Developing a List of Key Performance Indictors for Benchmarking the Success of Construction Megaprojects

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Abstract

An increasing number of construction megaprojects have been invested and built worldwide over the past decades, yet effective indicators for assessing construction megaproject success (CMS) are not validated, which leads to an ineffective assessment of megaprojects. Therefore, current study attempts to identify a series of key performance indicators (KPIs) to assess the success of construction megaprojects. By conducting a questionnaire survey, research data were collected, which contained 129 valid replies from three groups of respondents, namely, owners, contractors, and designers from the Chinese construction industries. The SPSS software was employed to analyze five underlying dimensions for CMS: (1) “project efficiency,” (2) “key stakeholders’ satisfaction,” (3) “organizational strategic goals,” (4) “innovation and development of the construction industry” and (5) “comprehensive impact on the society.” Afterward, the fuzzy set theory was utilized to evaluate the KPIs’ effectiveness.

The results of this research can contribute to the body of knowledge in the field of megaproject management, and serve as theoretical foundation for the enhanced performance assessment of construction megaprojects and related management success.

Keywords: Construction Megaproject; Fuzzy Set Theory; Key Performance Indicators (KPIs); Project Success

Introduction

The term "mega" means great, large, vast, big, high, tall, mighty, or essential (Flyvbjerg 2014). Megaprojects are complex ventures that cost a large amount of money, take many years to develop and build, involve multiple stakeholders, and impact millions of people (Flyvbjerg 2014). Typically, megaprojects can be divided into three types, including scientific and technological megaprojects, military and national defense megaprojects, and construction megaprojects. Construction megaprojects refer to those permanent constructions, equipment, facilities, and the services they provide for people's living and social production. The primary purpose of this type of megaprojects lies in improving people's lives and facilitating social development (Sheng 2018). Over the past few decades, increasingly more construction megaprojects are being invested and built worldwide. As pointed out by Merrill Lynch, US$2.25 trillion annually has been spent on infrastructures in emerging markets between 2009 and 2012 (Caldas and Gupta 2017). Till now, the market for infrastructure construction still prospects no less than US$57 trillion for future investment by 2030 (Garemo et al. 2015).

Although the rapidly increasing investment and construction of megaprojects, the performance of project management and delivery is not always satisfactory. According to the research results of Flyvbjerg (2017), nine out of ten megaprojects are subject to cost overruns. This poor performance in megaproject delivery so-called "megaprojects paradox" was first identified by Flyvbjerg as well. The overruns of construction megaprojects are universally international phenomena, and this problem in developing countries is more severe than that in developed countries (Flyvbjerg et al. 2003). For example, according to Ansar et al. (2016), who collected and analyzed China's 95 railroad and railway projects (between 1984 and 2008), the average rate of cost overruns is 30.6%, and the delay rate of railways is 25%.

The Key Performance Indicators (KPIs) were initially proposed to measure the performance of projects and organizations throughout the construction industry (Cox et al. 2003). KPIs are considered to reflect the quality of outputs or outcomes that related to the key aspects of a project. However, at current stage, manageable number of KPIs are insufficient, particularly for the megaprojects. At the same time, generating too many KPIs can be a waste of resources (Chan and Chan 2004). Over the last decades, different concepts of KPI settings were proposed to benchmark studies in the field of construction engineering and management. For example, Yeung et al. (2012) developed a list of KPIs for measuring the success of construction projects in Hong Kong. Xu et al. (2012) identified six KPIs for the sustainability of building energy efficiency retrofit in hotel buildings. Shen et al. (2010) explored twenty key assessment indicators grouped into economic, social, and environmental dimensions, respectively for sustainability of infrastructure projects. Samra et al. (2018) selected four KPIs when developing a multi-objective framework for managing municipal integrated infrastructure. Praticò and Giunta (2018) proposed a KPI for railway tracks after taking both reliability, availability, maintainability & safety (RAMS) and lifecycle costing (LCC) into consideration.

However, megaprojects are not magnified version of smaller projects but a different kind of ones to lead. Consequently, the research outcomes based on normal-sized projects could not be applicable to megaprojects (Flyvbjerg 2017). Although studies on normal-sized projects have provided researchers and managers in practice with insightful information to help improve project success, the KPIs used to evaluate the success of construction megaprojects are not systematically explored yet (He et al. 2019). In this study, KPIs refer to those critical success criteria, to which a megaproject is assessed (Shenhar and Holzmann 2017).

Therefore, this research aims to conduct a systematic investigation on KPIs for measuring the success of construction projects to contribute to an insightful understanding of effective and successful ways of delivering such projects. Specifically, the three objectives of this research are (1) to explore a list of optional assessment indicators for measuring the CMS; (2) to identify different groups of assessment indicators for measuring the CMS by questionnaire survey; and (3) to identify a list of KPIs for measuring the CMS via fuzzy set method. The fuzzy set theory was established to address subjectivity and uncertainties (Zadeh 1965). This theory uses linguistic variables and membership functions with variations of grades. As such, it accepts a developing measurement of ambiguities and generates related concepts in the natural language (Zimmermann 2001). Since KPIs are usually fuzzy in nature, which involve experts' subjective judgement, the fuzzy set theory was utilized in this study to select the final KPIs for CMS in China.

According to the research aim and research objectives, the rest of this paper is organized as follows. Next is the literature review of existing studies on success criteria and indicators in projects and megaprojects respectively. Then research methods adopted in this research, including comprehensive literature review, expert interviews, questionnaire survey and fuzzy set method, are introduced. They are followed by identifying the option list of assessment indicators. Afterwards, data collection and analysis are discussed in detail. Then followed by the discussions of findings. Last but not least, the conclusions of this article are stated.

Previous Studies on Success Criteria/Indicators

Project Success Criteria/Indicators

The concept of project success is not new, but it is difficult to have a uniformed definition of it since researchers have defined it from various perspectives (He et al. 2019). For example, Tuman (1986) indicated that the full use of resources and achievement of desired goals could be considered as a successful project. The concept of success is multidimensional, ambiguous, and inclusive, which should be defined in a specific context (Ika 2009).

