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Risk Identification and Management in EPC Project: A Comprehensive Review and Recommendation

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Author's contribution

The sole author designed, analysed, inteprted and prepared the manuscript.

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Review Article

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ABSTRACT

At present, the competition to participate in international projects through the EPC general contracting mode is becoming more and more fierce. Accurate identification and objective classification of risk factors in EPC projects are the prerequisites to ensure the success of the project. In order to improve the research level of China's EPC project risk management, based on the relevant journal literature and expert interviews on the risk management of EPC general contracting projects, the existing research results are summarized and analyzed. The main content includes, introducing the EPC risk management system and process, explaining the scope of the main risk management research, summarizing and commenting on the identification and classification of risks, analysis and evaluation methods, and coping strategies, etc., and finally focusing on EPC based on the existing research results. Project Risk Management made recommendations.

Keywords: EPC project; risk assessment; risk factors; strategy.

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1. INTRODUCTION

1.1 Overview of EPC Project Risk Management

EPC mode is a contracting mode that combines design, procurement and construction, and integrates the general contracting of the project.EPC project general contracting is conducive to the coordination and cooperation of design, procurement and construction, control and reduce the total cost [1], it has gradually become the current mainstream general contracting mode [2]. Under the guidance of the "One Belt and One Road", "going global" strategy and "economic globalization" development process, Chinese EPC enterprises have responded to national policies, actively participated in international projects, and conducted in-depth study on the risk management of EPC projects. Risk management is a management method adopted by the project manager to deal with the risks that may be encountered in the project. The specific approach is to develop targeted plans for the potential adverse factors in a certain stage or the whole stage of the project through risk identification and research, risk assessment and evaluation, so as to achieve the purpose of consuming the lowest cost, bearing the least risk and completing the project. Risk management is really a process of assessment and control, as shown in Fig. 1. Among them, risk research and analysis is the basis of risk assessment, the content of risk research includes: risk identification, definition and screening.

In the construction process, the project will be affected by internal factors and external environment, so there is uncertainty and instability in the construction process. Risk factors will change with the change of time, construction technology and process. So project management is a dynamic process. All elements in the risk management system are interrelated and influence each other, and its dynamic management flow chart is shown in Fig. 2.

1.2 Research Status of EPC Project Risk Management

So far, China has contracted international projects covering more than 200 countries and regions. As Fig. 3 shows, the value of new contracts signed in 2017 increased by more than $100 billion from 2012 to $265.276 billion. In 2021, under the impact of the COVID-19 epidemic, the business volume of foreign contractors increased by 1.2% compared with 2020.The turnover of Chinese enterprises contracted to foreign countries is mainly distributed in Asian countries, and cooperation projects with Asian countries are the main source of income. As shown in Fig. 4, from 2012 to 2020, the income contribution rate of Asia gradually increased from 46.6% to 57.2%, becoming the business source of more than half of China's foreign contracting enterprises [3].

While EPC projects bring huge profits to the general contractor, they are also accompanied by huge risks and hidden dangers, which are determined by the characteristics of EPC projects such as large engineering quantity, long project cycle and large investment scale [4]. Therefore, the general contractor needs to systematically identify risks, digitize and visualize risk factors, as an important basis for correct risk analysis and scientific risk response, so as to minimize risks.

