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RESEARCH ARTICLE

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# Identifying the driving factors of successful megaproject construction management: Findings from three Chinese cases



**Abstract** The construction of megaprojects has always resulted in extensive and long-term impacts on the society. However, the performance of megaproject management is poor, and improving it remains an urgent and necessary issue. Although many studies on megaproject success have been conducted, existing studies on the driving factors of successful megaproject construction are rather limited. Therefore, this study aims to systematically explore the key factors that can lead to successful megaproject construction management based on three cases: The Beijing–Shanghai High-Speed Railway, the Three Gorges Dam, and the Hong Kong–Zhuhai–Macao Bridge. Mixed research methods, such as literature review, case studies, and expert interviews, were used in this study. Consequently, 11 driving factors, namely, government support, public support, accumulation and application of technology and experience, development and innovation of technology, innovation and application of management system, organizational mode and structure, top management support, project culture, megaproject citizenship behavior, corporate reputation, and fulfillment of social responsibilities, were identified and grouped into five categories, namely, project environment, construction capabilities, organization, positive culture and behavior, and requirements for sustainable development. The contributions of this study lie in two aspects. First, the driving factors of successful megaproject construction are identified to deepen the understanding of industrial practitioners, assist them in focusing on key factors, and aid them in effectively managing megaprojects. Second, researchers could use the identified driving factors in conducting further empirical studies and apply them in future projects to enhance their chances of success.

**Keywords** megaproject management, driving factors, project success, case study, China

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## 1 Introduction

Megaprojects are typically defined as large-scale and complex ventures that cost more than $1 billion, take many years to build, involve multiple stakeholders, and have extensive impact on the development of regional economy, environment, and society (Flyvbjerg, 2014). Examples of megaprojects, such as airports, dams, bridges, and high-speed railways, are varied (Flyvbjerg, 2017). These megaprojects are magnified versions of normal projects and comprised interdependent subsystems that aim to improve socio-economic development and public service and welfare. In recent years, rapid global urbanization has triggered investment in infrastructure megaprojects (Hu et al., 2015b). For example, McKinsey estimated that the world needed to invest approximately $57 trillion on

infrastructure by 2030 to maintain the expected GDP growth (Garemo et al., 2015).

However, the performance of megaproject management is always disappointing. "Over budget, over time, under benefits, over and over again" seems to have become the iron law of megaproject management (Flyvbjerg, 2017). For instance, Flyvbjerg (2007) emphasized that 9 out of 10 of worldwide megaprojects experienced cost overruns. The average cost overrun ratio of road projects is approximately 20% to 30% for bridge projects, 35% for tunnel projects, 40% for rail projects, and almost 96% for dams (Cantarelli, 2011; Flyvbjerg, 2014; 2017). Delay is another common problem in megaproject management. For example, research results showed that the average delay ratio of dams is 45% (Ansar et al., 2014). Moreover, cost overruns and delays are not independent, and delays in the construction phase would further contribute to the problem of cost overruns. Existing studies found that a 1 year delay in construction implementation phase could increase cost overrun by 4.64% (Flyvbjerg et al., 2004). Thus, scholars and practitioners have exerted considerable efforts on the research of megaproject management and have attempted to improve the chances of megaproject success.

Existing studies on megaproject management include the analysis of megaproject management (Shenhar and Holzmann, 2017; Söderlund et al., 2017), cost and schedule management (Flyvbjerg, 2007; Flyvbjerg et al., 2007), organization and stakeholder management (Eriksson and Kadefors, 2017; Szentes and Eriksson, 2016), and risk analysis and management (Sanderson, 2012; Wang et al., 2011). However, two main limitations still exist in previous studies. First, these studies rarely focus on the driving factors behind a successful megaproject. Previous studies on driving factors primarily concentrated on permanent organizations. Thus, studies on temporary project-based organizations are rather weak and limited. Second, existing relevant studies, such as Mišić and Radujković (2015), are conducted in the context of western countries. Hence, the results in these studies would be inapplicable to other countries, such as China. Contextual elements, including social, cultural, and institutional environment, are crucial in megaproject management; and differences in contextual environment would lead to various research outcomes (Hu et al., 2015b). This study only focuses on the driving factors of successful megaproject construction management while considering the unique social, cultural, and political environment of China.

Therefore, this study aims to identify the driving factors for the successful management of megaproject construction within the context of China. The authors will focus on the driving factors that might be considered distinctive to megaproject construction. The remainder of this work is organized as follows: Section 2 entails literature review, including project success and its driving factors. Section 3 introduces the research methodology and explains two stages in detail. Section 4 presents the results and discussions. Section 5 concludes this study.