A criterion is "a principle or standard that a thing is judged by," thus, project success criteria could be defined as a group of principles or standards to judge or assess project success (Ika 2009). Over the years, the literature and understanding of project success criteria keep evolving (Müller and Jugdev 2012), and its developments can be divided into three main periods. In Period 1 (the 1960s-1980s) the theoretical and empirical works were somewhat limited (Belassi and Tukel 1996). During this period, the “Iron Triangle” (project management success), which mainly includes time, cost, and quality indicators, was mostly used as the criterion for measuring success (Jugdev and Muller 2005). Project management success, which aims to answer the question “was the project done right?” is generally viewed as the first dimension of project success (Cooke-Davies 2002). At this level, the principle of success is relatively simple, namely, to fully accomplish a project within the emerged constraints.

During Period 2 (the 1980s-2000s), although the “Iron Triangle” played a fundamental role in assessing success, other success criteria were welcomed (Atkinson 1999). Besides, it witnessed a shift from project management success to project/product success (Shenhar et al. 1997). Project success answers the question, “was the right project done?” (Cooke-Davies 2002). It is worth noting that it was the De Wit (1988) who first distinguished the concept of project success and project management success. Generally, apart from the “Iron Triangle,” this dimension considers other more indicators, especially stakeholders’ satisfaction and organizational benefits (Atkinson 1999). For example, Westerveld (2003) suggested that project success can be assessed by the following criteria, including appreciation by the client, project team, users, contractors, and other parties of interests.

Period 3 (21st century), is moving to criteria of complex projects, such as portfolio, program, megaproject success criteria. Moreover, strategic goals are considered when measuring project success (Ika 2009). This stage can be called consistent project success, which is intended to answer the question, "were the right projects done right, time after time?" (Cooke-Davies 2002). Typical criteria at this level include, such as be competitive in markets for scarce resources and effectiveness in implementing business strategy (Pinto and Morris 2004). For instance, Shenhar et al. (2001) found that project success is a strategic management concept, and the creation of economic value and competitive advantage should be considered in measuring project success.

Megaproject Success Criteria/Indicators

Megaprojects are different from normal-sized projects. They are entirely different in terms of their level of project aspiration, delivery time, complexity, and stakeholder involvement (Flyvbjerg 2014). Although numerous megaprojects have been built worldwide over the past decades, the "over budget, over time, under benefits, over and over again," which was called the "iron law of megaproject management," (Flyvbjerg 2011; Flyvbjerg 2014; Flyvbjerg 2017) is still prevalent today. Therefore, Megaprojects have been described as the "wild beast" of the project world (Alias et al. 2014). All megaprojects could be measured as unsuccessful if the threshold for assessing their success is attributed to the traditional measurement criteria, such as on time, on budget, on specifications (Pitsis et al. 2017). Consequently, it is necessary to take a broader perspective of project success when evaluating megaprojects (Söderlund et al. 2017).

Currently, researchers have conducted studies on megaproject success criteria. For example, Yan et al. (2019) pointed out that four dimensions of construction megaproject success, such as organizational strategic goals, performance of construction program, social harmony, and satisfaction of project stakeholders, should be highlighted. Similarly, Turner and Xue (2018) identified four levels of construction megaproject success. The first level is megaproject management success, which refers to delivering output with desired functionality and performance within a defined timeframe, cost, and other requirements. The second level is called megaproject success level 1A, meaning the project should deliver the desired outcome. They are then followed by megaproject success level 1B, referring to delivering positive net present value. The fourth level refers to megaproject success level 2, and it is often characterized by meeting the desired business or public need. It is worth noting that the impact on society could be one of the most distinguishing characteristics of project success and megaproject success (Shenhar and Holzmann 2017; Yan et al. 2019). As mentioned, megaprojects are well known for their large-scale investments, long duration and extraordinary levels of uncertainties and complexities (Flyvbjerg 2014). For these projects, maximizing economic benefits could not be the priority; instead, a harmonious relationship would improve the reputation of a company and create more business potentials in future (Yang et al. 2018).

Although existing studies have outlined different dimensions to assess the success of construction megaprojects, a systematic set of KPIs for such complex projects is still to be developed. As a result, previous research outcomes of both KPIs for normal-sized construction projects and success criteria for construction megaprojects are combined to explore KPIs for construction megaprojects in this paper.

Research Methods

Fig.1 illustrated the process of research in this study.

(Insert Fig. 1. here)

Firstly, to identify potential assessment indicators, the authors conducted a comprehensive literature review first. Two academic databases, namely Web of Science and Scopus, which are the world's largest web sources of peer-reviewed literature and demonstrated as robust tools to facilitate the review work such as Hu et al. (2015), were used to search the target articles in this study. When choosing the search codes in TITLE-ABSTRACT-KEYWORD search, the authors combined the words similar to ("megaproject" OR "megaprojects") and the words ("success" OR "successful"). Based on the definition of construction megaprojects mentioned above, the words similar to "megaproject" included: (1) "mega project" or "mega-project" which are also applicable in this research filed; (2) "giga" or "tera" instead of "mega" to classify projects relatively bigger than megaprojects (Flyvbjerg 2014); (3) other words used to connote "megaproject" in academic publications, such as "major projects," "complex projects," "large/grand-scale projects," "large projects," "public works projects," "transportation infrastructure projects," "public construction projects" and "tera/giga/giant project and program" (Li et al. 2018). In this study, only peer-reviewed journal articles published from 2000 to 2018 were considered. During further review of these filtered articles, two main criteria were used in paper selection: (1) papers mainly focused on megaprojects, and (2) papers related to the success criteria of projects.

Secondly, expert interviews were adopted to validate the indicators obtained from the literature review as well as supplement several indicators according to experts' suggestions. The interview is a kind of practice through a qualitative strategy, which is designed to identify the core themes of the real world of the subjects by recording and analyzing the underlying meanings from the interviewees' statements (Kvale and Brinkmann 2009). This approach has been widely used in construction engineering and management research, such as Yang et al. (2018) and Hu et al. (2015). The experts' selection is generally determined by the disciplinary areas of expertise required by the topic under study. In this study, a two-step approach was adopted to select the experts. Official invitation letters requesting support from the members of the Research Institute of Complex Engineering Management (http://ricem.tongji.edu.cn/#/Home), which includes one academician in China, more than 30 industry researchers and more than 50 postgraduates and Ph.D. students in the area of complex project and megaproject management, were sent. The members were asked to nominate qualified practitioners (within and outside the institute) based on the predefined criteria in the letter. The predefined criteria are listed below.

1) Possess an extensive working experience (at least 5 years) and a good knowledge of construction megaproject management in China;

2) Have recent hands-on experience in at least one construction megaproject in China; and

3) Possess expertise and good knowledge of the concept of project and megaproject success.

