Identifying the gaps in construction megaproject management research: A bibliographic analysis

The worldwide growth of megaprojects has triggered an increasing number of academic publications in the past few decades. However, there are few studies drawing the whole picture of construction megaproject management. This study aims to investigate the status and identify research implications of construction megaproject management by conducting a systematic review. A total of 155 journal articles in 2007-2018 were identified and analysed, mainly using a bibliographic analysis on annual circulation, major journals, research origins, and categories of research interests. Results indicated that IJPM, JME, PMJ, FEM, JCEM, Sustainability, PICE-MPL and ECAM are the major journals, and developed regions/countries such as the United Kingdom rather than developing regions/countries such as mainland China are the dominant contributors in this field. Ten categories of research interests on megaproject management were also displayed and respectively discussed in depth. Moreover, three implications for future research, namely, 'construction megaproject research in developing areas', 'human factors in construction megaproject research' and 'external complexity in construction megaproject research', were proposed. The clear picture of existing literature might provide insights for academic research into megaproject management. Besides, the frontiers of megaproject research could equip practitioners with updated problem-solving strategies and then facilitate faster development in megaproject management.

Keywords: Bibliographic analysis; Megaproject management; Construction projects; Project success; Review

Introduction

Megaprojects are generally defined as large-scale and complex ventures that cost more than $1 billion and take many years to build (Flyvbjerg 2014). The typical megaprojects include airports, seaports, high-speed railways, hospitals, ICT systems, dams, the Olympics, and the manufacture of new aircrafts etc. (Flyvbjerg 2017). Megaprojects are not simply magnified versions of normal projects. Actually, they are comprised of

interdependent subsystems aiming to improve socio-economic development or to provide public service and welfare. Over the past few decades, increasingly more megaprojects are being built on a global scale. One explanation to this phenomenon is the worldwide ever-increasing needs for economic growth and improvement (Söderlund et al. 2017). According to the estimation by McKinsey Global Institute in 2013, to keep up with the anticipated growth of global GDP, no less than US$57 trillion were expected to be invested in economic infrastructure in 2013-2030 (MGI 2013). And in 2016 they updated this estimated amount to an average of around US$3.3 trillion a year between 2016 and 2030 (MGI 2016). However, the huge investments in megaprojects often end up with unsatisfactory outcomes, such as cost overruns and schedule delays (Flyvbjerg 2007a), which is academically known as 'megaproject paradox' (Flyvbjerg 2017). Ernst and Young Global (EYGM) reported in 2014 that around 64% of hydrocarbon megaprojects were faced with cost overrun issues around the world (EYGM 2014). Flyvbjerg (2007a) pointed out that the cost escalation of an urban rail project was estimated as 45% in average. Therefore, the management of megaprojects is a global challenge and should be paid more attention to.

In recent years, considerable amount of investigations focusing on megaproject management have been conducted. Literature review, considered as a key methodology for identifying the trend of research in a particular discipline (Yuan and Shen 2011), has been widely used in the area of megaproject management to critically summarize these investigations. Zhou and Mi (2017), for instance, conducted a review on 83 papers about social responsibility in the context of megaproject management, and identified trends, gaps and opportunities for future research. The study done by Yuan and Shen (2011) examined the status quo of construction and demolition waste management, and further discussed the future research topics in detail based on 87 papers published in eight

selected journals from 2000 to 2009. Hu et al. (2015) investigated the status and the trends of megaproject research by identifying and analyzing 85 articles from eight selected construction and engineering management (CEM) journals in the period of 2000 to 2010. However, two main limitations of previous studies cannot be ignored. On the one hand, most of these studies only partially discussed one or several specific issues in the area of megaproject management, and the whole picture in relation to different sectors of megaprojects has not been critically reviewed. This could cause difficulties for potential researchers to gain a comprehensive understanding of research progress or to identify the hot topics in the realm of megaproject management. On the other hand, most previous studies only reviewed articles from selected journals, and left out plenty of high-quality articles published in other journals.

Therefore, this paper aims to examine the state-of-the-art study on megaprojects and identify future research directions of megaprojects within the context of CEM by analyzing the academic articles in peer-reviewed journals published during the period of 2007 to 2018. And the following questions are expected to be answered:

- What was the coverage of megaproject research published in journals from 2007 to 2018?
- Who were the main contributors to the research of megaproject management and what were the major research interests in the same period?
- What are the research implications in future?