## 2 Literature review

### 2.1 Project success

The study on project success began in the 1980s. Although relevant fruitful research outcomes have been obtained, no unified definition for a successful project has been provided. Researchers have proposed various perspectives for defining project success. For example, Tuman (1986) considered a project successful when resources are fully used and the desired goal is achieved. Notably, many previous studies assessed project success based on the "Golden Triangle" concept, which considered cost, quality, and schedule. Ashley et al. (1987) emphasized that a successful project should meet five requirements, namely, cost, schedule, quality, safety, and satisfaction of the project participants. Pinto and Slevin (1987) stated that successful projects must be completed on time, should be within budget, must accomplish all planned goals, and the results should be accepted by customers. De Wit (1988) differentiated the success of project management, which measures time, cost, and quality, and a successful project, which normally depends on a wide range of measures. Afterwards, many scholars have noticed and distinguished the differences between successful project management and successful projects in their studies. However, merely focusing on the distinctions between successful projects and project management may be insufficient (Cooke-Davies, 2002).

Cooke-Davies (2002) suggested that the three levels of success should be distinguished. The first level is project management success, which answers the question "Was the project done right?" This measure of success is dominant in previous literature. For project managers, this level corresponds to time, cost, and quality management. Generally, the principle, which is to deliver the project so that it meets the objectives within the project's constrains, is simple (Pinto and Morris, 2004). Moreover, the success measurements (time, cost, and quality) allow the project team as a coherent organizational unit to be accountable for its performance. Meanwhile, capturing data on project management success enables the enterprise to compare the practices that are associated with successful projects with those associated with unsuccessful ones (Pinto and Morris, 2004).

The second level of success is what de Wit (1988) calls project success, which answers "Was the right project done?" In this level, the project will only be considered successful if it successfully benefits the owner, sponsor, or organizations. In a sense, this level is a measure of "value for money" (Pinto and Morris, 2004). The next level is

consistent project success, which answers "Were the right projects done right, time after time?" Consistency mainly refers to being competitive in markets for scarce resources, such as customers. Considering the unique characteristics of megaprojects, especially those with long construction and operation period and multiple stakeholders involved, success in this study mainly focused on the first level (project management success). The authors considered the factors that successfully drive the triumphant delivery of construction megaprojects.

### 2.2 Driving factors of project success

The driving force concept originated from physics. Generally, periodic external forces can be called driving forces. In management, the concept of driving force, which refers to the forces that influence the organization and system to move toward a particular goal, would be different (Lindbeck and Snower, 2000).

Existing studies that focus on the driving factors of project success are relatively weak and limited. Wang et al. (2001) stated that the factors behind successful engineering projects were divided into four groups, namely, the characteristics of engineering projects, contract and agreements, participants, and coordination in organizations. Bredillet and Dwivedula (2008) pointed out that clear goals, training, performance feedback, communication, and top management support, were significant factors of project success. Crosby (2012) found that good control systems, clear project missions and goals, project communication, support from top management, project baseline, performance monitoring, and capabilities of project leaders are top-ranking success drivers in large high-technology projects. Jetu and Riedl (2012) concluded that work morale, project team learning, and leadership were the three most important dimensions of team project success. Ndihokubwayo (2014) explored and compared monetary and non-monetary incentives to achieve project delivery success based on two models. Each model included four parts, namely, project objectives, demographic information, short-run project-based interventions, and long-run interventions. The research results showed that monetary incentives could be a useful short-term project-based intervention mechanism to achieve secondary project objectives, and non-monetary incentives could be useful in achieving primary project objects, such as quality management. Additionally, some studies only focus on a specific aspect of project success. For example, Iyer and Jha (2006) only concentrated on schedule performance and found that the project participators' inputs, owner's capabilities, and conflict among project participants are three important success factors of schedule performance.

Megaprojects are generally crucial to political and economic development, and they are distinct from general projects (Shen and Shi, 2015). Currently, only a few studies focus on the study of the driving factors in megaprojects. Li et al. (2018) highlighted the important role of government and political impacts on successful decision making and construction of megaprojects. Van Marrewijk et al. (2008) highlighted the essential role project culture plays in the cooperation of managers and partners to successfully achieve project objectives. Hu et al. (2015a) identified 12 principal program organization factors (i.e., contextual understanding, program strategy, program leadership, scope management, program governance, matrix organizational structure, program management office, use of project breakdown structure and work breakdown structure tools, partnering with key stakeholders, technology management, communication management, and team building) that were established by a client to manage a megaproject based on an in-depth analysis of the Shanghai Expo. From the literature review, 4 groups with 11 factors were identified and summarized in Table 1.