This step produced a pool of potential candidates for the interviews. These target interviewees were then contacted and asked if they were willing to participate in the study and what time they would be available for the interviews. Ten such practitioners agreed to participate in the study.

Then the combined literature review and expert interviews in this study proposed a set of optional CMS assessment indicators, which were grouped into five categories, including project efficiency, key stakeholders' satisfaction, organizational strategic goals, innovation and development of the construction industry, and comprehensive impact on the society.

Thirdly, based on the optional indicators for assessing the success of construction megaproject, a questionnaire survey aiming to different groups of experts was implemented to analyze the significance of each assessment indicator. The selection process of questionnaire respondents was similar to that of selecting interviewees. Briefly speaking, the authors sent the questionnaires to the members of the Research Institute of Complex Engineering Management and asked them to help complete or distribute the questionnaire to qualified respondents. Respondent experts (excluded who were in interviews) were required to scale the importance of KPIs from 1 to 5 (Likert scale).

Finally, both the reliability and validity of the survey, which represent the basis for data analysis, were checked. Generally, reliability can be tested by examining the consistency with which different items express the same concept (De-Vaus 2001). Cronbach's alpha coefficient method, which was one of the most common approaches to test the reliability, was used in this study. Cronbach's alpha (Cronbach 1951) measures the average correlation or internal consistency amongst the factors in the survey and estimates the reliability of a questionnaire set (Dawson et al. 1996). The value of Cronbach's alpha ranges from 0 to 1 in accordance with the increase in reliability (Santos 1999). Normally, a value of Cronbach's alpha of 0.7 or higher is acceptable, which indicates a reliable group classification set (Kim and Mueller 1978). Afterward, based on reliable and valid data, a fuzzy set model was conducted to identify the final KPIs. The detailed calculations and procedures for identifying KPIs will be discussed in the Section of "Analysis of KPIs with Fuzzy Set Theory."

Option List of Assessment Indicators

Indicators Based on Literature Review

Table 1 lists the success indicators summarized in the literature review. As shown, according to the comprehensive literature review, the authors identified four groups of success indicators, including project management success, stakeholders' satisfaction, organizational strategic goals, and impact on society.

(Insert Table 1. here)

Indicators After Expert Interviews

In this study, the interview method was employed to research the success criteria for assessing the CMS after a literature review, which aims to validate the results acquired from the literature review and provide a solid foundation for questionnaire design and survey. Semi-structured interviews were conducted in Shanghai (June and July in 2018) to identify the success criteria for the construction megaprojects in China. Ten interviewees with abundant practical experience and academic knowledge of construction megaproject management were selected. Seven industrial interviewees were with extensive working experience in construction megaproject engineering and management, and three academic researchers were related to the large-scale and complex megaprojects. Fig. 2 shows the experts' background information.

(Insert Fig. 2. here)

Each interview took from 45 minutes to one hour of time, which was conducted in a semi-structured manner with richer feedback (Lucko and Rojas 2010). The interview outline included three major parts, including a brief introduction of the interviewer (e.g., research interests), several essential notes of this interview (e.g., interview aim), and formal interview questions. The structured interview part included two sections, namely the respondents' personal information and their opinions on success indicators for assessing the success of construction megaprojects. Questions were open, and interviewees were encouraged to express their views and add any details that they considered to be necessary.

(Insert Table 2. here)

Based on the literature review and interviews, preliminary indicators for measuring the success of construction megaprojects were established as the foundation of the questionnaire design. It consists of twenty-three success indicators grouped into five categories (Table 2), and the framework is shown in Fig. 3. As illustrated in Fig. 3, optional indicators were categorized into five types, namely “project efficiency,” “key stakeholders’ satisfaction,” “organizational strategic goals,” “innovation and development of the construction industry,” and “comprehensive impact on the society.” The “project efficiency” mainly focuses on project level, the “key stakeholders’ satisfaction” and “organizational strategic goals” are mostly specific on organization level, the “innovation and development of the construction industry” is primarily to industry level, and the “comprehensive impact on the society” is mainly on society level. The “project efficiency” is on short-term benefits, while the other three categories are majorly on long-term benefits.

(Insert Fig. 3. here)

Data Collection and Analysis

Results from questionnaire surveys were used to validate the theoretical framework for measuring the success of construction megaprojects. At the same time, a pilot study was conducted to test the questionnaire’s adequacy and readability. Five experts with more than ten years’ working experience in megaproject management, who were not involved in the expert interview stage, were invited in the pilot study and their feedbacks were also incorporated for the design of questionnaire.

The final questionnaire included three sections. The first section contained questions about necessary project information, such as the name of the megaproject, the commencement year of the megaproject, and the city where the megaproject is located. Respondents were required to select one construction megaproject that they recently participated in and take this megaproject as a reference to answer the questions in the questionnaire. The second section was developed by the basis of the twenty-three success criteria proposed in Table 2. The respondents were required to rate the importance of each success criterion on a five-point Likert-type scale (1=strongly disagree; 2= disagree; 3=neutral; 4=agree; 5=strongly agree). The final section of the questionnaire was background information of respondents, such as years of experience in megaproject management. The background information can enhance the data quality of the second section in the questionnaire (Yan et al. 2019).

The questionnaire survey was conducted between June and August 2019. According to the study of Zheng et al. (2019), the cost of one construction megaproject over one billion RMB (Chinese currency) is only considered in the survey. Consequently, there were 300 pieces of questionnaires sent in total by email and online linkage, of which 129 were deemed to be valid replies and were analyzed. The response rate was 43%, which is higher than the average (10%-15%) (Xu et al. 2012), among which 47 respondents were from owners (government officials directly related to the project, owner's team member and consultants commissioned by the owner), 69 respondents were from contractors, and 13 respondents were from designers (designers commissioned by the owner and design consultants). The backgrounds of respondents are shown in Table 3.

According to the survey, statistical calculations among assessment indicators were conducted. As shown in Table 4, x_1 indicated "Meeting time, quality, budget goals" with an mean value of 4.287 (±0.886). In different responding groups, the indicators' scores were also different. As shown in Table 4, x_1 was equivalent to 4.340 (±0.939) for the owners' group, while this value became 4.377 (±0.824) from contractors. This discrepancy among different groups of experts should be noted in that they could prioritize assessing megaproject success with different perceptions (Shen et al. 2010).

