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# A major infrastructure risk-assessment framework: Application to a cross-sea route project in China

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## Abstract

This paper proposes a major infrastructure risk assessment framework (MIRAF) based on an adapted Analytic Hierarchy Process (AHP) risk assessment model, and applies it to a cross-sea route project that is expected to connect Guangdong Province and Hainan Island. Two alternative schemes for the cross-sea route namely the tunnel scheme and the bridge scheme, are compared in terms of risks during their different project time spans. Results indicate that the risk of the bridge scheme is larger than that of the tunnel scheme, and that the risk will increase over time. Several risk factors, including damage to commercial interests of local fishermen, damage to habitat for rare and endangered animals, financial crisis and sea storm surge, are identified as significant factors during the implementation of the tunnel scheme. This approach can be used as a decision tool to identify, analyze and assess the risks existing in the major infrastructure projects.
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*Keywords:* Infrastructure; Risk assessment; Cross-sea route; Time span; China; Case study

## 1. Introduction

Major infrastructures are a class of large-scale and critical public infrastructure projects that have significant impacts on the economy, society, environment, politics, security, and safety of wide regions or even the whole country. According to a report of infrastructures in China (Wilkins and Zurawski, 2014), the investment in infrastructure accounted for between 25% and 35% of total fixed asset investment in China, with a growth in nominal terms by an average annual rate of 20% from 2004 to 2014. An estimated CNY 42 trillion of investments (74% of one year's worth of GDP) will spread over the next five years until 2020 in order to converge with the levels of development and standards of living in the developed economies of China. Municipal infrastructures, utilities, highways and rails, which usually have major infrastructure projects involved, take about 80% of the total infrastructure investment. Due to huge controversies over the successes or failures of previous major infrastructure projects, such as the Three Gorges Project (Tan and Yao, 2006; Xu et al., 2013) and the South-to-North Water Transfer Project (Feng et al., 2007; Zhang, 2009), the Chinese government tends to be much more prudent when making decisions on major infrastructure projects. More consideration is given to potential environmental and social impacts because of the projects, rather than the previous focus on economic benefits to the Gross Domestic Product (GDP). The increase in public surveillance in China impels the government to assess major infrastructure projects from a more comprehensive, objective, and scientific perspective. Integrated risk assessment is a key criterion in making decisions on major infrastructure projects.

Major infrastructure projects in China are usually: 1) Strategic. Major infrastructures have a huge impact on the economy (Chen et al., 2013), society (Shen et al., 2012), environmental policy,

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and sustainability (Shen et al., 2010; Zeng et al., 2015). Great harm can be caused by decision-making or implementation errors. 2) Unique. Major infrastructure projects in China are usually more difficult than similar projects in the rest of the world (Flyvbjerg, 2011). It is difficult to find previous projects that have the unique social, natural, legal, economic, and technological environment of China. 3) Integrated. Major infrastructure projects usually involve multi-stage, multi-agent, multi-disciplinary, multi-interface, multi-target, and multicultural factors (Flyvbjerg, 2011; Guo et al., 2014). Integration of all these elements is a critical prerequisite for project success. 4) Complex. The complexity of major infrastructure projects reflects not only their large scale and numerous complex working interfaces, but also their highly dynamic, nonlinear, and uncertain work processes (Flyvbjerg, 2011; Miller and Hobbs, 2005; Vidal, 2008). The systems of major infrastructures include not only quantitative “hard” data, but also myriad descriptive and qualitative “soft” data. All the above characteristics of a major infrastructure project of China directly affect and cause huge risks during its life cycle (Guo et al., 2014; Shen et al., 2010; Shi et al., 2015; Zayed et al., 2008; Zeng et al., 2015), relative to the characteristics of small scale projects. Therefore, it is critical to conduct careful and systematic risk assessment research for decision making on major infrastructure projects.