This paper is divided into four major parts. The following section outlines the current situation of megaproject management, followed by introducing the research methodology for selecting papers and analysing the data. Afterwards, the paper presents

the research results and analysis, finally followed by presenting future research directions and conclusions of this study.

The status quo of megaproject management

'Mega' origins from Greek, which means great, large, vast, big, high, tall mighty, and important. As a scientific and technical unit of measurements, 'mega' is defined as one million; while, other terms like 'giga' and 'tera' would indicate larger projects. 'Giga' specifically means one billion, and 'tera' is the next unit up which is the measurement for one trillion (Flyvbjerg 2014). The term 'megaproject' was first introduced in the year of 1976, and meanwhile some other terms are also used to describe megaprojects, such as 'major project' (Martin et al. 2016), 'large project' (Eriksson 2015), 'complex project' (Yang 2007), 'public works project' (Flyvbjerg et al. 2007) and 'transportation infrastructure project' (De Jong et al. 2013). In this review, all these terms were concluded under the scope of megaprojects. According to Flyvbjerg (2014), *'Megaprojects are large-scale, complex ventures that typically cost a billion dollars or more, take many years to develop and build, involve multiple public and private stakeholders, are transformational, and impact millions of people'*. Although this mainstream cost threshold of US$1 billion for a megaproject has been criticized since it is not suitable for some developing countries with low GDPs (Hu et al. 2015), many researchers agree on the features of megaprojects, such as large investment, long life-cycles, high uncertainty, extensive effects and attractive long-term outcomes (Miller and Lessard 2000; Kovaka 2005; Zhai et al. 2009; Eweje et al. 2012). The term megaproject could refer to very large-scale projects, but not all large projects can be megaprojects. According to the study of Sykes (1998), nine characteristics can distinguish megaprojects from other large but less complicated projects, including size and the likelihood of multiple owners; time—a decade or more to plan, design, finance, and build; unique risk, especially when the

project spans economic cycles; etc.

In spite of the rapidly increase in investment and construction of megaprojects, the performance of project management and delivery is always poor. Merrow (2011) analysed the data of 318 industrial megaprojects, majority of which were considered as failures if they were comprehensively evaluated against the requirements of schedule, budget, and benefit in the operation phase. Why are megaprojects so challenging and difficult to manage? From the perspective of Flyvbjerg (2017), there are ten main factors to explain why the performance of megaproject management is often disappointing: (1) Inherently risks from long-period construction horizons, nested interfaces, and high complexity. (2) Planners and managers' shortages of experiences and capacities to lead and manage megaprojects. (3) Difficulties to establish effective governance mechanisms across multi-stakeholders with diverse social and cultural backgrounds. (4) Lack of standards regarding technology, design, and construction experience (Söderlund et al. 2017). (5) Decision makers' being overcommitted or specified to partial concepts at an early stage, which could lead decision makers to give priority to less favourable megaprojects as the weakest one runs the risk of surviving because they were at the table earlier than the better ones (Söderlund et al. 2017). (6) Optimism bias of decision makers and project managers. (7) Significant variation of the scope and ambitions through the whole life cycle of megaprojects. (8) The occurrence of 'black swans' incidents, imposing extremely negative impacts on ongoing projects. (9) Lack of understanding of the complexity, unplanned events and managerial situations for the implementation of megaprojects. (10) The misinformation of costs, schedules, benefits and risks.

Over budget and delay are two mostly discussed parts of the performance of megaproject management (Flyvbjerg 2014). Currently, some studies have been done to explore the reasons why megaprojects are often affected by over budget and delay.

