and research, risk identification, risk measurement, and risk measurement and calculation. This research is divided into three stages in method and procedure, respectively, risk evaluation on the basis of RBS, risk evaluation on the basis of WBS-RBS, and risk evaluation on the basis of WBS-RBS-OBS, are shown, as follows:

Stage 1: Risk evaluation on the basis of RBS

(1) Establish RBS: The establishment of RBS for risks existing in a project mainly includes project risk, risk source, secondary risk source, and risk factor levels.

(2) Establish mutual relationship of risk factors: It is required to identify the risk factors of a project, and link the mutual relations between the risk factors.

(3) Design the ANP questionnaire based on RBS: The ANP questionnaire is designed on the basis of mutual relations between risk factors, with the content including the relative comparison of risk sources, the relative comparison of risk sources in a dependency

relationship, the relative comparison of the secondary risk sources under risk sources, the relative comparison of risk factors under secondary risk sources, etc.

(4) Calculate risk factor weight: Through the calculation of effective returned questionnaires using Super Decision software, the risk weight values will be determined.

(5) Select the key risk factors: Based on the risk weight values determined by the Super Decision software, the risk factors are ranked, and after elimination of negligible risk factors, the key risk factors are selected and used for the questionnaire design in the following stage.

Stage 2: Risk evaluation on the basis of WBS-RBS

(1) Establish WSB: The WBS of a project is established, which mainly includes project, tasks, work, and other layers.

(2) Establish WBS-RBS: It is required to establish the mutual relationship between the key risk factors selected in the first stage and the important work items.

(3) Design the ANP questionnaire based on WBS-RBS: The ANP questionnaire is designed based on the mutual relations between important work items and risk factors. The content can include a comparison of key risk sources in relative importance, a comparison of key risk sources under the existence of a dependency relationship, and a comparison of key risk sources in relative importance.

(4) Calculate the risk factor weights: With the Super Decision software, the effective returned questionnaires are subject to calculation of compared weight values of key risk sources.

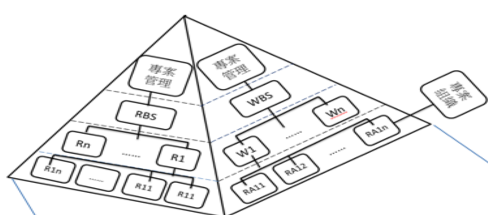
(5) Risk ranking and evaluation: The risks are ranked based on the calculated weights of key risk sources under important work, in order to identify and treat the priority of key risks.

Stage 3: Risk evaluation on the basis of WBS-RBS-OBS

Finally, OBS is added to WBS-RBS to form WBS-RBS-OBS, in order to understand the overall responsibility distribution and relationship between the risks of a project.

WBS-RBS-OBS Matrix in Risk Identification

In a project, especially in a large project, uncertain factors will be confronted, and risk occurrence will have social and economic influences that result in a project being unable to be completed as scheduled, or with the expected satisfactory quality. In the implementation of such projects, all participant personnel are the closest link in the entire process, thus, in the risk identification part hereof, the organization and individuals are listed in the factors of consideration. In previous research, the WBS-RBS method is combined with OBS to form the WBS-RBS-OBS model for project identification, which will not only identify the risk influence on works, but will also consider the appropriateness of individuals and organize the distribution of responsibility. The following is a pyramid model that represents the concept of WBS-RBS-OBS, as shown in Figure 2:



			RBS		
			R1	R2	R3
WBS-OBS	W1	O1	RA11R1	RA11R2	RA11R3
		O2	RA12R1	RA12R2	RA12R3
		O3	RA13R1	RA13R2	RA13R3
	W2	O1	RA21R1	RA21R2	RA21R3
		O2	RA22R1	RA22R2	RA22R3
		O3	RA23R1	RA23R2	RA23R3
	W3	O1	RA31R1	RA31R2	RA31R3
		O2	RA32R1	RA32R2	RA32R3
		O3	RA33R1	RA33R2	RA33R3

Fig. 2. WBS-RBS-OBS

In the pyramid, the right side is developed up to down with the two-dimensional shape of WBS, while the left side is developed up to down with the two-dimensional shape of RBS. At the bottom of each layer of the pyramid is the coupling matrix of WBS-RBS, from which the relationship between WBS and RBS can be clearly seen. In the lowest layer of WBS, OBS is combined to form WBS-OBS in order to understand the relationship between individuals and organization in work responsibility. Finally, RBS is combined to form the WBS-RBS-OBS model, in order to comprehensively understand the relationship of the influence of risk and responsibility distribution on the works of a project. In Figures 3-5, W is work, R is risk, O is organizational, RAxyRz: the interaction between responsibility distribution xy (work x, organizational y) and risk Z.

