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Risk Management of Large Infrastructure Projects: Risk, Uncertainty, and Complexity

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Abstract: The development of large infrastructure projects requires the consideration of many different risks in advance, of which the two common risks are strategic risk and project risk. This study provides an overview of the different relevant literature on risk management of large infrastructure projects. Based on the Hong Kong section of the Guangzhou-Shenzhen-Hong Kong high-speed rail, this study identified the project's main strategic risks and project risks, and provided suggestions for risk management.

Keywords: Transport infrastructure; Risk; Uncertainty; Complexity; Guangzhou-Shenzhen-Hong Kong high-speed rail

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1. Introduction

Large infrastructure projects are infrastructure projects of national importance, and they are complex. Therefore, appropriate management of the risks of such projects is of crucial significance. There are three types of planning uncertainty which are as follows: the uncertainty of the planning environment, the uncertainty of decision-making in the relevant areas of decision-making, and the uncertainty of the environment [1]. Effective risk management ensures that projects develop corporate strategies based on changing opportunities and risks [2], which can increase certainty and reduce exposure to potential chaos.

2. Literature review

2.1. Risk uncertainty and complexity

There are many ways to classify the risks of large infrastructure projects. Strategic risk is regarded by many experts in the field of infrastructure planning and development as one of the important risks for large infrastructure projects which may affect the achievement of corporate objectives during the development of a large infrastructure project [2]. Meanwhile, project risk is another common risk for large infrastructure projects. It stems from varying degrees of uncertainty in all projects, especially during project development process [3]. The focus of risk management is to reduce its uncertainty and impact [2], and risks can be divided into positive risks and negative risks. The former means that positive outcomes are more likely to occur, and vice versa [4,5]. In real life, people are more concerned about negative risks than positive risks. However, positive risks should also be given high priority [1].

Risks stem from varying degrees of uncertainty [3], and the focus of risk management is to reduce its uncertainty and impact [2]. There are four levels of uncertainty which are as follows: a clear enough future, an alternative future, a range of future, and true ambiguity. On the other hand, innovation, discontinuity, abrupt change, rapid change, historical contingency, diversity, pluralism, and heterogeneity all contribute to the complexity of matters [6]. Together, uncertainty and complexity are factors that should be highly valued by project developers as they can cost them a serious loss due to various negative consequences if they do not highlight the importance of risk mitigation.

Firstly, if infrastructure has already been built, it is impossible to change its purpose. Secondly, the benefit of investment is positively correlated with economic growth. This means that if the growth is promising, the project will go well; if the growth is low, the project will perform poorly [7].

2.2. Risk management

Scenario planning is used to explore multiple possible futures [8], which is very beneficial for exploring strategic risks. In addition, it is considered an effective tool in transport planning, supported by reasons as follows [9]: (1) Scenario planning is thought to be effective in negotiation and group decision-making. (2) Scenario planning constrains the scope of possible futures. (3) Scenarios help people explore multiple possible futures. Multi-criteria analysis is thought of as an effective tool for strategic risk management, and has been successfully applied in environmental impact assessment. It is also used to assess risk from different perspectives, that is, different criteria. Some people combined scenario planning and multi-criteria analysis to form a scenario-based multi-criteria analysis method, and this combinatorial method can take full advantage of these methods. More specifically, scenarios provide multiple possible futures, and multi-criteria analysis provides comprehensive analysis based on various criteria [10].

The aforementioned tools are more commonly used in strategic risk management. For project risk management, there are many other commonly used risk management tools [11], such as document review, brainstorming, Delphi techniques, interviews, root cause analysis, checklist analysis, assumption analysis, diagramming techniques, SWOT analysis, and expert judgement [4,12].

Project appraisal is used to explore, review, and evaluate proposed courses of action to determine whether a given proposal is viable, and risk analysis is widely used in project appraisal.

The project risk management methods include steps as follows: 1. Identify project risks. 2. Analyze risks using both qualitative and quantitative methods. 3. Plan risk responses to control risks [4,12]. Risk analysis includes identifying existing controls, possibilities, and consequences, and estimating risk levels. Quantitative analysis and qualitative analysis are important in risk analysis [13].

A risk map is a useful tool for risk management. It requires people to map risk based on impact and probability, as shown in **Figure 1**, where people need to decide which risks are the key risks to consider based on the plotted map.