According to previous studies (Flyvbjerg 2006, 2007a, 2007b), four major points were highlighted: 1) technically, which refers to poor project design, uncertainty and inappropriate organizational structure; 2) psychologically, such as cognitive bias and cautious attitudes towards risk; 3) underestimation of costs, mainly from vendors/contractors and strategic misrepresentation; 4) poor financing/contract management. And among them, the underestimation of costs and psychological aspect was considered as the major reasons. Merrow (2011) summarized the top seven reasons for over budget and delay in megaprojects, including greed, pressure to reduce construction time, poor bidding phase, reduction in the upfront cost, unrealistic cost estimations, poor risk allocation and excessive pressure on project manager. Locatelli, Invernizzi, et al. (2017) pointed out that a series of project characteristics linking to successful performance on avoidance of overruns and delays. Moreover, project environment (Locatelli, Mariani, et al. 2017) and project complexity (Bjorvatn and Wald 2018) could also be closely related to the performance of megaproject management. The unique features of megaprojects have brought much challenges to their construction and management. And improvement in their performance is extremely urgent, which calls for great efforts from both scholars and practitioners in megaproject management.

Research Methodology

This study adopted a structured method, which was suggested by Darko et al. (2018) and Luo et al. (2017), to identify, select and assess the outputs of megaproject research related peer-reviewed journal articles. As is shown in Figure 1, our entire research process included three phases.

(Insert Figure 1. Here)

Phase 1: Search for target academic papers

Authors conducted comprehensive explorations within the context of CEM via the Web of Science and Scopus databases. These search engines are the world's largest web sources of peer-reviewed literature, and have already been demonstrated as good tools to carry out review work, such as in the study of Zheng et al. (2016). Based on the abovementioned definitions of megaprojects, the keywords of *megaproject*, *mega project*, *major project*, *large project*, *complex project, public works project* and *transportation/transport infrastructure project* were used in the Title/Abstract/Keyword field under the selected databases. In addition, since the selected databases do not record all academic journals concerning CEM studies between 2007 and 2018, the authors further used the EBSCO database to facilitate our article selection, where the Project Management Journal, one of the most popular journals in the construction project field, was fully included in our review.

Phase 2: Selection of target academic papers

The selection process continued with an analysis of the article's title and abstract, and a full-text analysis if both the title and abstract did not provide enough valid information. The following criteria were considered for article selection.

(1) Articles should be directly linked to megaproject management in CEM. Papers not related to the construction and engineering projects, such as IT project management, were excluded.
(2) Articles published under the broad categories of editorial, book review, forum, discussion/closure, letter to editor, introduction, conference/seminar paper/report, comment, article in press, miscellany were excluded.

(3) Articles focusing on construction and engineering projects but not within the context of megaprojects were also excluded.

Phase 3: Analysis of target academic papers

Selected articles in Phase 2 were then analysed mainly with bibliographic methods, including 1) counting and graphing annual published papers, 2) quantifying the contributions of research origins, and 3) identifying the categories of major research topics.

Firstly, presenting the trend of annual published papers with statistical tables and graphs is usually conducted in bibliographic analysis (e.g. Yuan and Shen 2011; Hu et al. 2015). After counting the annual publication number of selected papers and total papers (both excluded articles against criterion 2 in phase 2) in different journals, the authors added up the number of selected papers categorized separately by journal and by year, as well as calculating the ratios between number of target articles and the total for every journal in every year.

Secondly, an examination of research origins could be regarded as an indicator of the extent to which industrial practices in academic areas are progressing in that location (Yuan and Shen 2011; Hong et al. 2012). Thus, in this paper, research regions/countries were analysed by calculating the contributions of authors in the field of construction megaproject management to get a sense of the current industrial practices in specific areas. To be specific, this paper adopted Equation (1) to score the contributions from different countries (or regions) in a multi-authored paper (Howard et al. 1987), which has long been employed to identify research trends of construction journals (e.g. Hong et al. 2012), and then summed up scores of all researchers in a country (or region) as the final score for the corresponding origin. According to the following formula, scores were calculated based on their authorship orders to quantify the contributions of research

origins. Additionally, the contribution scores of authors with two or more origins were divided equally which is a common and recognized method to handle such problem (Yuan and Shen 2011).

$$score = \frac{1.5^{n-i}}{\sum_{i=1}^{n} 1.5^{n-i}} \quad (1)$$

where *n* is the number of authors in the article and *i* is the order of the specific author. Table 1 shows details of the scoring matrix.

