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Analysis on Engineering Risk Identification and Response Paths of Overseas EPC Projects Based on System Dynamics

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Abstract

The EPC general contracting mode is the most used operation mode in overseas engineering projects. However, there are more risk factors in overseas EPC projects due to differences in national conditions, environments, and cultures. In EPC engineering projects, especially overseas EPC engineering projects, the risk factors have complex causal relevance, and it is necessary to use overall concepts and systematic thinking to study them. However, research methods of traditional risk management lack overall concepts, causal analysis, and systematic thinking. Therefore, this paper introduces the method of system dynamics to construct the risk identification model of overseas EPC engineering projects based on preliminary identification of the risk factors of overseas EPC engineering projects through the literature analysis method. At the same time, this paper also gives five measures to avoid risks. The research results of this paper can help project managers better understand the causal relationship of various risk factors in overseas EPC projects to formulate more effective risk management strategies.

Keywords

Engineering risk identification; Overseas EPC projects; System dynamics.

1. Introduction

The general contracting mode of engineering procurement construction (EPC) is the most widely used operation mode in large-scale engineering projects such as overseas engineering projects. It has been widely applied and is becoming more specialized and globalized (Liang Ma et al., 2019). However, there are often various risk factors in overseas EPC projects due to the differences in national conditions, environment, and culture of various countries. Also, overseas EPC projects have the characteristics of multiple subjects (Guo Xu, 2019). Therefore, the project's actual implementation often involves multiply related and various uncertain factors inside and outside the project. Once individual uncertain factors change, The overall project may be significantly affected (Rongjun Lei, 2004). In order to accurately identify, evaluate and control risks and study the risk transmission process and action mode during the implementation of engineering management of overseas EPC projects, practical tools and methods should be used to identify and evaluate risks and take effective decision-making measures to deal with risks. Hence, this paper studies the risk identification of overseas EPC projects using system dynamics and puts forward the corresponding improvement path.

2. Research Review

In recent years, domestic and foreign scholars have done a variety of research on EPC project risk management, and they have used a variety of research methods in the research process. In terms of risk identification, taking China Railway Saudi Mecca light rail project as a research case, Pengcheng Xiang and Zhenzhen Wan (2011) deeply analyzed the risks faced by the project in different stages and put forward risk management countermeasures. Also, Ameyaw e et al. (2013), combined with relevant literature and multiple cases of Ghana's water supply

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department, comprehensively identified eight categories of 40 risk factors according to risk sources. In terms of risk assessment, Chen w K et al. (2013) established an extended element model based on EPC contract risk assessment indicators, extended analysis, and related functions to assess EPC contract risk. Besides, Qiyun Liao et al. (2013) comprehensively used ANP Method and grey clustering method to evaluate the risk of an international railway EPC project and verified the applicability of this method with practical cases. In terms of risk response measures, Wang Y B et al. (2012) built the engineering risk management information system (ERMIS) based on the international EPC cement project, collected and processed risks based on the risk database through the expert system integrated evaluation software. They carried out dynamic data collection and project control. Meanwhile, Kim h et al. (2019) established a project completion level index system, which can be used by EPC contractors to continuously predict construction costs and arrange a performance to ensure the adequacy of project resources and make a trade-off between resources investment and reducing cost/schedule risk. Yin ZG et al.(2014) also took the metallurgical project as the research object, described the method and process of cost risk identification in detail through case study and expert investigation, and finally formed the risk breakdown structure table. However, the risk factors of EPC projects, especially overseas EPC projects, have complex causal correlation, which needs to be studied by using the overall concept and systematic thinking. However, the traditional research methods of risk management lack concept, causal analysis, and systematic thinking.

System dynamics refers to the theory of studying the system's overall behavior by analyzing the feedback structure relationship between various variables within the system (Pingping Rao et al., 2020). Professor Forrester first put forward this theory of the Massachusetts Institute of technology in the United States. It is mainly used to solve the problems of contradiction and correlation of factors in the system, time delay of feedback structure, both quantitative and qualitative problems, and early used to solve economic problems such as production and inventory, namely, the impact of change on steady-state under equilibrium conditions (Jay W.Forrester, 1987).