## 3 Research methodology

An inductive approach that helps establish social science theory in specific scenarios and is suitable for situational theoretical research (Yang et al., 2018) was primarily used in this study. Descriptions on the driving factors of successful megaprojects construction were collected from an open resource and then categorized through content analysis using an agreement index that was established with multiple judges (Hinkin, 1998). To be specific, considering the impact of contextual factors on the research process and outcomes, this study only focused on the context of China. Moreover, three typical and representative Chinese construction megaprojects, namely, Three Gorges Dam, Beijing–Shanghai High-Speed Railway, and Hong Kong–Zhuhai–Macao Bridge, were selected as case studies in this research. The Three Gorges Dam in China is the world's largest hydroelectric dam and managed by a government-owned company. The cost was estimated at $22.5 billion, and the construction duration was approximately 17 years (Shenhar and Holzmann, 2017). The Beijing–Shanghai High-Speed Railway is one of the largest high-speed railways in the world. Investment was estimated at $33.6 billion, and the construction duration was only approximately 3 years (Yang et al., 2018). The Hong Kong–Zhuhai–Macao Bridge is the first large cross-sea transportation project in Guangdong, Hong Kong, and Macao under the "One Country, Two Systems" policy (Liu et al., 2018). It was delivered in October 2018 with an investment of approximately $10.9 billion and a construction duration of approximately 9 years. The case selection in this study has three main reasons. First, they were all built in the last two decades, indicating that these three projects are in similar political, economic, and cultural environments. Second, these three megaprojects are recognized to have shown great performance in project

**Table 1** Identified driving factors of project success from related literature review

| Categories | Driving factors | Descriptions | References |
|---|---|---|---|
| Nation/Government | Political environment | Guides, support, and encouragement from government, and policy interests | Li et al. (2018); Shen and Shi (2015) |
| | External supervision | Mandatory regulations and rules from government, legal constraints, supervision from government, and governmental legal system | Wang (2008) |
| Society | Corporate reputation | Corporate reputations, and requirements for the maintenance of brand and reputation | Shi et al. (2017) |
| | Public opinions | Disclosure of information, public expectations, social and public attitudes, requirements of stakeholders, and pressure from NGO (Non-Governmental Organization) | Qin (2006); Zhou and Mi (2017) |
| Project teams | Corporate/Project culture | Corporate culture, organizational culture, working spirit, and coordination and communication | van Marrewijk et al. (2008) |
| | Project organizations | Structure and design of organizations, and education and training within organizations | Jetu and Riedl (2012); Hu et al. (2015a) |
| | Project management system | Management system, monetary incentives, and performance of monitoring | Ndihokubwayo (2014) |
| | Project goals | Requirements from owner, project mission, clear scope and goals, and attractive project objectives | Bredillet and Dwivedula (2008); Hu et al. (2015a) |
| | Strategies and vision | Corporate strategies and vision | Tao and Guo (2013) |
| Individuals in project teams | Capabilities and leaderships of leaders | Spirits of the entrepreneur, leaders' incentive art, project leadership, capabilities of management, and top management support | Bredillet and Dwivedula (2008); Crosby (2012) |
| | Commitment and devotion of individuals | Employees' sense of achievement and ownership | Zhu and Huang (2004) |

management. For example, the Beijing–Shanghai High-Speed Railway has won the special award for 2015 National Award for Science and Technology Progress and the excellence award for Outstanding Major Civil Engineering Projects in the Past Century awarded by FIDIC (International Federation of Consulting Engineers). Third, the three projects are famous worldwide and have already accumulated plenty of accessible data for in-depth analysis.

Then, one Ph.D. candidate was asked to identify and gather examples of drivers of megaproject construction success observed from open document resources of the three selected cases, based on the initial categories and framework listed in Table 1 obtained from literature review. Afterwards, classifying and selecting materials were mainly based on content analysis. Industrial and academic experts were also invited as interviewees to examine the reliability of our inductive study with an agreement index. As previous studies that employed inductive approach, such as Farh et al. (2004) and Yang et al. (2018), this study included two stages.

### 3.1 Stage 1: Identification of driving factors in successful megaproject construction

This stage aims to gather information regarding the driving factors of megaproject construction success from an open resource and classify them into a series of categories using content analysis (Hinkin, 1998). In Section 2, the initial categories and driving factors of project success were identified as the foundations of event collection (Table 1).