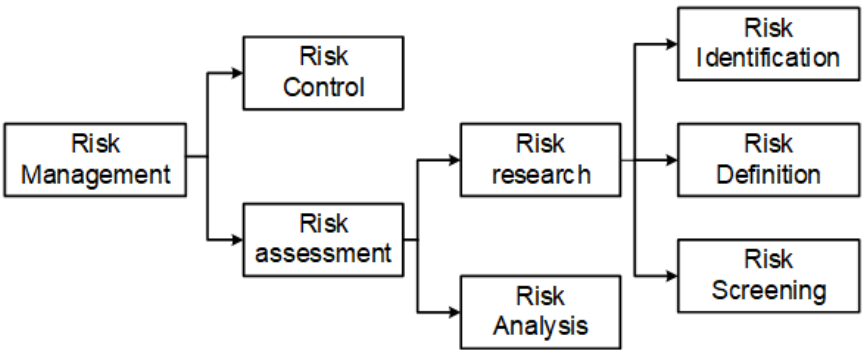

Fig. 1. Risk management system

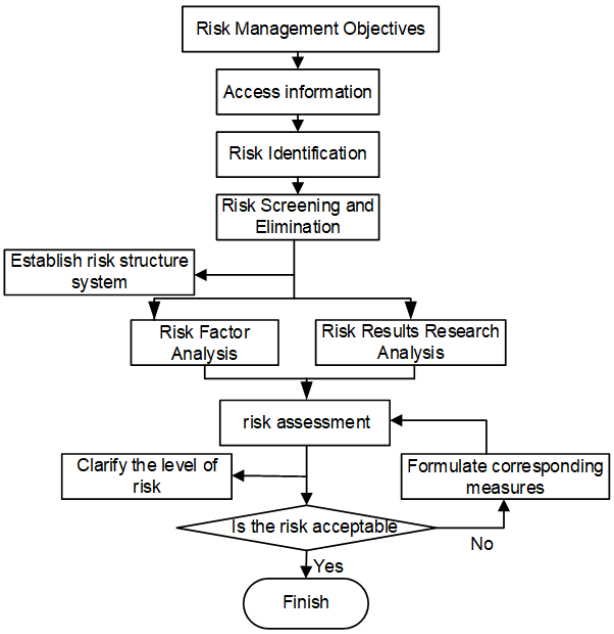

Fig. 2. Dynamic management flow chart

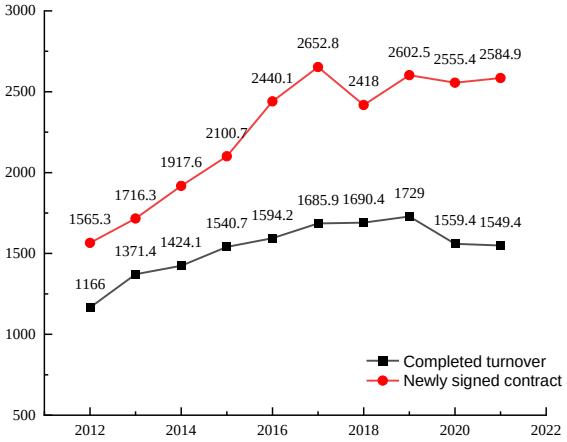

Fig. 3. 2012-2021 China's foreign contracted project scale (100 million U.S. dollars)

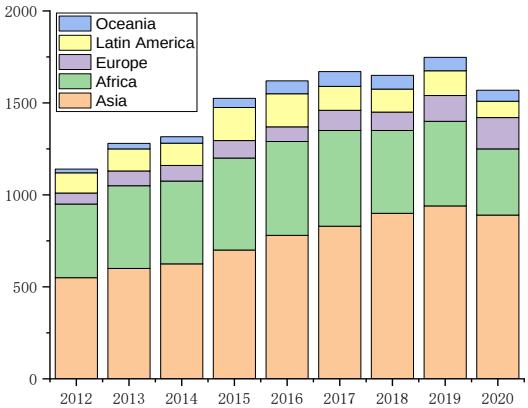

Fig. 4. Distribution of turnover by continent from 2012 to 2020 (US$100 million)

With the development of the market, EPC general contracting is led by construction enterprises, forming advantageous cooperation in all links of the construction industry and sustainable development mode of construction enterprises.EPC mode is an emerging management mode developed by combining experience and practice [5,6]. Many scholars have carried out in-depth studies. Relevant studies mainly focus on three aspects: First, the traditional mode is compared with the EPC mode. For example, Tsering Dondrup et al. [7] compare the EPC general contracting mode with the traditional mode in terms of application scope, bidding method, risk sharing project management, etc., and summarize and analyze the main characteristics and differences between the EPC mode and the traditional mode. The second is to study the risk assessment and response management of EPC actual project cases. For example, Liu Lijun [8] established a risk index system from five aspects including environment, cost, schedule, management and technology by identifying risk factors, and established a scientific and reasonable risk assessment and control model for risk assessment and analysis. YangS [9] summarized various risks of thermal power projects, established a Bayesian theory risk model suitable for wind power plants, and proposed targeted countermeasures by analyzing the risk model. The third is the application research of risk assessment using innovative methods and combining multiple theories. Xing BI et al. [10] believe that AHP can not reflect the consistency of human way of thinking, which may lead to inaccurate results. Therefore, a risk assessment model is established based on Fuzzy-AHP theory to make risk assessment and strategic decision-making of EPC contractors more accurate. Yang Baochen et al. [11] designed a diversified evaluation index system, built a comprehensive integrated risk management system for EPC projects in combination with dynamic risk management module, and then constructed a qualitative and quantitative integrated risk assessment method by combining Delphi method, fuzzy comprehensive evaluation model, F-AHP and risk matrix analysis in accordance with the reasonable and feasible principle. Design EPC project integrated risk management process. Yang Jianping et al. [12] analyzed and summarized relevant research experience from five aspects of the whole process management information system: integrated management, multi-factor, multi-participant, multi-satisfactory project objectives and integration, etc., combined with similar cases of integrated management of domestic and foreign engineering projects, and built an integrated management model based on project management theories and integrated management theories.