(Insert Table 3. here)

Reliability Analysis

As mentioned in the part of "Research Methods," the Cronbach's alpha coefficient was employed to test the data reliability in this study. If Cronbach's alpha coefficient is no less than 0.7, it proves that this is a reliable set of items (Kim and Mueller 1978). Calculations for Cronbach's alpha coefficient were derived for five-factor groups, including "project efficiency," "key stakeholders' satisfaction," "organizational strategic goals," "innovation and development of the construction industry," and "comprehensive impact on society," from the information provided by the 129 valid respondents. Cronbach's alpha coefficient for each factor group is 0.823, 0.889, 0.876, 0.911, and 0.908, respectively, which all exceed the value of 0.7, suggesting the reliability of the questionnaire survey.

(Insert Table 4. here)

Analysis of KPIs with Fuzzy Set Theory

Data used for the identification of KPIs were derived from the questionnaires. However, experts' opinions could be influenced by their fuzziness. As a result, fuzzy set theory was adopted to assist in analyzing the KPIs (Xu et al. 2012). This theory is very suitable and appropriate to address complex issues because systems in real words were affected by uncertain and even wrong information (Tah and Carr 2000). After first introduced by Zadeh (1965), it has been applied widely in many research areas, such as engineering, management, and social science (Xu et al. 2012). For instance, Tah and Carr (2000) used it to evaluate construction project risk in terms of time, cost, quality, and safety performance measures. Shen et al. (2010) employed this theory to identify the key indicators for evaluating the sustainability performance of infrastructures.

Compared to traditional theory, fuzzy theory generates the membership value from 0 to 1, which determines the degree of membership of a given set (Tah and Carr 2000). That is, the grades of membership in the fuzzy set may fall anywhere in the interval [0, 1], indicating that an element is not a member of the set if the grade of membership falls on the degree of 0. Conversely, in terms of degree 1, it means that an element belongs to the set (Hadipriono 1988). For instance, a fuzzy set is (A, m), where X is a set and m is the degree of membership of the set A ($\mathrm{m}: \mathrm{A} \rightarrow [0,1]\mathrm{m}: \mathrm{A} \rightarrow [0,1]$). For each $\mathrm{x} \in \mathrm{A}\ \mathrm{x} \in \mathrm{A}$, m(x) is the grade of membership of x in (A, m). if m(x)=0, then x is called not included in the fuzzy set (A, m); if m(x)=1, then x is called fully included; if $0 < \mathrm{m}(\mathrm{x}) < 1$, x is called fuzzy member. For a finite set $\mathrm{A} = \{x_1, \dots x_n\}$, the fuzzy set (A, m) is denoted by $\left\{\frac{m(x_1)}{x_1}, \dots m x_n / x_n\right\}$. $\mathrm{m}(x_i)/x_i$ indicates the degree of membership of x_i in A is $\mathrm{m}(x_i)$.

The importance of each indicator is scored from 1 to 5. Here, the value of 3 was set as a neutral level and 4 as an essential level. The standard deviations were also included for the determination of KPI sets, a higher significance of which corresponds to a lower SD value. In addition, the parameter Z (1) was arranged as an indicator of the effectiveness of KPIs.

$$Z = (\text{Mean} - 4)/\text{SD} \quad (1)$$

According to the statistics theory, 95% probability that an indicator is ranged within $[4, \infty]$ exists when Z=1.65 (Xu et al. 2012).

However, the survey based scores are not in a normal distribution probably due to subjective judgment by respondents (Shen et al. 2010). Therefore, a fuzzy distribution was used instead of a normal distribution. Based on the fuzzy set theory, the degree of membership of the variables was used to categorize their belonging groups in the fuzzy set (Zimmermann 2001).

$$\mathrm{m}(x_i) = \int_4^{\infty} f(x_i)dx = 1 - P_f \quad (2)$$

Where P_f refers to the possibility that the indicator does not belong to the group.

A benchmark value is needed to identify whether an indicator is a KPI. That is, $\mathrm{m}_A(x_i)$ should meet a given value (λ) if an indicator x_i can be considered as a critical assessment indicator. In this study, the questionnaire data is from three major groups of experts, namely, owners, contractors, and designers. Thus, $\widetilde{A_O}$, $\widetilde{A_C}$ and $\widetilde{A_D}$ were represented as three different KPI fuzzy set respectively. Base on the calculation results shown in Table 4 and Equation (1) and (2), the value of the parameter Z and $\mathrm{m}(x_i)$ can be calculated. The results of $m_O(x_i)$, $m_C(x_i)$ and $m_D(x_i)$ are shown in Table 5.

According to previous study (Yager 1980), the integrated fuzzy set can be described as follows:

$$\tilde{A} = \widetilde{A_O} \cup \widetilde{A_C} \cup \widetilde{A_D} = \left\{x, m_{\tilde{A}_O \cup \tilde{A}_C \cup \tilde{A}_D}(x)/x \in X\right\} \quad (3)$$

Where

$$m_{\tilde{A}_O \cup \tilde{A}_C \cup \tilde{A}_D} = min\left\{1, \left(m_{\tilde{A}_O}(x)^n + m_{\tilde{A}_C}(x)^n + m_{\tilde{A}_D}(x)^n\right)^{1/n}\right\} \quad (4)$$

In this study, n is 23, which refers to the number of indicators. According to the Equation (3) and (4), the results of the final integrated fuzzy set $\mathrm{m}(x_i)$ can be found in the last column of Table 5.

(Insert Table 5. here)

To determine the final KPIs, the λ-cut was used, which transferred a fuzzy set to a standard set. According to the study of Tervonen et al. (2009), a value for λ within the range of 0.5 and 0.8 is effective for analysis. In this study, $\lambda = 0.7$ was adopted as the criterion to select KPIs.

The procedures for identifying KPIs are illustrated in a flow chart. Fig. 4 shows that have a clear map on how to calculate and identify a KPI in this study. The indicator x_i was selected as a KPI when its integrated $\mathrm{m}_A(x_i)$ was equal to or more than 0.7.

(Insert Fig. 4. here)

Discussions of Findings

This section discusses the research findings shown in Fig. 5 and Table 5. As illustrated in Fig. 5, a total of nine KPIs were identified. They are project efficiency (meeting regulations or specifications, meeting health, safety and environment (HSE) goals, meeting designed function and delivering value/services that the public needed), key stakeholders' satisfaction (owner's satisfaction, government's satisfaction), organizational strategic goals (improved brand/reputation), and comprehensive impact on the society (enhancing people's national pride and confidence, delivering social-economic benefits to the community/local).

