

# Review of EPC project risk management research

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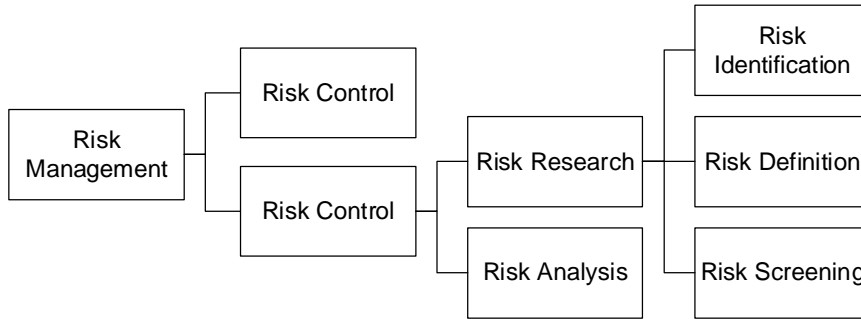
## ABSTRACT

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 EPC project risk management in my country, based on the relevant journal literature results and expert interviews of EPC general contracting project risk management, 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 management; risk factors; strategy*

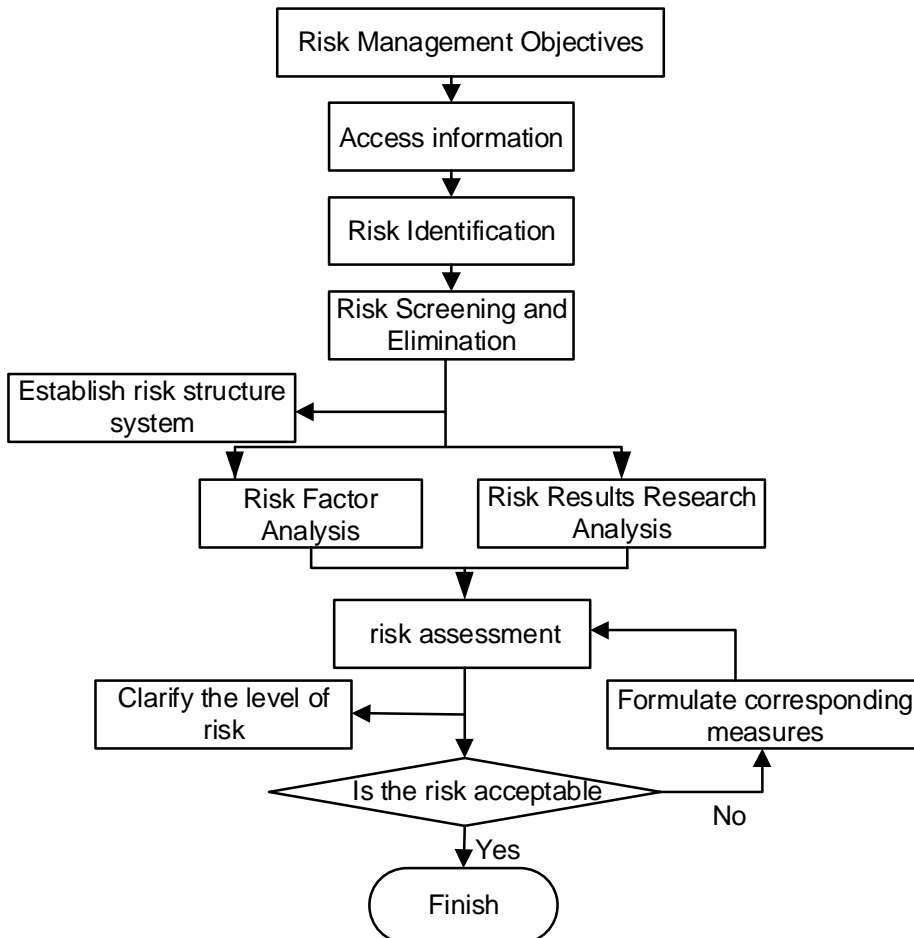
## 1. OVERVIEW OF EPC PROJECT RISK MANAGEMENT

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 <sup>[1]</sup>, so it has gradually become the current mainstream general contracting mode <sup>[2]</sup>. 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 Figure 1. Among them, risk research and analysis is the basis of risk assessment, the content of risk research includes: risk identification, definition and screening.