From February to May 2018, relevant events documents were collected from open resources, which mainly included books, newspapers, published reports, periodicals on official websites, and statements in documentaries. Given that megaprojects received concerns from almost all aspects of life in the society, their processes in each stage have been displayed to the public via news and interview records in printed newspapers or online websites, published reports, and periodicals on official websites. After the completion of construction works, books were published and documentaries were produced to review the success and failures of the project from the perspectives of the participants (including owners, contractors, designers, supervisors, consultants, etc.), coordinators (all levels of government), and observers (e.g., journalists and scholars). As a result, these resources were selected for several reasons: (1) they were available to the public, (2) detailed descriptions were involved, and (3) experiences were recorded from multiple perspectives.

When judging whether a textual event was valid or not, three main elements were considered: "driving force", "driving results", and "the relationship between driving force and driving results", which should be included in a sentence or a semantically coherent paragraph to stand as evidence of a driving factor. To be specific, the "driving force" referred to a specific behavior, condition, or factor in the process of project construction, with textual

descriptions such as "coordination and support from government". The "driving result" indicated that partial or overall project in a certain stage was successfully achieved, with descriptions such as "the construction of the project went smoothly", "the execution of project goals in each stage", and "the accomplishment of a first-class project". The "relationship between driving force and driving results" implied that a certain relationship exists among the behavior, condition, or factor and the successful outcomes of the project, with descriptions such as "promote", "ensure", and "benefit". For example, as mentioned in the book report on Beijing–Shanghai High-Speed Railway (Beijing–Shanghai High-Speed Railway Co., Ltd., 2012), "to ensure the sectional works to be completed on time, Wusong Wen (an engineer) usually kept staying in the construction site for several days and supervising the construction work day and night without adequate rest", this was identified as a textual event to show the commitment and devotion of individuals in this megaproject. Additionally, although textual descriptions would not obviously contain all these three elements, descriptions with similar meanings could also be considered in data collection.

A total number of 541 textual events on driving factors of successful megaproject management were obtained at this stage, which were then categorized on the basis of their matching degree with factors shown in Table 1. Subsequently, all events were screened based on two criteria. One was that the event must have a distinct and clear statement that a specific factor could drive construction megaprojects toward success. The other was that the event must refer to the context of infrastructure megaprojects. Ultimately, 49 materials were discarded, and a total number of 492 were obtained, including 64 materials for the Three Gorges Dam, 168 materials for the Beijing–Shanghai High-Speed Railway, and 260 for the Hong Kong–Zhuhai–Macao Bridge. Additionally, one more driving factor (namely, technology accumulations and innovations) was added and compared with the results shown in Table 1.

### 3.2 Stage 2: Reliability test based on experts' interviews

Interview is a useful technique for establishing face validity in the research process (Lucko and Rojas, 2010). Expert interviews were employed to modify and refine the driving factors by referring to previous case studies in project management (e.g., Yang et al. (2018)), to test the reliability of the identified driving factors based on the inductive method of document analysis.

A total of 10 experts with fruitful practical experience and academic knowledge were invited to participate in face-to-face interviews between June and July 2018 in Shanghai. Each interview lasted for approximately 45 minutes to 1 hour, and the interview was undertaken in a semi-structured manner, thereby enabling extensive feedback (Lucko and Rojas, 2010). After participants briefly introduced their experiences in researches or practices in megaproject management, they were provided with the definitions of successful megaproject management, a list of driving factors, as well as the resources and representative events obtained from Stage 1. Primary questions were asked, and additional questions were added during the interview (Liu et al., 2013; 2015). Some of the primary questions are listed as follows. Questions numbered (1) to (3) were asked in several iterations to ensure that experts' agreement or disagreement on each factor was based on their comprehensive understanding of successful megaproject management and its driving factors.

(1) Do you agree that this factor is a driving factor of successful megaproject management? If so, please provide an example from your experiences in megaproject management. If not, please explain the reasons why you disagree.

(2) Can you add other driving factors? Please provide some examples.

(3) Do you think that some factors in this list need to be renamed? Please explain the reasons.

(4) Can you give some suggestions on how to categorize these driving factors?

To ensure the reliability and quality of interviews, the selection of interviewees considered the diversity of their backgrounds and professional expertise. Figure 1 shows the backgrounds of the interviewees. Seven industrial experts all had significant working experience in project management for the three selected projects in this study and other similar megaprojects (one in Three Gorges Dam, two in Hong Kong–Zhuhai–Macao Bridge, and the others in projects similar to these three selected cases), and three academic experts were working on research in large-scale and complex megaprojects, including the three cases in this paper and other projects, such as the Shanghai Expo. Ultimately, the discussion results included a 30000-word record and related agreement scores.

## 4 Results and discussion

### 4.1 Results of identified driving factors of megaprojects construction success

Table 2 shows the results of identified driving factors of megaprojects construction success after being modified on the basis of expert interviews. As shown, 5 categories including project environment, construction capabilities, organization, positive culture and behavior, and requirements for sustainable development, with 11 drivers were identified.