(Insert Fig. 5. here)

Project efficiency

As shown in Fig. 5, a total of three indicators were identified as the KPIs under this construct. Among them, the indicator "meeting regulations or specifications" is ranked as the most important with the $\mathrm{m}_{\tilde{A}}(x_3)$ of 0.791. Then followed by the indicator "meeting health, safety and environment (HSE) goal with the $\mathrm{m}_{\tilde{A}}(x_2)$ of 0.782. "Meeting designed function and delivering value/services that the public need" is the last one in this category with $\mathrm{m}_{\tilde{A}}(x_4)$ of 0.722.

"Meeting regulations or specifications" is an essential prerequisite for the smooth delivery of projects. The client would not accept an unqualified project. Compared with normal-sized projects, megaprojects tend to produce critical facilities that are highly regulated (Greiman 2013). The reason could be that megaprojects are always receiving great attention by the government, the public, and the media considering its characteristics, including large-scale investment, political importance, far-reaching impacts on the environment, society, and welfare. In China, many megaprojects are government-funded, which the money is actually from taxes (Le et al. 2016). Thus, the public would pay more concerns on the news of megaprojects than other types of projects. Besides, governmental sectors would also implement stricter regulations to make the project delivered smoothly. For example, the audit sector could implement a more rigorous audit process to improve transparency and better oversight (Greiman 2013). Participants in megaprojects could take a higher standard of regulations or specifications. For example, in the construction of Beijing-Shanghai High-Speed Railway, participants put forward the slogan of “climbing the peak, to be world-class” (Wang 2016). Similarly, in another mega infrastructure project, the Three Gorges Dam, the leader pointed out that this megaproject must be built with world-class standards (Li 2011).

“Health, Safety, and Environment (HSE) goals” is always an important criterion to assess the success of projects because the construction industry is characterized with a high rate of fatalities (Hare et al. 2006); meanwhile, projects typically pose a large negative environmental impact, such as consumption of materials and resources, consumption of large amount of energy, and generation of solid waste (Chan and Chan 2004; Wang et al. 2018; Yan et al. 2019). This indicator could be more prioritized in assessing megaproject success. This is because once an accident occurs during the construction of a megaproject, it would often lead to more severe consequences and widespread public opinion.

Safety issues in China's infrastructure projects are prevalent. For instance, according to the statistics of the World Health Organization, road fatalities in China are some of the highest in the world (18.8 fatalities/100,000 inhabitants/yr.), and the number in the U.K is only 2.9. The main reasons that lead to this phenomenon are poor technical design and road quality issues (WHO 2015). But now, with the increasing importance of safety and environment related issues in China, "health, safety and environment" problems in projects are getting more and more attention. For example, as said by Kecen Han, the Shanghai Airplane Design and Research Institute and administrative commander of the C919 airliner project, "*Time is not the most important element; the top priority is to guarantee the safety of the plane'. . . . Words that would not have been heard a decade ago, when the 'old normal' in China was speed, first and foremost.*" (Chen 2014). In the Hong Kong-Zhuhai-Macau Bridge, Xihong Dai, Vice Minister of Safety and Environmental Protection Department of Hong Kong-Zhuhai-Macao Bridge Administration, used to praise this megaproject achieve the goal of "zero injury, zero pollution, zero accident" (Gao et al. 2018).

The last key criterion in this group is "Meeting designed function and delivering value/services that the public need." The primary purpose of construction megaprojects lies in improving people's lives and facilitating social development (Sheng 2018). Without considering the value, the project may be regarded as a failure. This is because the public usually are clients or users of megaprojects, then the value or services that the public need should not be ignored. Some infrastructures have not been efficiently used as they cannot meet the value or provide services that the public actual need (Shen et al. 2010).

Key stakeholders' satisfaction

Only two indicators were identified as KPIs in this group of key stakeholders' satisfaction, namely “owner’s satisfaction” with the $\mathrm{m}_{\tilde{A}}(x_6)$ of 0.848 and “government’s satisfaction” with the $\mathrm{m}_{\tilde{A}}(x_5)$ of 0.835. Stakeholders are the receivers and implementers of success indicators; thus, their needs should be satisfied. Many studies have shown project stakeholders’ satisfaction plays a critical role in sustaining success (Hu et al. 2015). Usually, the owner is at the core of all stakeholders in a construction project (Yan et al. 2019), and they are critical to ensuring project success (Winch and Leiringer 2016). Thus, it is not difficult to understand that the indicator “owner’s satisfaction” would have a priority in this group.

The project owner (assets holder) and sponsor (financing party) sometimes can serve in a dual role as consultant and funder (Greiman 2013). Generally, owners and sponsors are separated in private funded projects. However, in construction megaprojects, the government usually plays diverse roles, such as decision-maker, funder, project manager, and operator. Taking the Hong Kong-Zhuhai-Macau Bridge as an example, in view of the particularity of the co-construction and management of Guangdong, Hong Kong and Macau and based on the existing laws and regulations, the innovative decision-making mechanism for the co-construction and management of the three local governments is established (Gao et al. 2018). In this super project, governments including central government, local government (the People’s Government of Guangdong Province, the Government of Hong Kong Special Administrative Region, the Government of Macau Special Administrative Region) and related governmental sectors (e.g., National Development and Reform Commission) are involved in this megaproject (Qiu et al. 2019). Even if they play different roles in the project, they all play an essential role in the successful delivery of it. Therefore, the indicator “government satisfaction” should be considered as a KPI in the group of key stakeholders’ satisfaction.