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34 **Fig. 1. Risk Management System**  
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36 In the construction process, the project will be affected by internal factors and external  
37 environment, so there is uncertainty and instability in the construction process. Risk factors  
38 will change with the change of time, construction technology and process. So project  
39 management is a dynamic process. All elements in the risk management system are  
40 interrelated and influence each other, and its dynamic management flow chart is shown in  
41 Figure 2.

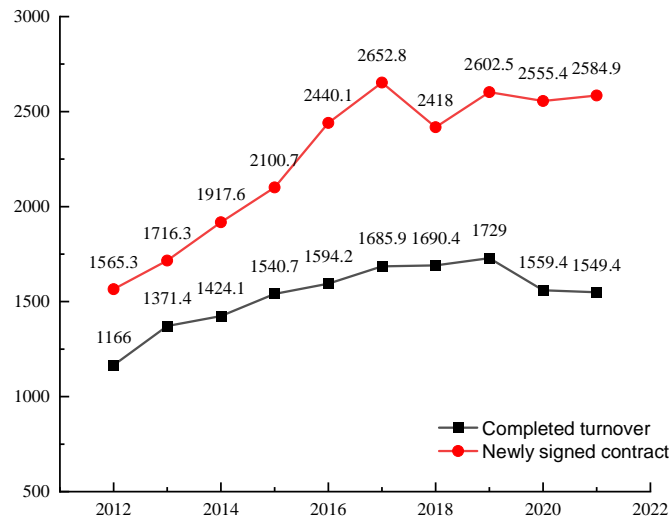


42 **Fig. 2. Dynamic management flow chart**  
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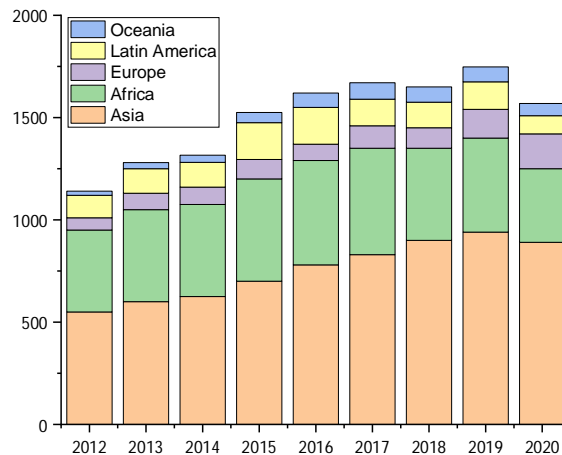
## 2. RESEARCH STATUS OF EPC PROJECT RISK MANAGEMENT

So far, China has contracted international projects covering more than 200 countries and regions. As Figure 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 Figure 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<sup>[3]</sup>.



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



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

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

65 projects such as large engineering quantity, long project cycle and large investment scale  
66 <sup>[4]</sup>.Therefore, the general contractor needs to systematically identify risks, digitize and  
67 visualize risk factors, as an important basis for correct risk analysis and scientific risk  
68 response, so as to minimize risks.

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

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

### 107 108 **3. RISK IDENTIFICATION STUDY**

#### 109 110 **3.1 Risk classification principle**

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

115 (1) The classification of risks should be objective, and the classified risk factors should be  
116 neither leaked nor serious.It can be classified according to the level of risk influence, such as

117 target layer, criterion layer and indicator layer, to cover all possible risk factors and ensure  
118 the integrity of the system.

119 (2) The classification of risks is reasonable and must conform to the thinking logic process  
120 and management process of risk analysis. The classification of risk is narrowed from  
121 generous to small, such as from the country to the market, to the project; In this way, risk  
122 influencing factors are not easy to be omitted, and it is conducive to the management and  
123 implementation of risk response measures.

124 (3) Risk classification should be conducive to the risk analysis of the project. At the project  
125 level, risk analysis is carried out from different perspectives of the general contractor, the  
126 owner and other participants, and the risk systems and risk factor weights established are  
127 different. Therefore, the subject-object perspectives should be clearly defined, so as to  
128 establish a risk system specifically, obtain more accurate risk factor weights, and take  
129 correct preventive measures.