Based on the results of expert interviews, some driving factors were modified according to three principles. First, not all factors identified in Stage 1 play an important role in driving the success of megaproject management. Thus, the

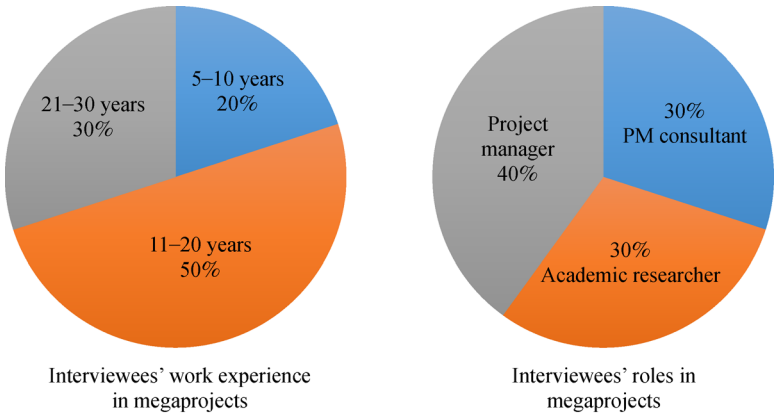


**Fig. 1** Background information of experts in the interviews (PM means project management).

**Table 2** Identified driving factors of successful infrastructure megaprojects management after expert interviews

| Categories | Diving factors | Number of events | Experts' agreement |
|---|---|---|---|
| Project Environment | Support from government | 44 (9.5%) | 9 (90%) |
| | Support from the public | 28 (6.1%) | 8 (80%) |
| Construction Capabilities | Accumulation and application of technical experience | 34 (7.4%) | 7 (70%) |
| | Development and innovation of technology | 54 (11.7%) | 8 (80%) |
| | Innovation and application of management system | 59 (12.8%) | 9 (90%) |
| Organization | Organizational mode and structure | 58 (12.6%) | 9 (90%) |
| | Top management support | 41 (8.9%) | 7 (70%) |
| Positive Culture and Behavior | Project culture | 55 (11.9%) | 8 (80%) |
| | Megaproject citizenship behavior | 46 (10.0%) | 6 (60%) |
| Requirements for Sustainable Development | Corporate reputation | 27 (5.8%) | 6 (60%) |
| | Fulfillment of social responsibilities | 16 (3.5%) | 5 (50%) |

authors excluded or integrated some factors to make them more concise. For example, the role of "external supervision" emphasizes the constraints of megaproject construction rather than the function of driving; thus, experts suggested the exclusion of this factor. Similarly, the factor "project goals" was removed. In addition, the "strategies and vision" in this study mainly reflected the pursuit of long-term development in the reputation of the enterprises. Therefore, "corporate reputation" was incorporated as a factor in Table 2. Second, great modifications were applied to rename factors. Names of factors in Stage 1 continued to use words used in the literature. However, the names of these factors might come from the field of enterprise organization management or project management in general, which would not be necessarily applicable to the context of megaproject management. Thus, some factors were renamed according to the experts' suggestions. For instance, the factor "project management system" was renamed as the "innovation and application of management system" in Table 2 because this factor emphasized the innovations or new distinctive management systems in megaprojects. The factor "commitment and devotion of individuals" was changed into "megaproject citizenship behavior" because this factor mainly refers to the spontaneous behavior of the participants beyond their required job duties. Third, modified driving factors were classified into five categories according to the commonality of each factor. Notably, if a driving factor had less than 2.5% of related events and obtained less than 50% of experts' agreement, it would be excluded (Farh et al., 2004; Yang et al., 2018). After the modification process, the number of events was narrowed to 462.

The first category was "project environment", which referred to external environment factors that contribute to the construction of megaprojects, especially political and social environment factors in this study. It included two driving factors, namely, "support from government" (44 events, supported by 9 experts) and "support from the public" (28 events, supported by 8 experts).

The second category was "construction capabilities",

which referred to "hard" and "soft" capabilities that are indispensable for project teams to complete the construction of megaprojects. The factors of "accumulation and application of technology and experience" (34 events, supported by 7 experts), "development and innovation of technology" (54 events, supported by 8 experts), and "innovation and application of the management system" (59 events, supported by 9 experts) were involved. The first two driving factors were more inclined to the "hard" aspect, and the latter was likely to belong to the "soft" aspect. It is interesting to note that the driver "innovation and application of management system" was the most significant one among all driving factors.