Organizational strategic goals

Two KPIs were identified in the group of organizational strategic goals, including the indicator “improved brand/reputation” with the $\mathrm{m}_{\tilde{A}}(x_{12})$ of 0.734 and the indictor “new market or improved market share” with the $\mathrm{m}_{\tilde{A}}(x_{11})$ of 0.721. Typically, improving company’s brand or reputation is always viewed as an important success criterion in organizational goals (Shenhar et al. 2001). Companies that participate in megaprojects usually have already achieved great success in certain areas, and they would value more about enterprise’s development or other long-term interests instead of only focusing on maximizing economic benefits (Li and Liang 2014; Yang et al. 2018). And a good brand or reputation can improve a company’s competitiveness, thereby contribute to getting more long-term potential interests further (He et al. 2019). Additionally, participants are mostly state-owned enterprises or successful enterprises highly associated with the government (Hu et al. 2015). Thus, many project managers or leaders hold part-time positions in semi-official industry associations; the phenomenon is called Participating Entities’ Government Connection (Le et al. 2016). For instance, in the Beijing-Shanghai High-speed Railway (BSHSR) of China. Peiyan Zeng, who is the former vice-premier of the State Council of the People Republic of China, serves as the group leader in Construction Leading Group of the BSHSR. And vice groups leaders are Ping Zhang, director of the Development and Reform Commission; Guangzu Sheng, minster of Railways; Jiwei Lou, deputy sectary of the State Council. A similar phenomenon is also in Construction Leading Group Office of BSHSR, BSHSR Co., Ltd and Construction Headquarter of BSHSR (Beijing-Shanghai High-speed Railway Co. 2012). Participating in the construction of megaprojects is one of the ways for companies to maintain or strengthen their ties with the government (Li et al. 2011). And companies with a good brand or reputation are more likely to get the favor of the government, thereby to obtain more resources such as higher legitimacy and market assess rights (Li and Liang 2014). Meanwhile, managers or leaders from good reputation companies, especially from state-owned enterprises, are also more likely to get political promotion. And the pursuit of political promotion may also motivate them to perform better in megaprojects, thereby could further contribute to enhancing the company's brand or reputation.

Similar to the indicator "improved brand or reputation," the indicator "new market or improved market share" is also belongs to a long-term organizational goal. This success criterion is identified as a KPI in the group of organizational strategic goals, which is in line with other previous studies, such as Yan et al. (2019) and Shenhar et al. (2001). As mentioned, participating in the construction of megaprojects is a good opportunity to show participants' strength and good brand image. And brand effects and experience of megaproject construction can help companies gain more project opportunities and market share (Chi et al. 2011; Xing and Chalip 2009). Compared with short-term benefits, long-term goals such as new markets or improved market share are more valued by the participants (Turner and Muller 2003). What's more, megaprojects tend to produce significant socio-economic impacts. According to the study of (Ernst and Terco 2011), the World Cup in June and July 2014 and the Summer Olympic Games in 2016 in Brazil could bring about $100 billion and create 120 thousand new jobs. In the U.K, Graham (2007) used data for the London metropolitan region to show how a new rail line, Crossrail, would lead to an increase of social-economic benefits.

Comprehensive impact on society

Two KPIs were identified in the group of extensive impact on the society, including the indicator "enhancing people's national pride, confidence and cohesion" with the $\mathrm{m}_{\tilde{A}}(x_{23})$ of 0.728 and the indictor "delivering social-economic benefits to the communities/local" with the $\mathrm{m}_{\tilde{A}}(x_{20})$ of 0.705. Typically, megaprojects often cause wide public concern. When the project is successfully delivered, the public would feel pride of it. Sometimes this feeling could be very important to help main social harmony and stability, especially for China, with a population of 1.4 billion (Wang and Cui 1993). Additionally, megaprojects are usually with political importance (Flyvbjerg 2014). For example, the Qinghai-Tibet Railway is the highest and longest plateau railway in the world with a total length of 1,142 kilometers. According to the requirements of the Ministry of Railways, the People's Republic of China, the Qinghai-Tibet Railway company which is in charge of the construction of this megaproject, should take promoting national unity and cohesion as a political task. Through the five-year construction of the Qinghai-Tibet Railway, the economy of Qinghai and Tibet has been developed, and the societal cohesion has been improved (Wang 2008).

Conclusions

Numerous construction megaprojects have been built worldwide to expand investment in construction activities over the past decades. However, little research has been done to explore assessment indicators and KPIs for evaluating the success of construction megaprojects. Therefore, the focal point of this research is to identify what constitutes construction megaproject success. First, comprehensive literature review and expert interviews were used to explore the option list of assessment indicators. Second, the questionnaire survey was adopted to analyze the significance of each assessment indicator, and a total of 129 construction industry practitioners responded in China. Afterward, five categories of crucial assessment indicators were revealed, including "project efficiency," "key stakeholders' satisfaction," "organizational strategic goals," "innovation and development of the construction industry," and "comprehensive impact on the society." Third, the fuzzy set theory was employed to identify nine KPIs for evaluating the success of construction megaprojects. They are "meeting regulations or specifications," "meeting health, safety and environment (HSE) goals," "meeting designed function and delivering value/services that the public needed," "owner's satisfaction," "government's satisfaction," "improved brand/reputation," "enhancing people's national pride and confidence," "delivering social-economic benefits to the community/local."

This study contributes to the body of knowledge, mainly in two ways. On one hand, this study identified twenty-three key success indicators grouped into five categories for assessing the success of construction megaprojects. And these could be used by construction practitioners to understand better success indicators and further to manage construction megaprojects effectively. On the other hand, the fuzzy set theory has been used to develop the KPIs for a wide range of application. Moreover, the application of KPIs facilitate decision-makers to optimize solutions and to maximize construction megaproject success potentials. The results of this research can be used to guide the performance assessment in practice.

As for the limitations of this study, since all the participants in expert interviews and questionnaire survey were from China, the application of findings in this paper is limited by the context-specific data sources to some extent. Nevertheless, with China becoming a leading country in global construction megaprojects, research findings in this paper can help scholars and practitioners in other countries/regions understand KPIs for assessing megaproject success in China. In future research, it is possible to conduct various context-specific studies by using the procedure and methods in this research.

Data Availability Statement

Data generated or analyzed during the study are available from the corresponding author by request.

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References

Alias, Z., Zawawi, E. M. A., and Yusof, K. (2014). "Determining Critical Success Factors of Project Management Practice: A conceptual framework." *International Conference on Quality of Life*, Sabah, Malaysia, 9.

Ansar, A., Flyvbjerg, B., Budzier, A., and Lunn, D. (2016). "Does infrastructure investment lead to economic growth or economic fragility? Evidence from China." *Oxford Review of Economic Policy*, 32(3), 360–390.

Atkinson, R. (1999). "Project management: cost. time and quality, two best guesses and a phenomenon, its time to accept other success criteria." *International Journal of Project Management*, 17(6), 337-342.

Beijing-Shanghai High-speed Railway Co., L. (2012). *Report on Beijing-Shanghai High-speed Railway*, China Railway Publishing Press, Beijing.

Belassi, W., and Tukel, O. I. (1996). "A new framework for determining critical success/failure factors in projects." *International Journal of Project Management*, 14(3), 141-152.

Caldas, C., and Gupta, A. (2017). "Critical factors impacting the performance of mega-projects." *Engineering, Construction and Architectural Management*, 24(6), 920-934.