Due to the wide environmental and social impacts and the huge risks of major infrastructure projects, the Chinese government has begun to realize the importance of comprehensive risk assessment and planning of those projects. Previous risk assessment methods have some deficiencies for major infrastructure projects. Taking into account the features of major infrastructure projects, this study establishes a major infrastructure risk assessment framework (MIRAF) based on an adapted analytic hierarchy process (AHP) risk assessment model (Zayed et al., 2008), which originated from previous studies (Dias and Ioannou, 1996; Zayed and Chang, 2002). Comprehensive risks are considered in the risk assessment framework, including the natural and social environment, construction techniques, and decision-making behaviors of the government decision makers. In particular in the MIRAF, risk impacts during different time spans of major infrastructure projects are taken into consideration to meet the long life cycles and long-term impacts of those projects. To test the effectiveness of the established MIRAF, this paper presents a case study using a real project in China, in which a cross-sea route (bridge or tunnel) is planned to connect Guangdong Province and Hainan Island. The research is supported by China’s National Development and Reform Commission, which is in charge of administrative approval for major infrastructure projects. The established MIRAF is applied to compare the risks from different time span perspectives of two cross-sea alternatives, namely a tunnel scheme and a bridge scheme. The results of the case study provide validated experiences of the MIRAF, and also present the risk mitigation tendency of Chinese-government decision makers.

## 2. Literature review

Many researchers have pointed out the significance of recognition and control of the complexity, and risks of major infrastructure projects (Zayed et al., 2008). Although all general information on a project (estimated duration, estimated cost, stakeholders, etc.) can be obtained, it is still quite difficult to accurately understand, predict, and control the overall situation and development trends of the project (Vidal, 2008), leading to the risks of major infrastructure projects. Bosch-Rekveldt (2011) summed up 50 project complexity factors, including multi-project objectives, project scale, project diversity and variability, project interdependencies and correlation, and the complex project environment. On the one hand, the complexity of the project makes managers unable to fully grasp its status or accurately predict its trend, which triggers risks. Similarly, the difference between the real complexity of the project and the complexity its managers can comprehend will also increase the risks. The direct impact of complexity is to increase the risk of management activities (Vidal, 2008). Therefore, comprehensive risk assessment is the key to understanding and ameliorating the risks of major infrastructure projects.

To comprehensively and systematically assess the risks of major infrastructure projects, numerous approaches have been applied in recent years, which are classified by the types of major infrastructure, risk areas, risk dimensions, and types of methods, as shown in Table 1. Moreover, much effort has been made to identify and analyze specific risk factors evolved in infrastructure projects, expanding the cognitive domain of the project risk. According to de Corn (2013), the contribution of human intervention to the overall probability of a system failure can be quantified through a framework. Crăciun (2011) discussed the macroeconomic and political risks of infrastructure projects and tried to find new ways to answer the challenges related to such risks. Impacts of climate change on the road transport infrastructure were assessed by Regmi and Hanaoka (2011). Using a decision support analysis that considered fatality risks and the cost-effectiveness of protective measures, Stewart (2011) evaluated terrorist threats to the infrastructure projects. Several critical considerations in project risk assessment, that are interdependency, vulnerability, and sustainability, were discussed by Santos-Reyes et al. (2014); Thekdi (2014), and Padgett and Tapia (2013) respectively.

All of the risk assessment methods presented in Table 1 can be used to analyze a specific risk factor or the risk of a project according to particular aims of the executor. However, only the methods of Kuo (2013); John et al. (2014) and Zayed et al. (2008) can generate quantitative and comparable results of risk assessment, which can be directly used for the comparison and selection of alternative schemes.

As shown in Table 1, many previous studies focus on one stage of major infrastructure projects, such as construction stage or operation stage. Other studies assess the risks from a life cycle perspective. However, all of the researches in Table 1 have not considered the changing of probability of the risks or their consequences as time goes on. The time spans of project implementation and operation is rarely taken into account in the literature. Since major infrastructures usually have a long period of service, many changes to their natural and social environments may be caused by the features of the projects, as discussed above. Static risk assessment may lead to

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