RESEARCH ANALYSIS AND RESULTS

This paper shows an empirical case aimed at WBS-RBS-OBC in the risk management of aircraft wing and belly manufacturing of a space corporation, in combination with ANP.

Key Risk Identification (RBS)

In the first stage, the entire project is developed through the RBS method to identify the risk factors, and then, through ANP, the weight values of risk factors are calculated in order to select important risks. The second stage is initiated, and ENS-RBS is developed.

Through a review of related literature regarding projects risks, and the previous project data, as provided by the case company, the project risk sources in the aerospace industry are sorted into four main risks, “internal risk”, “external risk”, “technical risk”, and “project management”, and then, the hierarchical relationship is established downwards to form the secondary risk source layer. The secondary risk sources of “internal risk” include “company organization” and “operation procedure”; “external risk” includes “customer”, “industry market”, “supplier”, “natural disaster”, and “environmental factors”; “technical risk” includes “demand”, “capability”, “application”, “quality”, and “new product”; and “project management” includes “goal achievement”, “demand evaluation”, “planning”, “supervision”, and “communication”.

The first stage of this research is mainly to select the key risk factors, and then, based on the evaluation model, to compare the importance of “internal risk”, “external risk”, “technical risk”, and “project management” through pairwise comparison, in order to obtain the effect weight of each risk rule on the project. The pairwise comparison results are as shown in Table 1:

TABLE 1
PAIRWISE COMPARISON MATRIX TABLE W_a OF EVALUATION CRITERIA

	Internal risk	External risk	Technical risk	Project management	Eigenvector
Internal risk	1	3	1/3	3	0.24761
External risk	1/3	1	1/3	1/3	0.07364
Technical risk	3	5	1	3	0.54949
Project management	1/3	3	1/5	1	0.12926

C.R.= 0.08242(C.R.≦0.1)

According to the eigenvector judgment in Table 5, “technical risk” is the most important, followed by “internal risk”, project management”, and “external risk”.

Next, aiming at the comparison of relative influence degrees under the independency relationship between evaluation criteria, consider the interdependence between criteria “internal risk”, “external risk”, “technical risk”, and “project management”, and through pairwise comparison, the interdependence weight values of criteria will be obtained. In this stage, “external risk” is taken as the example to analyze the interdependence between criteria, and the pairwise comparison results are as shown in Table 2:

TABLE 2
DEPENDENCY RELATIONSHIP UNDER “EXTERNAL RISK” CRITERION

	Internal risk	External risk	Technical risk	Project management
Internal risk	0.27452	0.34645	0.16667	0.27452
External risk	0.09151	0.14597	0.16667	0.15849
Technical risk	0.47548	0.41492	0.50000	0.47548
Project management	0.15849	0.09266	0.16667	0.09151

After completion of the pairwise comparison matrix, based on the eigenvectors and consistency indices (C.I.) of the obtained 4 risk sources, 17 secondary risks, and 62 risk factors, the consistency ratio (C.R.) value is calculated for verification.

The case herein shows that C.R. = 0.08242(C.R.≦0.1), indicating that the eigenvectors are authentic. In the second stage, the key WBS to identify secondary risk sources is combined with the important work of the influence degrees of the key secondary risk sources in the work.

In a project where the case company cooperates with a foreign space corporation to manufacture aircraft wing and belly using composites, the previous internal project participants meet to discuss and evaluate the important work items in the project, which has 5 more important work packages, “manufacturing specification”, “revenue estimate”, “manufacturing and processing”, “blueprint and labor planning”, and “work stop order extension disposal”.

According to the above rankings, the case company’s management personnel in the aerospace project hold that, under “blueprint and labor planning”, “operation flow”, “capability”, and “corporate organization” there are first three influencing risks; under “work stop order extension disposal”, “blueprint and labor planning”, “operation flow”, “capability”, and “corporate organization” there are three influencing risks; under “manufacturing and processing”, “operation flow”, “capability”, and “quality” there are three influencing risks; under “manufacturing specification”, “capability”, “quality”, and “operation flow” there are three influencing risks; and under “revenue estimate”, “corporate organization”, “capability” and “operation flow” there are three influencing risks.