In addition, System dynamics can start with the nature and logical structure of each part of the system, study the complex causal logical relationship in the system, and represent the changes of the internal structure of the system by using a causal relationship diagram and system flow diagram (Guangqing xu and Gi Xu, 2016), to find feasible strategies to solve problems and deal with problems. Also, the modeling process of system dynamics can realize the combination of opinions between managers and expert groups. The natural process of engineering management can also be simulated using the theory and method of system dynamics. Therefore, system dynamics is suitable for the risk management research of overseas EPC projects and can be used as a supplement to the traditional risk management research methods to a certain extent.

3. Risk Identification of Overseas EPC Projects

The risk sources of overseas EPC projects are diverse. Sorting out the risk sources of overseas EPC projects in advance can create conditions for subsequent project risk management, take positive and effective countermeasures, reduce the probability of risk occurrence and reduce the loss caused to the project. Because overseas EPC projects generally have the characteristics of a long construction cycle, significant investment, high technical standards, and relatively high risk, the risks caused by many uncertain and random factors cannot be accurately predicted during the implementation of the project. This paper uses the method of literary analysis to screen out the risk factors of overseas EPC projects. In detail, the principal risks of overseas EPC

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projects mainly include natural environment risk, political and economic risk, procurement management risk, design management risk, and organizational risk.

3.1. Natural Environment Risk

Natural environmental risks include natural disasters, climatic environment and geographical conditions of the project site, and ecological environment protection requirements of the host country (Baojun Zhang and Yuchen Meng,2020). Natural disasters are uncontrollable risks because of their sudden and catastrophic nature. Although the climate environment and geographical conditions cannot be changed artificially, they can be avoided, and countermeasures can be designed through preliminary exploration, attributed to semi controllable risks. However, for the requirements of eco-environmental protection in the host country, the risk is subjective and manageable to a certain extent. It is mainly affected by human subjective factors and belongs to controllable natural environmental risk.

3.2. Political and Economic Risks

Political and economic risks are usually manifested in the aspects of system, politics, economic environment, and security. Among them, institutional risks mainly involve implementing and supervising government power and legal system, the transparency and stability of policy implementation, bureaucratic and corruption control, and the treatment of nepotism among interest groups (Baojun Zhang and Yuchen Meng,2020). Political environment risks include war, civil strife, changes in policies and regulations, corruption of power departments in the country where the project is located (Xiao Nan,2019).

For example, turbulence and war have occurred in some regions and countries in South Asia and the Middle East. Some owners may take advantage of the alternation of political power or their own identity to forcibly stipulate that all risks shall be borne by the contractor, which may lead to the failure of the project or the stagnation of huge risks, or even the termination of the project contract, and the contractor's massive investment in the early stage cannot be compensated (Yanbin Qin, 2021). Economic and environmental risks include exchange rate fluctuation, inflation, economic recession, and other economic risks. Generally, according to FIDIC terms, the owner will usually pay all the international currency (USD), or part of the international currency and part of the local currency as the project payment. The EPC contract signed by the contractor is usually a fixed total price contract, resulting in that the profit and loss of the project being very sensitive to the fluctuation of the spot exchange market exchange rate of the payment currency. Security risks mainly refer to violent activities such as war, civil strife, terrorist activities, riots, and conflicts, which are sudden, inflammatory, difficult to control and highly destructive, and are likely to endanger the safety of project personnel and equipment (Songtao Li et al.,2011)

3.3. Procurement Management Risk

Under the EPC model, procurement management risks mainly include logistics delay, customs seizure, and incomplete or unqualified materials. Since the procurement of materials or equipment is usually not completed in a short time, it takes time from material ordering, manufacturing, goods transportation, customs clearance, and delivery. If there is no plan and sufficient buffer time is reserved, the construction schedule of the project will be affected due to the untimely supply of materials (Songtao Li et al.,2011&Nan Geng, 2017).

3.4. Design Management Risk

Generally, the risks of design management mainly include design errors, design quality defects, changes proposed by the owner, and unclear design standards and specifications (Yanbin Qin, 2021). EPC projects are relatively complex in most cases, including a variety of construction technologies and special schemes, which require the cooperation of various departments of the

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design unit. In the preliminary design stage, there may be design omissions due to inadequate understanding, design defects due to complex technical processes, or large-scale design changes due to failure to combine with the actual project implementation conditions. If not exposed in the design stage, it will lead to severe rework and affect the construction progress (Zhi Xiong, 2014).