The third type was "organization", which referred to the organizational factors that mainly help in coordinating the work on intra-organizations or between extra-organizations of megaprojects. This category comprised two drivers. One is "organizational mode and structure", with 58 events and supported by 9 experts, ranked second according to number of events. The other is "top management support", with 41 events and supported by 7 experts.

The next type was "positive culture and behavior", which referred to the positive attitudes and benign behaviors of participants in intra-organizations and extra-organizations to promote their performance during the construction of megaprojects. It included "project culture" (55 events, supported by 8 experts) and "megaproject citizenship behavior" (46 events, supported by 6 experts). The "project culture" was the third important factor, considering the number of events.

The last category was "requirements for sustainable development", which referred to the factors that contribute to the continuous development of participant enterprises, or the harmonious and stable surrounding environment of the megaprojects. Two driving factors were involved: One was "corporate reputation" (27 events, supported by 6 experts) and the other was "fulfillment of social responsibilities" (16 events, supported by 5 experts).

## 4.2 Findings and discussions

A total of 11 drivers were eventually identified using an inductive approach to explore the driving factors of successful megaproject construction management. Each identified factor was illustrated and explained with unique meanings.

### 4.2.1 Support from government

Considering that megaprojects are generally symbols, central and local governments always attach great importance to their construction. The role of the government cannot be replaced in the decision-making and construction of megaprojects, especially infrastructure megaprojects and mega event projects (Li et al., 2018). Although some scholars argued that "projects and politics do not mix", they tend to mix in China (Zhai et al., 2017). Meanwhile, many participants either are state-owned companies or connect closely with the government (Chi et al., 2011). At times, this kind of situation indeed contributes to successful project outcomes, such as the Bird's Nest Project built for the 2008 Beijing Olympic Games (Manzenreiter, 2010).

In China, the government often acts as the regulator and an active coordinator in the projects. On the one hand, the government actively establishes many specific agencies with its regulatory supervision to monitor and control the operation of private companies within the networks of megaprojects, which could effectively promote megaproject governance and prevent corruption (Zhai et al., 2017). On the other hand, it coordinates major issues in the construction of megaprojects to provide convenience for project teams and help solve key problems. For example, without the strong support and cooperation of local governments involved in the Beijing–Shanghai High-Speed Railway, land acquisition could not be smoothly carried on, and on-time delivery would not be achieved.

### 4.2.2 Support from the public

Megaprojects are often considered an issue of public interest. It attracts a high level of attention from the public because public entities and public spending are involved in their construction process (Feldmann, 1985). 8 out of 10 experts in the interviews agreed that support from the public is necessary to establish a harmonious and stable social environment for the construction of megaprojects, especially when some works may have a negative impact on people's living surroundings, such as demolition work. On such occasions, support from the public, such as positive comments on the project and construction work, and active cooperation in migration, can reduce conflicts so that the project teams can achieve their objectives. The megaproject Three Gorges Dam involved a large amount of immigration work, and the support of immigrants became one of the critical issues that affected the success of this project (Li, 2011).

### 4.2.3 Accumulation and application of technology and experience

The "uniqueness bias" among designers and managers leads them to tend to take their projects as singular, which impedes learning from other projects. This is one of the main factors that lead to the failure of megaproject delivery (Flyvbjerg, 2014). In fact, technological experience, managerial experience, as well as accumulated and cultivated professionals in previous project practices or relevant academic programs can provide valuable experience and technologies for similar megaprojects. As stated

by Davies et al. (2009), experiences involving project processes, ideas, and developed technologies can aid the construction of an undergoing megaproject and further improve its performance. The factor "accumulation and application of technology and experience" could refer to: (1) construction experience and expertise accumulated through previous practice; (2) advanced technologies developed by academic institutes and participated entities; (3) mature technologies and experience imported from foreign countries. For example, the technology of the ballast-less track applied in the Suining–Chongqing Railway was adopted in the Beijing–Shanghai High-Speed Railway (Wang, 2016).

#### 4.2.4 Development and innovation of technology

Technological challenge has been recognized as an important issue that cannot be ignored in megaprojects (Kipp et al., 2008). New technologies and operating procedures were explored, identified, selected, and experimented by project organization to support improvements in megaproject processes (Davies et al., 2009). In the Beijing–Shanghai High-Speed Railway, technological innovations followed the principle of "Introducing, Absorbing, and Independent Developing", which help to deal with some key problems smoothly to ensure project delivery (Wang, 2016). Additionally, the idea of industrial lean manufacturing has been pioneered to ensure the quality and duration of construction of the Hong Kong–Zhuhai–Macao Bridge. For instance, compared with traditional process, the production efficiency of the steel structure plate was increased by more than 300%, and the quality has been significantly improved after the application of advanced production line and equipment (Zhu et al., 2018).