Chan, A. P. C., and Chan, P. L. (2004). "Key performance indicators for measuring construction success." *Benchmarking: An International Journal*, 11(2), 203-221.

Chen, S. (2014). "As China's Economy Matures, It Trades Speed for Build Quality on Big Projects." *South China Morning Post*.

Chi, C. S., Ruuska, I., Levitt, R. E., Ahola, T., and Artto, K. (2011). "A Relational Governance Approach for Megaprojects Case Studies of Beijing T3 and Bird's nest projects in China." *Engineering Project Organizations Conference*, Estes Park, Colorado.

Cooke-Davies, T. (2002). "The "real" success factors on projects." *International Journal of Project Management*, 20(3), 185-190.

Cox, R. F., Issa, R. A., and Ahrens, D. (2003). "Management's Perception of Key Performance Indicators for Construction." *J. Constr. Eng. Manage.*, 129(2), 142-151.

Cronbach, L. (1951). "Coefficient alpha and the internal structure of tests." *Psychometrika*, 16, 297-334.

Dawson, J., Fitzpatrick, R., Carr, A., and Murray, D. (1996). "Questionnaire on the perceptions of patients about total hip replacement." *The Journal of Bone and Joint Surgery (British volume)*, 78(2), 185-190.

De-Vaus, D. A. (2001). *Research design in social research*, Sage Publications, London.

De Wit, A. (1988). "Measuring project success: An illusion." *International Journal of Project Management*, 6(3), 164-170.

Ernst, and Terco, Y. (2011). "Sustainable Brazil: social and economic impacts of the 2014 World Cup."

Flyvbjerg, B. (2011). "Over Budget, Over Time, Over and Over Again: Managing

Major Projects." *The Oxford Handbook of Project Management*, Oxford University Press, Oxford, 321-344.

Flyvbjerg, B. (2014). "What You Should Know About Megaprojects and Why: An Overview." *Project Management Journal*, 45(2), 6-19.

Flyvbjerg, B. (2017). "Introduction: The Iron Law of Megaproject Management." *The Oxford Handbook of Megaproject Management*, Oxford University Press, Oxford, 1-18.

Flyvbjerg, B., Hon, C. H. K., and Rothengatter, W. (2003). *Megaprojects and Risk: An Anatomy of Ambition*, Cambridge University Press, Cambridge.

Gao, X., Sheng, Z., Wang, L., and Liu, Z. (2018). "Social responsibility in infrastructure mega-projects: A case study of ecological compensation for Sousa chinensis during the construction of the Hong Kong-Zhuhai-Macao Bridge." *Frontiers of Engineering Management*.

Gao, X., Zhang, J., and Zhu, Y. (2018). "Construction management and technical innovation of the main project of Hong Kong–Zhuhai–Macao Bridge." *Frontiers of Engineering Management*.

Garemo, N., Matzinger, S., and Palter, R. (2015). "Megaproject: The good, the bad, and the better." McKinsey Company, New York.

Graham, D. J. (2007). "Agglomeration, productivity and transport investment." *Journal of Transport Economics And Policy*, 41, 317-343.

Greiman, V. A. (2013). *Megaproject Management: Lessons on risks and project management from the Big Dig*, John Wiley & Sons, Hoboken, New Jersey.

Hadipriono, F. C. (1988). "Fuzzy set concepts for evaluating performance of constructed facilities." *Journal of performance of constructed facilities*, 2(4), 209-225.

Hare, B., Cameron, I., and Duff, R. A. (2006). "Exploring the integration of health and safety with pre-construction planning." *Engineering, Construction and Architectural Management* 13(5), 438-450.

He, Q., Wang, T., Chan, A. P. C., Li, H., and Chen, Y. (2019). "Identifying the gaps in project success research： A mixed bibliographic and bibliometric analysis." *Engineering, Construction and Architectural Management*, 26(8), 1553-1573.

He, Q., Xu, J., Wang, T., and Chan, A. P. C. (2019). "Identifying the driving factors of successful megaproject construction management: Findings from three Chinese cases." *Frontiers of Engineering Management*, 1-12.

Hu, Y., Chan, A. P. C., and Le, Y. (2015). "Understanding the Determinants of Program Organization for Construction Megaproject Success: Case Study of the Shanghai Expo Construction." *J. Manage. Eng.*, 31(5), 1-10.

Hu, Y., Chan, A. P. C., Le, Y., and Jin, R. (2015). "From Construction Megaproject Management to Complex Project Management: Bibliographic Analysis." *J. Manage. Eng.*, 31(4), 1-11.

Ika, L. A. (2009). "Project Success as a Topic in Project Management Journals." *Project Management Journal*, 40(4), 6-19.

Jugdev, K., and Muller, R. (2005). "A retrospective look at our evolving understanding of project success." *Project Management Journal*, 36(4), 19-31.

Kim, J. O., and Mueller, C. W. (1978). *Factor analysis: Statistical methods and practical issues*, Sage Publications, London.

Kvale, S., and Brinkmann, S. (2009). *InterViews: Learning the Craft of Qualitative Research Interviewing*, SAGE Publications.

Le, Y., Bai, J., Li, Y., and Zheng, X. (2016). "The factors and mechanism of administrative incentives on top managers in Chinese major infrastructure projects-based on 208 samples in 43 projects." *Chinese Journal of Management*, 13(8), 1164-1173.

Le, Y., Xu, J. Y., and Bai, J. (2016). "Evolutionary Analysis of Mega Infrastructure Investment and Finance Scheme in China from Perspective of Institutional Transition." *Journal of Tongji University (Natural Science)*, 44(8), 1272-1279.

Li, P. (2011). *Opinions on the Three Gorges Project by Li Peng*, China Three Gorges Publishing Press, Beijing.

Li, X. H., and Liang, X. (2014). "A Confucian Social Model of Political Appointments among Chinese Private-Firm Entrepreneurs." *Academy of Management Journal*, 58(2), 592-617.

Li, Y., Lu, Y., and Peng, Y. (2011). "Hierarchical structuring success factors of project stakeholder management in the construction organization." *African Journal of Business Management*, 5(22).

Li, Y., Lu, Y., Taylor, J. E., and Han, Y. (2018). "Bibliographic and comparative analyses to explore emerging classic texts in megaproject management." *International Journal of Project Management*, 36(2), 342-361.

Lucko, G., and Rojas, E. M. (2010). "Research Validation: Challenges and Opportunities in the Construction Domain." *Journal of Construction Engineering and Management*, 136(1), 127-135.