3.5. Organizational Risk

Organizational risks mainly include the decline of managers' quality, quality supervision level, and fatigue (Guo Xu, 2019). A significant source of organizational risk is the contradiction among the three elements of project scope, time, and cost determined in project decision-making. The relationship of the three elements is interdependent and mutually restrictive. Unreasonable matching will inevitably lead to difficulties in project implementation, resulting in risks. The organization mode of the project management team and the quality requirements for members are also different from the traditional construction enterprise organization team. Companies engaged in engineering projects generally adopt a strong matrix organizational structure. According to the contents of the project contract, relevant personnel is transferred from all company departments to form a project management group, which operates in the mode of the working group, and the project manager is fully responsible for the activities of the working group. At the same time, the management departments of the company exercise the functions of leadership, supervision, guidance, and control over the work of the working group according to the legal rights of the company to ensure that the activities of the working group are in line with the interests of the company, the owner and the society. Therefore, the construction of the project organization plays a significant role in the smooth progress of the project. The organization's team spirit and cultural atmosphere will lead to some risks, such as the lack of teamwork and improper personnel incentive, resulting in internal disunity and personnel turnover. This is because the whole project is inseparable from the operation of personnel. If the quality (ability, efficiency, sense of responsibility, and morality) of the owner's personnel, designers, supervisors, general workers, technicians, and managers are not high, it will bring significant risks.

4. Construction of System Dynamics Model for Risk Identification of Overseas EPC Projects

4.1. Applicability Analysis

The system dynamics model focuses on the detailed analysis and research of system structure, relationship, and feedback mechanism and has apparent advantages in studying the relationship between structure and system. Existing studies believe that compared with traditional quantitative research methods, the SD model, as a structure-dependent model, is suitable for simulating complex, large-scale systems. It can analyze the structural relationship of the system and clarify the relationship between internal and external factors of the system through causality and flow diagrams. It can also carry out dynamic simulation experiments on the system, investigate the behavior and change trend of the system under different states through the input of different parameters and control factors, make the decision-makers clear the control parameters and sensitive parameters of the system, and provide judgment basis for the decision-makers.

The above characteristics of the system dynamics model are consistent with the research needs of risk identification of overseas EPC projects. On the one hand, the overseas EPC project is a complex, large-scale system, including three subsystems of cost, construction period and quality. It just needs an SD model, a research tool suitable for complex, large-scale system analysis. On the other hand, the detailed analysis of system relationship and structure is to

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study the risk of overseas EPC projects deeply, and the SD model based on the analysis framework of structure and feedback loop can provide an effective method for this research and analysis.

4.2. Establish System Dynamics Risk Identification Model

The researcher inputs the risk factors in the preliminary risk identification list and the logical relationship between factors into Vensim software as the input condition of the risk identification model of the project. The risk identification model is shown in Figure 1. Specifically, each risk factor is represented by a box, and the name of the risk factor is marked inside. In addition, the logical relationship is represented by an arrow, the risk factor pointed by the arrow is an independent variable, and the back-to-back risk factor is a dependent variable. "+" on the arrow indicates that the two risk factors are positively correlated, "-" indicates that the two risk factors are negatively correlated. The risk factors in "< >" refer to the cited factors to make the logical relationship in the model diagram intuitive and straightforward. Three risk factor subsystems can be constructed with the three objective dimensions of cost, construction period, and quality as the core for the secondary repeated risk factors.