It can be seen that domestic scholars often study the past case projects, choose the risk management system in line with the actual situation of the project, or study the EPC model, or study the risk assessment and response strategy; Or study the evaluation of risk. In the study of risk management system, in addition to the traditional method or literature research method, a variety of methods are combined to further improve the reliability of data and the accuracy of analysis results.

2. RISK IDENTIFICATION STUDY

2.1 Risk Classification Principle

For risk identification, risk factors should be classified according to the nature and characteristics of the research subject. At present, there are mainly the following classification principles [5]:

(1) The classification of risks should be objective, and the classified risk factors should be neither leaked nor serious. It can be classified according to the level of risk influence, such as target layer, criterion layer and indicator layer, to cover all possible risk factors and ensure the integrity of the system.
(2) The classification of risks is reasonable and must conform to the thinking logic process and management process of risk analysis. The classification of risk is narrowed from generous to small, such as from the country to the market, to the project; In this way, risk influencing factors are not easy to be omitted, and it is conducive to the management and implementation of risk response measures.
(3) Risk classification should be conducive to the risk analysis of the project. At the project level, risk analysis is carried out from different perspectives of the general contractor, the owner and other participants, and the risk systems and risk factor weights established are different. Therefore, the subject-object perspectives should be clearly defined, so as to establish a risk system specifically, obtain more accurate risk factor weights, and take correct preventive measures.

2.2 Sources and Types of Risk Identification

The first stage of risk management is risk identification, which is the foundation of the whole risk management system and a very important step in project management. Risk identification mainly comes from two aspects: first, through learning and referring to classic engineering cases, accumulate experience and analyze the possible time and adverse consequences of risks; Than. according to the environmental conditions and national policy requirements of the project, the project should be combined with its own characteristics to accurately identify risks.

Risk identification requires extensive and in-depth investigation and research, which requires project managers to have certain experience knowledge and judgment ability, and be familiar with scientific methods of risk identification. Common risk identification methods include:

2.2.1 Expert investigation method

The project risk manager can widely consult the relevant technical and management personnel of the project for their views on the project risk, and the "brainstorming method" can be adopted when inquiring. The project risk manager can list the risk factors that may be encountered in the project from different professional perspectives, different understanding levels and different perspectives. Finally, the project manager will screen and summarize the expert views. The advantage of expert investigation is that it can give full play to the collective wisdom, and the risk identification is more comprehensive. Since the opinions of most experts are concentrated, the conclusions are more authoritative and persuasive. This is an intuitive prediction and identification method that uses the creative thinking of experts to obtain future information. During risk identification, the risk list can be designed into a questionnaire, which is sent to experts, scholars or experienced project technicians and managers. After recovery, the correct risk factors can be selected according to the given weight through statistical classification [13].

2.2.2 Check list method

The checklist method establishes a detailed risk management system according to the previous experience of oneself or others in completing the project, makes a risk list by counting the project risks and sources, and then compares the actual situation in the project with the risk list to identify the risks. The checklist needs to include the risks of the entire process as fully as possible [14].The advantage of this method is that the potential risks of the project are listed on the table, which is convenient to identify and check, and easy to analyze the risk and its influence degree.

2.2.3 Project work breakdown structure method

Project decomposition is to decompose the total project project layer by layer, clarify the composition of the project, the relationship between the project and the environment, decompose the project into work units, and define the tasks of each work unit. Use the project work breakdown structure throughout the project management process. This method has more comprehensive risk identification and less risk omission.

2.2.4 Accident tree analysis

The method of accident tree analysis is suitable for projects with complex construction and strong technical requirements. It consists of nodes and lines, where nodes represent events in the project and lines represent relations between adjacent events. This method starts from the results, calculates the risk factors at all levels according to the relationship between each event, calculates the probability of risk accidents based on advanced evaluation methods, and makes a variety of emergency plans to control the risk factors. Its logic is strong, and the analysis results are systematic and accurate.