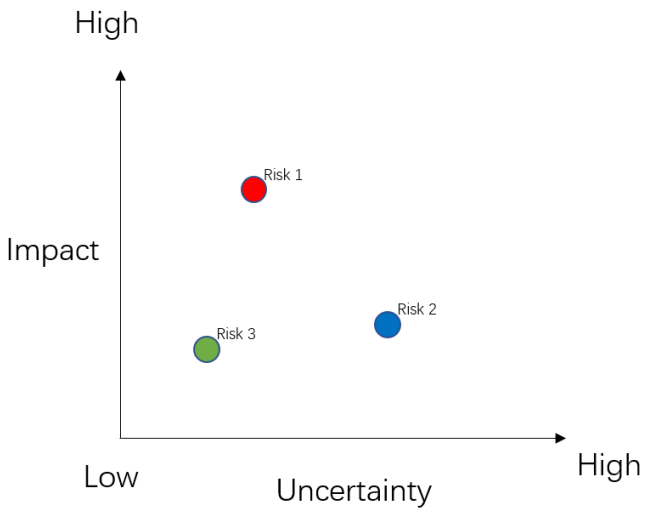

Figure 1. An example of a risk map

Risks can be mitigated by assigning them to those best suited to manage them, and by changing and insuring the project. To manage the risks, the most optimal response plan can also be implemented. Proactive stakeholder management plays an important role in risk management, and assigning risks to the stakeholders best suited to manage them is critical in managing large projects. In addition, the matrix is often used to allocate risks [2,14]. Non-professionals know things that many experts often overlook, contributing to hazard management over the lifecycle of large infrastructure projects. Therefore, a more respectful and balanced relationship between experts and non-professionals is beneficial [15].

3. Case study

3.1. Site selection

The Hong Kong section of the Guangzhou-Shenzhen-Hong Kong high-speed rail (XRL) is a large infrastructure project that can have a significant impact not only on the future development of Hong Kong, but also on that of the Guangdong-Hong Kong-Macao Greater Bay Area. **Figure 2** shows the overview of the area, where the underground high-speed rail line is about 26 kilometers long. The government has invested around £84.42 billion into the project, of which construction began in 2010 and took around eight years to be put into operation. The project aims to improve the connection between Hong Kong and mainland China, and promote Hong Kong's development.

Figure 2. Hong Kong section of Guangzhou-Shenzhen-Hong Kong Express Rail Line

3.2. Risk identification

We used a risk map to identify critical risks. Based on a comprehensive analysis, this study identified three main risks of XRL. Cost overruns are common and important in large projects, and should be identified as they will have a significant negative impact on the construction and operation of the project. Project delays are also common in large projects, which can increase the risk of cost overruns [2,14]. In addition, we identified three main project risks based on the analysis on risk impact and uncertainty matrix, which are tunnel collapse, corruption, and worker injuries [16].

3.3. Stakeholder involvement

Table 1 shows the key stakeholders and their roles in risk management provided in this study. Stakeholder analysis is critical for the risk management of large projects. As different stakeholders have better knowledge of risks than experts, assigning risks to different stakeholders is conducive to risk mitigation.

Table 1. Key stakeholders and their roles in risk management

Stakeholders	Roles
Government	Comprehensive risk management
Mass Transit Corporation (MTR)	Formulate risk management plans
Construction contractors	Manage construction risks with MTR
Communities	As non-professionals who provide suggestions for risk management
Independent board committee	Write reports on various matters

3.4. Suggestions for current risk management practices

One of the government's strategic goals was to complete the project with less than HK$70 billion. However, the final estimate of the cost of the project was £84.4 million, meaning that the project has a significant cost overrun. Scenario planning and multi-criteria analysis can be considered two useful tools for exploring the financial risks of the project [17]. Scenarios may be useful to explore multiple future trends in project costs, while multi-criteria analysis can be used to analyze a large project under different scenarios. This helps in exploring financial risks and adopting some useful strategies in advance.

Project delays are another issue to consider. Some experts had estimated that the project could be delayed, but they did not fully consider assigning the risk to different stakeholders. Project delays are a risk that can be easily influenced by different stakeholders, and in this paper, it is argued that non-professionals know better. In other words, different stakeholders should be involved in the management of this risk.

To explore project risks, an impact and uncertainty matrix was used to explore critical project risks, which is effective since a risk is determined by its impact and possibility. We believe that this matrix is rather beneficial for comprehensively considering all relevant project risks and identifying critical risks.

4. Conclusion

In summary, this paper comprehensively analyzed the risks associated with large projects, which can serve as a reference for those wishing to explore the risks of large projects. This study believes that strategic risk and project risk are two indispensable parts of risk management for large infrastructure projects, and argues that the public can be more involved in the risk management process.

Disclosure statement

The author declares no conflict of interest.

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