Under the influence of risks, it is required to consider the key risks in the above project and give priority to the disposal of these key risks, in order to avoid unnecessary costs and disasters.

OBS

In the case research, WBS and OBS are combined to form the WBS-OBS matrix, and as WBS and OBS are both of the hierarchy structure, each layer of the WBS-OBS matrix clearly shows each work responsibility distribution and relationship, and after risk identification, the management unit can conduct their works.

The organizations involved in the responsibility of the case research include the “engineering department”, “production department”, “product quality control department”, “materials department”, and “special investigation group”.

At this time, the 5 key secondary risk factors selected in the first stage are combined with RAM to form the RAM-RBS matrix, which identifies the influential relations of the key risks on work responsibility distribution.

CONCLUSION AND SUGGESTIONS

This chapter is composed of two sections. In the first section, based on literature review and case research, the conclusions are summed and sorted; in the second section, corresponding suggestions are given regarding the research conclusions, and corresponding suggestions and directions are provided for follow-up studies.

The main purpose of this research is to help managers and decision makers effectively make decisions and control risk expansion and occurrence in complicated projects in an era of technical development, in order to successfully complete the project.

In the early planning stage of a project, the “scheme decision making” process will be encountered, and in order to select a scheme suitable to the operation of such a project, it is required to carefully consider the evaluation of many levels and the occurrence of uncertain factors. To comprehensively understand the project situation, in this research, through a combination of WBS, RBS, and OBS, and based on the hierarchy structure, the work structure, responsibility distribution, and risk status are clearly identified. Moreover, it determines how to select the key evaluation criteria from numerous influencing factors, determines the interdependence and feedback relationship between risk evaluation criteria, work items, and responsibility distribution, which can cause dilemmas in decision making, and tests corporate management’s experience and judgment. However, individuals on the same team may have different opinions on the identification of the same issues. At this time, it is important to have a set of systematic decision analysis methods to help achieve project targets. Therefore, from the initial establishment of the research background and motivations to the obtainment of final results, this research has the following contributions:

1. This research presents a set of modularized risk management methods to help management personnel systematically conduct risk analysis and make effective decisions, and this method can be applied in different projects.
2. Through the WBS-RBS method, the hierarchy structure of a project, as well as influential relationships of the key risks between different levels, can be understood, and then, in combination with OBS, gain comprehensive understanding of the responsibility distribution of each work item and clearly know which organization shall be responsible for risk avoidance and treatment.
3. In a complicated project, after project identification and comprehensive understanding of the project situation, establish project objectives through the ANP method to obtain the interaction relationship of factors, and then, through the Super Decision calculations of different expert data, systematically provide objective decision data, thus, helping decision makers to know which risks shall be treated first, in order to effectively make decisions.
4. The analysis method used herein calculates risk degrees through risk quantization; therefore, it can be used to evaluate the risk factors of a single project, as well as to determine risk evaluation and comparison between different items of the same project, to provide reference for decision makers to select alternative schemes or realize risk priority ranking.

5. The "risk priority number", as obtained through quantization after ranking, can be taken as the basis of reference for cost control of limited resources for priority input, and the risk value obtained through the above calculation process is the expected value of the risk occurrence rate in combination with loss estimates.
6. In the case research, the 5 important items in the project are "blueprint and labor planning", "work stop order extension disposal", "manufacturing and processing", "manufacturing specification", and "revenue estimate", and according to the ranking of key secondary risk sources under these 5 items, "operation flow" and "capability" are the risk sources that require attention, and they shall be considered and avoided in the early stage of planning.

Suggestions

Organizational responsibility of risk management methods, which was seldom considered in previous studies, is added in this research; however, there are many areas that require improvement. The following shows suggestions and directions for future studies.

1. Regarding the research case, no specific details are discussed on the combination of organization and work items, or their weights, thus, future studies can address this issue in order to understand the influence of organizational responsibility distribution of work.
2. Risks are dynamic, and their influence will show different states within the time axis. This research statically discussed risk status, and time dynamics can be added to the discussion in future studies.

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