Duan Yonghui [15] adopted the key word retrieval method of CNKI database in accordance with scientific and objective principles, selected the risk factors of EPC projects to make questionnaires, and tested the literature correlation degree by using expert questionnaire and CiteSpaceV software, thus achieving the optimization of risk indicators.SPSS24.0 software was used to test the reliability and validity of the survey data to verify whether the questionnaire data met the requirements of factor analysis. Finally, the project level risk is summarized and classified. Chen Zhiding [16] et al. studied the construction risk assessment method of small and medium-sized hydropower projects, identified the construction risks of general

contractors according to the risk management theory, drew the causality diagram of project construction risks, and based on the causality diagram of project construction risks, adopted the theory of information entropy to eliminate the indicators that contributed little to the system, and built the hierarchical structure system of project risks.

In EPC projects, risks can be identified not only through mathematical methods, but also through relevant standards, expert experience or existing historical data. Guo Jiaxing [17] adopted the bid evaluation method of hydraulic engineering construction supervision, screened scientific risk indicators and applied them to actual projects for risk analysis and achieved good results. Xie Ying [18] collected literature and periodical data, comprehensively considered the constraints of project construction characteristics, and divided the target risk dimension of Daling River course renovation project into four categories: social, rational utilization of natural resources, economy and environment, and further divided it into 12 factor dimension risks in detail. Xu Guo [19] collected literature and materials through literature review, preliminarily identified project risks, and then screened key project risks through expert questionnaire survey, and concluded that the first-level risk of the project was cost risk, duration risk and quality risk.

To sum up, it can be seen that in EPC projects, the expert survey method and project work breakdown structure are mostly used. However, due to the large influence of subjective factors on evaluation results, various methods are often combined in the project to reduce the influence of subjective factors and strive to reach accurate conclusions.

3. RISK ASSESSMENT STUDY

After risk identification and preliminary classification, it is necessary to calculate the probability of occurrence of a certain risk. The calculated risk object is the individual risk of the project rather than the overall risk of the project [20].The methods of risk analysis include qualitative analysis, quantitative analysis, and the combination of qualitative and quantitative analysis. The most widely used methods in quantitative risk research include analytic hierarchy process, cluster analysis, grey system theory, fuzzy comprehensive evaluation method, MonteCarlo method, etc.

3.1 Qualitative Risk Assessment

Zhang Xuejia [21] used risk analysis methods such as brainstorming and interview to calculate the occurrence probability and influence degree of project risk factors, and substituted the results into the risk factor analysis matrix to divide each risk level. Li Kang [22] evaluated the identified risk factors with expert evaluation method and classified the levels of risk factors. Zhu Yumin [23] adopted qualitative work decomposition structure to identify risk factors, and then established WBs-RBS matrix to identify multi-level risk factors, which can provide reference for risk assessment and countermeasures.

3.2 Quantitative Risk Assessment

He Yongxiu [24] took urban power grid as an example and adopted fuzzy theory for risk recognition evaluation on the basis of identifying project risks.Hu Miao [25] calculated the probability of risk factors, combined with the quotation risk model of MonteCarlo constructed, simulated the random risk factors in the bidding price into random variables, and obtained a reasonable quotation. Xu Guo [19] took the Rania oilfield project in Chad as a case study of EPC project and studied the risk assessment of the project by using system dynamics method, proving that system dynamics is more applicable than traditional methods in the risk study of such projects.

3.3 A Combination of Qualitative and Quantitative Risk Assessment

Yin Yilin et al. [26] divided the whole life cycle of the project into four stages, established the organizational framework model of integrated risk management, and analyzed and studied the large construction projects with the whole life cycle combined with the E-PMC model. Gao Rui [27] used chromatography analysis and grey theory to build AHP-GM evaluation model to predict the risk level of construction cost. Based on the evaluation index of EPC projects, Hou Jianying [28] constructed a relatively complete evaluation index system and used fuzzy analytic hierarchy process (AHP) for comprehensive evaluation. Jin Haifeng [29] established a risk index system for the bidding decision of EPC general contract projects, and conducted a grade evaluation of the risk index on this basis. Liu Zheyi [30] drew a causal loop diagram (Fig. 5) from the process of schedule management with the help of Vensim platform, reflecting the