#### 4.2.5 Innovation and application of management systems

The innovation and application of management systems refers to establishing or promoting managerial systems to guide, standardize, and control the work according to the characteristics of megaprojects, aiming at the success of megaproject delivery. In the interviews, experts have pointed out that traditional or common management systems are insufficient in satisfying the requirements for schedule, cost, quality, and safety. These systems are also inadequate in dealing with emergencies or severe accidents in megaprojects, because these projects have significant differences compared with normal ones, such as high complexity, numerous risks, and multiple stakeholders. Hong Kong, Zhuhai, and Macao are different in existing laws and regulations, and a three-level organizational structure with a decision-making mechanism of co-construction and management was adopted in construction management. Meanwhile, a technical expert group headed by the transportation department, the legal branch, and consulting corporations were involved to support the project construction in all directions. Additionally, a unique management strategy, which provided advantages in market resources, was also formed in the implementation of each sub-project. For example, a design–build delivery management method was used in the island tunnel engineering, and the general contracting mode of systematic integration was employed in traffic engineering (Zhang and Qiu, 2018). All these innovations and applications in project construction systems guaranteed the implementation of construction and project delivery.

#### 4.2.6 Organizational mode and structure

Many existing studies indicated the important role of organizational mode and structure in the megaproject's performance and success (Hu et al., 2015a; Lundrigan et al., 2015). Organizational structure (such as project breakdown structure and work breakdown structure) and organizational mode (such as construction headquarter mode and project corporation liability system) both play significant roles in the coordination within or between project teams in megaprojects (Le et al., 2014). For instance, a three-level organizational structure of "task force—three prefectural party committee—project legal counsel" was adopted in the construction management of the Hong Kong–Zhuhai–Macao Bridge. This kind of structure provided strong support to project construction and effectively ensured the implementation of project goals (Zhu et al., 2018).

Organizations in megaprojects have special political characteristics under the co-effects of government and markets in China (Li et al., 2018). The mode and structure of organizations in megaprojects have close relationships with administrations, which refer to: (1) leading groups and construction committees that are established or organized by central or local governments; (2) key project leaders that took on dual roles in governmental sectors and project management systems (Hu et al., 2015a). For example, the project corporation, Beijing–Shanghai High-Speed Railway Co., Ltd., was in fact established and operated by the Ministry of China Railway. This kind of organization mode contributed to achieving project goals more effectively (Le et al., 2014).

#### 4.2.7 Top management support

Different from normal construction projects, megaprojects are commonly managed by a management team called the Top Management Team, which plays an essential role in overseeing the projects (Lundrigan et al., 2015). Crosby (2012) pointed out that support from the top level is thought to be necessary for project success. Wang et al. (2017) stated that as a core group that determines

organizational development and project progress, the Top Management Team plays a critical role in coping with complex circumstances and systems and ensuring the implementation of construction project and its successful delivery. For the Three Gorges Dam, the first generation of the Top Management Team was headed by Youmei Lu, a Chinese academician, who has served from the beginning of the construction in 2003; while the second generation was headed by Yongan Li, who has served from 2003 to the end of the construction. They both made great contributions to the success of the Three Gorges Dam Project (Li, 2011).

#### 4.2.8 Project culture

Culture in a construction project has significant influence on the behavior of participating entities and employees, thus promoting performance improvement in the project (Zuo and Zillante, 2011). According to a questionnaire survey of 118 project teams from Northeastern US, project culture is significantly related to efficiency, which is significantly related with project success (Aronson, 2015). Megaprojects encompass multi-stakeholders, which mainly include the government, owners, constructors, sub-constructors, designers, supervisors, consultants, suppliers, and monetary institutes (Flyvbjerg, 2014; Hu et al., 2015a). Existing studies have demonstrated that project culture effectively facilitates governance, reduces conflicts, improves the work enthusiasm of employees, and maintains harmonious atmosphere within or between organizations in megaprojects (Jia et al., 2011; Yang et al., 2018; Zhai et al., 2017). It is interesting to note that in China, project goals or spirits are usually transformed into brief slogans, which are posted in the construction sites to motivate all the employees (e.g., in the case of the Hong Kong–Zhuhai–Macao Bridge, the slogan was "building a world-class bridge across the sea channel, providing high-quality services to the users, and becoming landmark buildings") (Zhu et al., 2018). These slogans are beneficial in establishing a close partnership between participating entities in megaprojects, which contributes to improving work efficiency and achieving project goals.