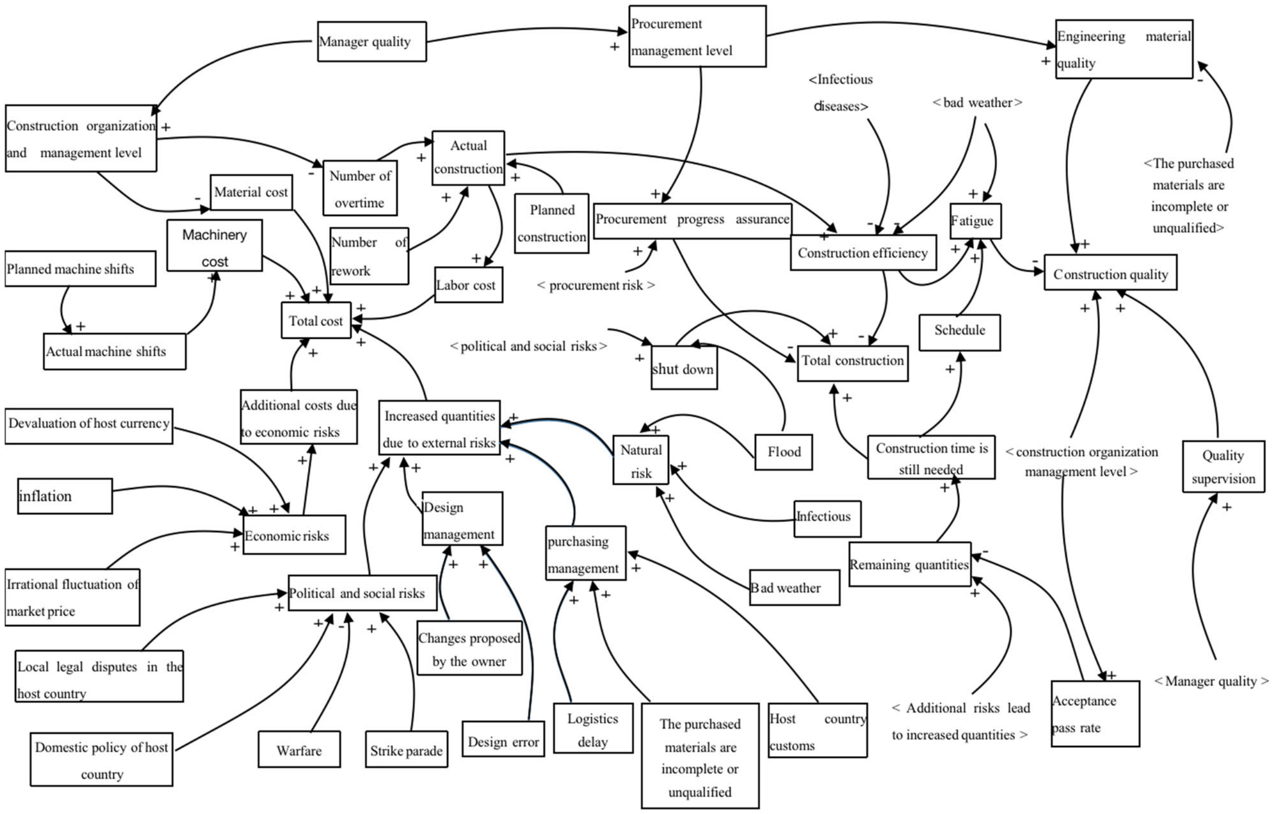

Figure 1. Risk identification model of overseas EPC project

4.3. Risk Factor Identification

After the risk identification model is established, each risk can be identified in the model. Selecting any risk in the Vensim model for "cause tree analysis" or "result tree analysis" can analyze the root factors of the risk, as well as the risks affected by the risk and possible consequences.

4.4. Risk Cause Identification

Taking "cost risk" as an example, the causes of cost risk are identified based on the risk identification model. The reason tree of "cost risk" can be obtained by analyzing the reason tree

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of "cost risk" in the model, as shown in Figure 2, which can be traced back to the root causes of cost risk with transparent layers and then targeted monitoring of the root causes.