Müller, R., and Jugdev, K. (2012). "Critical Success Factors in Projects: Pinto, Slevin and Prescott-the elucidation of project success." *International Journal of Managing Projects in Business*, 5(4), 757-775.

Pinto, J. K., and Morris, P. W. G. (2004). *The wiley guides to managing projects*, John Wiley & Sons, New Jersey.

Pitsis, A., Clegg, S., Freeder, D., Sankaran, S., and Burdon, S. (2017). "Megaprojects redefined-complexity vs cost and social imperatives " *International Journal of Managing Projects in Business*, 11(1), 7-34.

Praticò, F. G., and Giunta, M. (2018). "Proposal of a Key Performance Indicator for Railway Track Based on LCC and RAMS Analyses." *J. Constr. Eng. Manage.*, 144(2), 04017104.

Qiu, Y. M., Chen, H. Q., Sheng, Z. H., and Cheng, S. P. (2019). "Governance of institutional complexity in megaproject organizations." *International Journal of Project Management*, 37(3), 425-443.

Samra, S. A., Ahmed, M., Hammad, A., and Zayed, T. (2018). "Multiobjective Framework for Managing Municipal Integrated Infrastructure." *J. Constr. Eng. Manage.*, 144(1), 04017091.

Santos, J. R. A. (1999). "Cronbach's alpha: A tool for assessing the reliability of scales." *Journal of Extension*, 37(2), 1-5.

Shen, L. Y., Wu, Y. Z., and Zhang, X. L. (2010). "Key Assessment Indicators for the Sustainability of Infrastructure Projects." *J. Constr. Eng. Manage.*, 137(6), 441-451.

Sheng, Z. H. (2018). *Fundamental Theories of Mega Infrastructure Construction Management: Theoretical Considerations from Chinese Practices*, Springer, Switzerland.

Shenhar, A. J., Dvir, D., Levy, O., and Maltz, A. C. (2001). "Project Success: A Multidimensional Strategic Concept." *Long Range Planning*, 34(6), 699-725.

Shenhar, A. J., and Holzmann, V. (2017). "The Three Secrets of Megaproject Success: Clear Strategic Vision, Total Alignment, and Adapting to Complexity." *Project Management Journal*, 48(6), 29-46.

Shenhar, A. J., Levy, O., and Dvir, D. (1997). "Mapping the dimensions of project success." *Project Management Journal*, 28(2), 5-13.

Söderlund, J., Sankaran, S., and Biesenthal, C. (2017). "The Past and Present of Megaprojects." *Project Management Journal*, 48(6), 5-16.

Tah, J. H. M., and Carr, V. (2000). "A proposal for construction project risk assessment using fuzzy logic." *Construction Management and Economics*, 18(4), 491-500.

Tervonen, T., Figueiraa, J. R., Lahdelmab, R., Diasa, J. A., and Salminenc, P. (2009). "A stochastic method for robustness analysis in sorting problems." *European Journal of Operation Research*, 192(1), 236-242.

Tuman J. (1986). "Success modeling: A technique for building a winning project team." *Proceedings of Project Management Institute*, Project Management Institute.

Turner, J. R., and Muller, R. (2003). "On the nature of the project as a temporary organization." *International Journal of Project Management*, 21, 1-8.

Turner, J. R., and Xue, Y. (2018). "On the success of megaprojects." *International Journal of Managing Projects in Business*, 11(3), 1753-8378.

Turner, R., and Zolin, R. (2012). "Forecasting Success on Large Projects: Developing Reliable Scales to Predict Multiple Perspectives by Multiple Stakeholders Over Multiple Time Frames." *Project Management Journal*, 43(5), 87-99.

Wang, J. (2008). "Research on the success criteria of large scale construction projects-based on stakeholders theory." Doctoral degree, Central South University, Changsha, China.

Wang, T., Wang, J., Wu, P., Wang, J., He, Q., and Wang, X. (2018). "Estimating the environmental costs and benefits of demolition waste using life cycle assessment and willingness-to-pay: A case study in Shenzhen." *J. Clean Prod.*, 172, 14-26.

Wang, X. (2016). *Chinese Speed: The Development of High-speed Railway in China*, Foreign Languages Press, Beijing.

Wang, X. P., and Cui, G. J. (1993). *Project management of large projects in China*, Huazhong University of Science and Technology Press, Wuhan, China.

Westerveld, E. (2003). "The Project Excellence Model: linking success criteria and critical success factors." *International Journal of Project Management*, 21(6), 385-386.

WHO (2015). "Global Status Report on Road Safety." World Health Organization., Geneva.

Winch, G., and Leiringer, R. (2016). "Owner project capabilities for infrastructure development: A review and development of the “strong owner” concept." *International Journal of Project Management*, 34(2), 271-281.

Xing, X., and Chalip, L. (2009). "Marching in the Glory_ Experiences and Meanings When Working for a Sport Mega-Event." *Journal of Sport Management*, 23(2), 210-237.

Xu, P. P., Chan, E. H. W., and Qian, Q. K. (2012). "Key performance indicators (KPI) for the sustainability of building energy efficiency retrofit (BEER) in hotel buildings in China." *Facilities*, 30(9), 432-448.

Yager, R. R. (1980). "On a general class of fuzzy connectives." *Fuzzy Sets System*, 4(3), 235-242.

Yan, H., Elzarka, H., Gao, C., Zhang, F., and Tang, W. (2019). "Critical Success Criteria for Programs in China: Construction Companies' Pespectives." *J. Manage. Eng.*, 35(1), 1-13.

Yang, D., He, Q., Cui, Q., and Hsu, S.-C. (2018). "Organizational Citizenship Behavior in Construction Megaprojects." *J. Manage. Eng.*, 34(4), 1-11.

Yeung, F. Y., Chan, P. C., Chan, W. M., Chiang, Y. H., and Yang, H. (2012). "Developing a Benchmarking Model for Construction Projects in Hong Kong." *J. Constr. Eng. Manage.*, 139(6), 705-716.

Zadeh, L. A. (1965). "Fuzzy sets." *Information and Control*, 8(3), 338-353.

Zheng, X., Lu, Y. J., and Chang, R. D. (2019). "Governing Behavioral Relationships in Megaprojects: Examining Effect of Three Governance Mechanisms under Project Uncertainties." *J. Manage. Eng.*, 35(5), 1-16.

Zimmermann, H. J. (2001). *Fuzzy set theory—and its applications*, Springer, Netherlands.