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### 131 **3.2 Sources and types of risk identification**

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

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

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#### 145 (1) Expert investigation method

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

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#### 160 (2) Check list method

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

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#### 169 (3) Project work breakdown structure method

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

#### 175 (4) Accident tree analysis

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

183 Duan Yonghui<sup>[15]</sup> adopted the key word retrieval method of CNKI database in accordance  
184 with scientific and objective principles, selected the risk factors of EPC projects to make  
185 questionnaires, and tested the literature correlation degree by using expert questionnaire  
186 and CiteSpaceV software, thus achieving the optimization of risk indicators. SPSS24.0  
187 software was used to test the reliability and validity of the survey data to verify whether the  
188 questionnaire data met the requirements of factor analysis. Finally, the project level risk is  
189 summarized and classified. Chen Zhiding<sup>[16]</sup> et al. studied the construction risk assessment  
190 method of small and medium-sized hydropower projects, identified the construction risks of  
191 general contractors according to the risk management theory, drew the causality diagram of  
192 project construction risks, and based on the causality diagram of project construction risks,  
193 adopted the theory of information entropy to eliminate the indicators that contributed little to  
194 the system, and built the hierarchical structure system of project risks.

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

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

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## 212 4. RISK ASSESSMENT STUDY

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

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### 222 4.1 Qualitative risk assessment

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Zhang Xuejia<sup>[21]</sup> 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<sup>[22]</sup> evaluated the identified risk factors with expert evaluation method and classified the levels of risk factors. Zhu Yumin<sup>[23]</sup> 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.

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#### 4.2 Quantitative risk assessment

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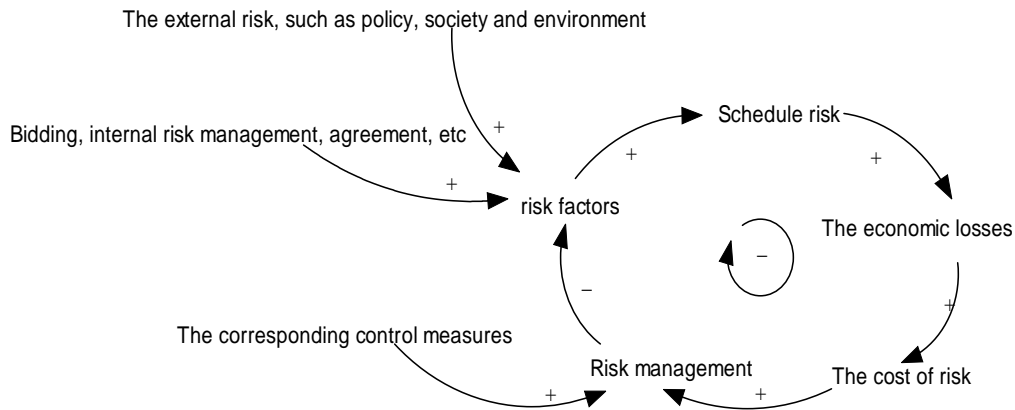
He Yongxiu<sup>[24]</sup> took urban power grid as an example and adopted fuzzy theory for risk recognition evaluation on the basis of identifying project risks. Hu Miao<sup>[25]</sup> calculated the probability of risk factors, combined with the quotation risk model of MonteCarlo constructed, simulated the random risk factors in the bidding price into random variables, and obtained a reasonable quotation. Xu Guo<sup>[19]</sup> 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.

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#### 4.3 A combination of qualitative and quantitative risk assessment

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Yin Yilin et al.<sup>[26]</sup> 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<sup>[27]</sup> 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<sup>[28]</sup> constructed a relatively complete evaluation index system and used fuzzy analytic hierarchy process (AHP) for comprehensive evaluation. Jin Haifeng<sup>[29]</sup> 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<sup>[30]</sup> drew a causal loop diagram (Figure 3) from the process of schedule management with the help of Vensim platform, reflecting the 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.



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Fig. 3. The causal loop diagram of the schedule management process

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

## 265 **5. RESEARCH ON RISK COPING STRATEGIES**

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

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### 273 **5.1 For different stages of risk**

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

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### 286 **5.2 Different coping strategies for project risks**

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

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### 294 **5.3 Strategies for different types of risk**

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

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

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## 306 **6. CONCLUSION**

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

313 The research on project risk and the strengthening of project risk management can promote  
314 the high level of project management, guarantee the project quality and investment benefit,  
315 and promote the standardized development of construction market order. At the same time, it

316 can increase the advantages of the company, and accelerate the integration of international  
317 engineering contracts and management methods, contributing to the country's capital  
318 construction and the development of the national economy.  
319 The existing risk management research of EPC projects mainly includes the establishment  
320 of risk management system, risk identification, risk assessment and risk response strategy  
321 research. In EPC project risk management, various methods can be combined to reduce the  
322 influence of subjective factors, combine qualitative and quantitative methods, improve the  
323 accuracy of analysis results, and provide appropriate risk coping strategies for different  
324 stages of the project to ensure the smooth progress of the project.  
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