#### 4.2.9 Megaproject citizenship behavior

Megaproject citizenship behavior can be defined as discretionary positive behavior of project participants that is not required by formal contracts or regulations, but facilitates achievement of project goals (Yang et al., 2018). This kind of behavior has been proven to benefit the improvement of labor productivity and organizational efficiency, and further benefits the megaproject as a whole (Wang et al., 2018; Yang et al., 2018). At the team level, participating entities aim at not just maximum economic profits, but also better quality and performance of the whole project. Meanwhile, at the individual level, participating employees devote themselves to the construction of megaprojects, such as working with long hours and in extreme conditions to pursue good megaproject performance. Labor contests that are always launched by the public sectors are common method to motivate megaproject citizenship behavior. In order to win, participants must go beyond typical requirements and deliver high performance. The winners would not get economic awards. Instead, they would receive medals, as well as media's and governmental praise (Tang et al., 2013).

#### 4.2.10 Corporate reputation

The management of megaprojects is under close public supervision, so the topic of reputation requires special attention (Randeree, 2014). "Although corporate reputation is always ignored in the research of project management because of its indirect contributions on making benefits, participating entities should still take it into consideration to avoid accidents on quality, safety, and time during the construction process so as to prevent their reputation from being damaged, and strive to improve their performance to enhance their reputation, which contributes to increasing their brand value and competitiveness in the market", as one of the interviewees said. Specifically, "promoting the brand of China Communications Construction Co., Ltd. and establishing a world-class construction enterprise" in the case of the Hong Kong–Zhuhai–Macao Bridge is a typical corporate strategy. In order to maintain and enhance their reputation, the management layer tried their best to avoid accidents, solve conflicts with other organizations, and improve work performance, which promoted the completion of the project construction.

#### 4.2.11 Fulfillment of social responsibilities

Social responsibility of major infrastructure projects involves the policies and practices of the stakeholders participating throughout the entire project life-cycle that reflect responsibilities for the well-being of the wider society. Immigrant settlements, pollution control, ecology protection, employee health and safety, corruption resistance, disaster prevention and mitigation, and eradication of poverty are unique issues in megaprojects compared with those involved in general corporate social responsibility (Zeng et al., 2015). Social responsibilities are essential for sustainable developments in megaprojects because severe troubles, such as quality problems, environmental pollution, and conflict within the community may happen if there is lack of social responsibilities (Lin et al., 2018). According to the case study, fulfillment of social responsibilities by project teams and proper

solutions for social problems from participating enterprises play important roles in the process of managing megaprojects. For example, effective measures such as optimization of design scheme, improvement in construction methods, and ecological compensation were adopted in the construction of the Hong Kong–Zhuhai–Macao Bridge to minimize its negative effect on Sousa chinensis (Liu et al., 2018).

## 5 Conclusions

Although the investment and construction of megaprojects have increased in recent decades, which are expected to witness a continuous increasing trend in the next few decades, low performance always exists in megaproject management. This study focused on the driving factors of successful megaproject construction management. A mixed methodology, including literature review, case studies, and expert interviews, was employed in this research to determine the five categories of driving factors. A total of eleven drivers were finally identified based on three representative cases, namely, Beijing–Shanghai High-Speed Railway, Three Gorges Dam, and Hong Kong–Zhuhai–Macao Bridge.

The main research results are as follows: (1) The category of project environment includes two driving factors, namely, support from the government and the public. (2) The category of construction capabilities consists of accumulation and application of technology and experience, development and innovation of technology, and innovation and application of management system. (3) The category of organization includes organizational mode and structure, and top management support. (4) The category of positive culture and behavior comprises two drivers, including project culture and megaproject citizenship behavior. (5) The final category is requirements for sustainable development, which refers to corporate reputation and fulfillment of social responsibilities.

The findings of this study are expected to provide useful reference for both researchers and practitioners in two main aspects. First, this research identified eleven driving factors of successful megaproject management and displayed their priority ranking based on both the number of relevant events and the agreement scores from experts, which would help industrial professionals understand the key drivers behind successful megaprojects to further improve management more effectively. Second, the identified driving factors strengthened an emerging stream of future studies by systematically examining the relationships between identified driving factors and successful megaproject management, which could further provide decision makers with insightful information for conducting managerial strategies to enhance project success. However, this study has two major limitations. First, expert interviewees in this study were not all from the three selected cases, and the number of respondents could be further increased to test the validity of achieved conclusions. Second, the data used in this study were context-specific and could only be generalized after large-scale empirical analysis without contextual constraints. Nevertheless, as China plays an important role in the global construction market, the findings from this study are believed to be beneficial to construction professionals involved in megaprojects construction not only in China, but in other countries as well.

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