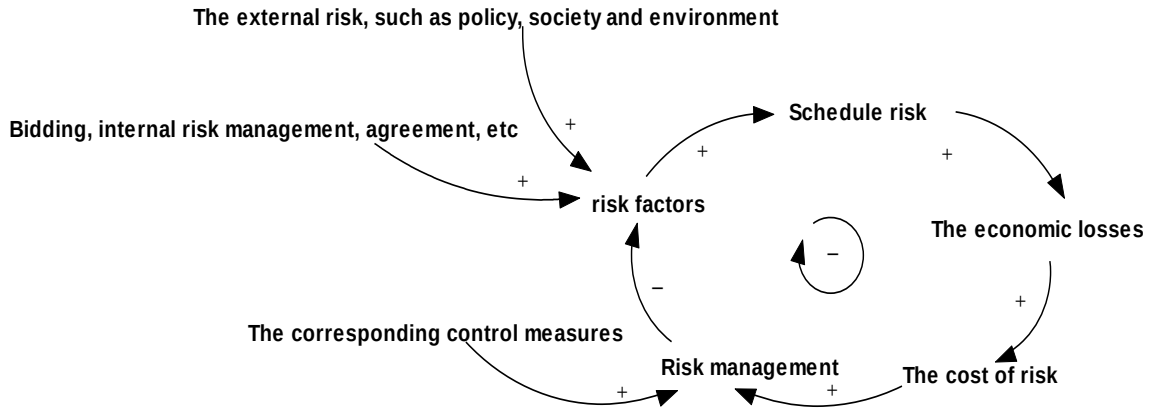

Fig. 5. The causal loop diagram of the schedule management process

relationship between schedule risk factors and risk management. The loop presented negative feedback, indicating that schedule management could effectively deal with risk factors and avoid the delay of construction period and the increase of cost.

It can be seen that scholars adopt different methods to assess risks at different stages of a project, and most of them use a combination of qualitative and quantitative methods.

4. RESEARCH ON RISK COPING STRATEGIES

After the qualitative and quantitative analysis of the risks of EPC projects, risks can be dealt with from the nature of risk factors, probability of risk occurrence, risk consequences and other three aspects combined with the characteristics of EPC projects. According to the evaluation results, formulate a variety of risk treatment methods and control strategies, and reduce the loss caused by risks, in order to improve the possibility of achieving the project objectives.

4.1 For Different Stages of Risk

Hao Baoquan [31] analyzed the financial items of overseas EPC projects and dealt with the risks from three aspects: bidding, implementation and settlement. Dong Yuliang [32] analyzed the importance of power plant equipment and made risk strategies from the three aspects of equipment importance, controllability and maintainability. Wang Sen [33] took Nigerian railway EPC project as the research object, and studied the coping strategies of tax risk from the bidding stage, contract negotiation and signing stage, contract execution stage and project completion settlement stage respectively. Jin Weifeng [34] quantified and modeled the risks in the project, divided EPC project risks into different stages according to the characteristics of project operation process and project life cycle, and discussed the countermeasures that could be taken at different stages.

4.2 Different Coping Strategies for Project Risks

Sun Limian [35] took investment in an international project as an example and proposed risk coping strategies based on four risk handling methods: avoidance, control, transfer and retention. Zhang Baojun [36] et al. took an international EPC project as an example and elaborated its coping strategies from four aspects: risk avoidance, risk transfer and hedging, risk control and mitigation, and risk liability undertaking.

4.3 Strategies for Different Types of Risk

According to the risk management theory, Chen Zhiding [37] et al. identified that the construction risks of hydropower projects mainly include self, environment, contract and other risks, eliminated redundant indicators according to the construction risk factor diagram, constructed the project risk hierarchy system, and made corresponding countermeasures accordingly.

To sum up, different projects have different strategies to deal with risks, even if the same project has different measures to deal with risks at different stages. Therefore, before the project starts, it is particularly important to do a good job of risk investigation and choose appropriate risk coping strategies.

5. CONCLUSION

EPC projects have the characteristics of large engineering volume and long construction cycle, and are susceptible to the influence of various factors in the construction process, with greater risks. This requires construction enterprises to continuously improve their management ability, production technology and capital strength, improve project operation efficiency, reduce costs, and do a good job in risk coping strategies.

The research on project risk and the strengthening of project risk management can promote the high level of project management, guarantee the project quality and investment benefit, and promote the standardized development of construction market order. At the same time, it can increase the advantages of the company, and accelerate the integration of international engineering contracts and management methods, contributing to the country's capital construction and the development of the national economy.

The existing risk management research of EPC projects mainly includes the establishment of risk management system, risk identification, risk assessment and risk response strategy research. In EPC project risk management, various methods can be combined to reduce the influence of subjective factors, combine qualitative and quantitative methods, improve the accuracy of analysis results, and provide appropriate risk coping strategies for different stages of the project to ensure the smooth progress of the project.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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