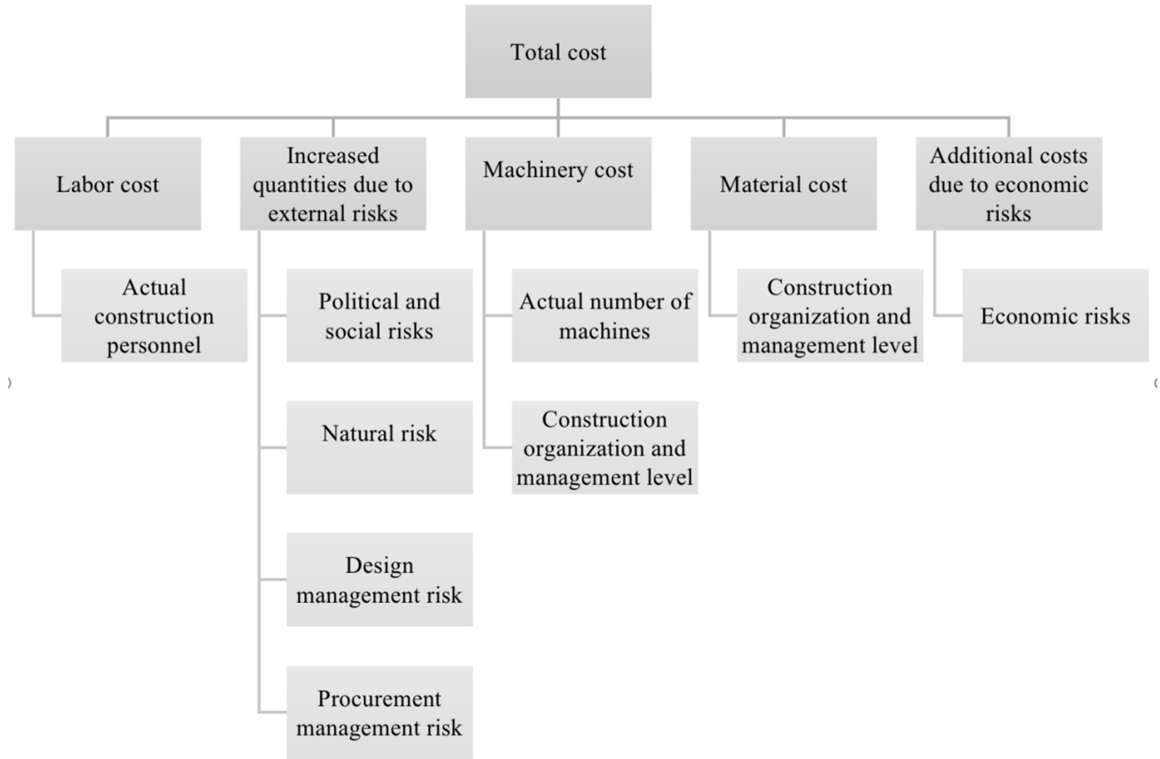

Figure 2. Total Cost Risk Cause Tree

4.5. Risk Consequence Identification

Taking "manager quality" as an example, the possible consequences of the risk of manager quality are identified based on the risk identification model. The result tree analysis obtains the result tree of "manager quality" as shown in Figure 3.

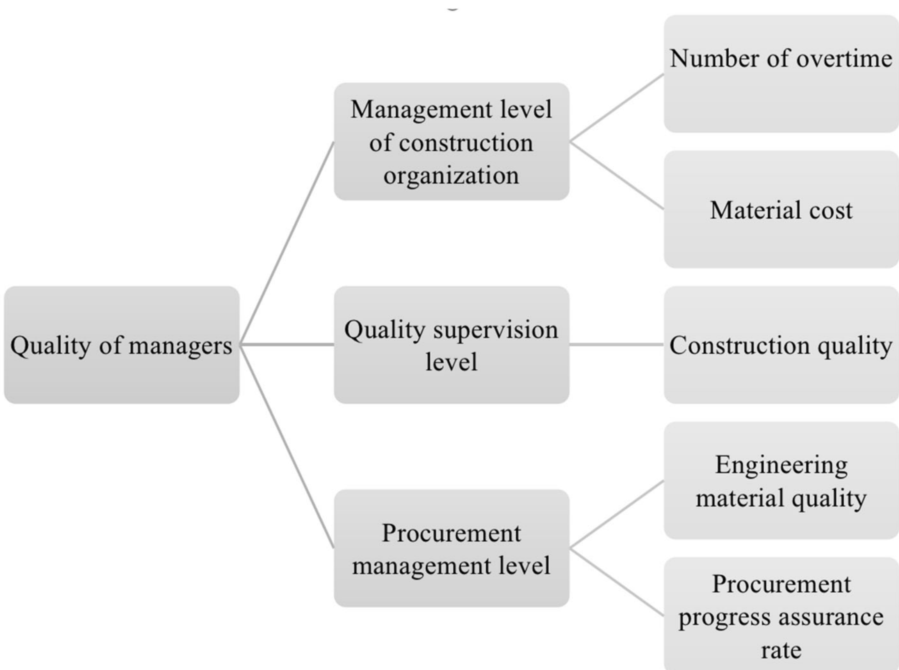

Figure 3. Manager Quality Result Tree

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It can be seen from Figure 3 that the risk factor of manager quality directly affects three risk factors: construction organization management level, quality supervision level, and procurement management level. The level of construction organization management and procurement management further affects the number of overtime, material cost, engineering material quality, and procurement schedule assurance rate. The more a risk factor can result, the greater the impact or disruption of the risk factor, and vice versa. System dynamics focuses on looking at each risk factor from a systematic point of view. Combined with the cause tree and result tree output from the above two examples, it can be seen that "total cost risk" and "manager quality" are not independent risks but are closely related to other risk factors, which affect other risk factors as well as other risk factors.

5. Risk Avoidance Measures

From the objective of eliminating or mitigating risk results, reducing the possibility of risk occurrence or weakening the impact of risk occurrence, there are four risk response measures: risk avoidance and reserve, risk suppression, risk transfer and hedging, and risk-bearing and compensation, which can be referred to (Zhi Xiong &Yiying Wu, 2014).

5.1. Risk Avoidance and Reserve

In the process of project design, it is an effective method to avoid the use of risk-prone design, technical equipment, and construction scheme as far as possible. Reasonable avoidance of possible risks can save a lot of cost and time for subsequent construction, and preventive measures shall be taken as much as possible for the identified or possible risk reserves.

If during the implementation of the project, it is found that the risk generated by activity will cause direct loss or may cause significant loss to the project, it shall choose to actively terminate the activity under the condition that it can be foreseen in advance, to avoid the possible risk actively. Generally, high risk means high return. Grasping the balance between risk and profit and avoiding major risks correctly will bring a considerable return to the project.

5.2. Risk Suppression

If it is found that a particular activity cannot be avoided during the implementation of the project, the foreseeable risks will also be unavoidable. When the risk cannot be avoided, the risk shall be weakened as far as possible to reduce the loss or injury caused by the risk to the project and minimize the loss of project cost and time. For example, the safety inspection on the project site, including fire prevention and oil spill inspection, is a method to take positive measures to reduce the probability of risk occurrence and prevent significant hidden dangers at a low cost.

5.3. Risk Transfer and Hedging

For major accidents that may occur in the project, the loss caused by accident will be fatal. In this case, specific measures need to be taken to transfer the risk and make up for the major accident at a small cost. The most typical method is to realize the risk transfer by insuring with the insurance company, for example, engineering all risks insurance and anti-fall insurance. After the accident within the insurance coverage occurs, the insurance company will make up for the economic losses of the contractor to reduce the losses of the recovery project significantly. Especially for overseas EPC projects, the project itself may be subject to local laws or the terms of the EPC implementation contract, and the project-related insurance is an effective means to realize risk transfer.

5.4. Risk Bearing and Compensation.

For the risks that cannot be identified, prevented, and have occurred, countermeasures should be taken to accept the risks and bear the risk consequences after confirming the causes and

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responsible subjects of the risks. Appropriately and reasonably bearing the risk consequences is an exemplary embodiment of corporate responsibility and reputation. In addition to this, it can make up for the losses caused by risks to a certain extent by taking proactive compensation measures.

6. Conclusion and Prospect

This study took the risk factors of overseas EPC projects as the research object and preliminarily obtained the risk factors of overseas EPC projects through literature analysis. Then, the risk identification model was constructed by combining the system dynamics method. From the cause tree and result tree in the model, it was understood that the risk of an overseas EPC project is not independent but is closely related to other risks, affected by other risk factors, and will also affect other risk factors.

Finally, this paper summarized the measures to avoid these risks through literature analysis. The risk identification model constructed in this paper can help project staff better understand the causal relationship between risk factors in overseas EPC projects, formulate risk countermeasures better, and improve project management performance.

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