(Insert Table 1. Here)

Lastly, identifying major research interests is a traditional topic of great interest to researchers in various disciplines and is also common in megaproject studies (e.g. Hong et al. 2012; Hu et al. 2015). In this study, the authors reviewed all the selected articles and extracted the scope of each article, then categorized each article into its best-fit research topic. In the process of deciding the category for each paper, possible deviations caused by uncertainty and subjectivity could be reduced or even avoided since the classification work was conducted by the same researchers and the results were mainly used for comparison purposes in this study (Hong et al. 2012).

Results and Analysis

After the searching and selecting process in Phase 1 and 2, a total of 155 journal articles between 2007 and 2018 were inventoried for subsequent analysis.

A bibliographic analysis of megaproject management in CEM

Number of published papers

Figure 2 presents the annual number of published papers related to megaproject management in CEM, where the publication showed a significant trend of increase from

2007 to 2018, with the largest number of 37 pieces in the year of 2017. In particular, the number of selected papers published between 2013 and 2018 (around 21.3) was over four times as many as the number of those published between 2007 and 2012 (4.5), which indicates a rapid growth of research efforts into the field of megaproject management as a result of the fast growth of megaproject construction.

(Insert Figure 2. Here)

According to our analysis, there were eight journals related to megaproject management in CEM, which were identified with more than three articles published during the selected period. These journals are *International Journal of Project Management (IJPM)*, *Journal of Management in Engineering (JME)*, *Project Management Journal (PMJ)*, *Frontiers of Engineering Management (FEM), Journal of Construction Engineering and Management (JCEM)*, *Sustainability, Proceedings of the Institution of Civil Engineers-Management, Procurement and Law (PICE-MPL)*, and *Engineering, Construction, and Architectural Management (ECAM)*. Our results are partly consistent with the previous ranking of construction management journals done by Chau (1997), which is highly recognized in the construction management field (Ke et al. 2009; Yuan and Shen 2011) and thus quoted many times in other review papers as reference, criterion or verification to select target journals, such as Ke et al. (2009), Tang et al. (2010), Yuan and Shen (2011), Hong et al. (2012), Luo et al. (2017) and Darko et al. (2018). According to this ranking, IJPM, JME, JCEM and ECAM were also listed among the top 10 construction management journals assessed mainly by experienced researchers interested in construction management.

As shown in Table 2, the top five journals were IJPM, JME, PMJ, FEM and JCEM, and they published 37, 13, 11, 9 and 6 articles in the selected period respectively. Among them, IJPM had the largest publication number, which represented nearly 23.72% of all the selected papers. Although the average ratio between publication number of

targeted articles and the total was 1.62%, the relative values of FEM (5.26%), IJPM (3.10%), PMJ (2.41%), JME (1.90%) were all higher than 1.62%, which indicates that these journals published more targeted papers than the average.

(Insert Table 2. Here)

Quantification of contributions of research origins

Table 3 shows that the United Kingdom is the biggest contributor to publish articles on megaproject management in CEM from the period of 2007 to 2018, with a score of 31.94 for 26 institutes/universities, 55 researchers and 39 targeted papers which is followed by the United States (score of 13.74), mainland China (score of 13.44) Australia (score of 12.58), and the Netherlands (score of 9.14). It is noteworthy that the contribution score of the United Kingdom is more than twice as high as that of the second one, the United States. This is probably because that the United Kingdom owns the leading universities which are significantly devoted to megaproject management, such as the University College London (e.g. Davies et al. 2014; Dimitriou et al. 2016), the University of Manchester (e.g. Jennings 2012; Winch 2013) and the University of Oxford (e.g. Ansar et al. 2014; Flyvbjerg 2014). These universities usually have separate research centers for the research on megaprojects. For example, the OMEGA Centre for Mega Infrastructure and Development was established based at the Bartlett School of Planning at University College London; the University of Manchester established the Center for Infrastructure Development at Manchester Business School in 2010; and the University of Oxford established the Center for Major Program Management at the Saïd Business School in cooperation with British Telecom in 2008 (Hu et al. 2015). In addition, as shown in the Table 3, only mainland China belongs to the developing country and others are all categorized as developed economies. This clearly indicates that the CEM related megaproject management is a topic drawing comparatively greater attention in developed

areas. However, developing regions/countries are regarded as increasing markets for huge investments in megaprojects (Amadi 2018). Thus, their lack of academic research with respect to megaproject management in CEM shall be strengthened.

(Insert Table 3. Here)

An in-depth analysis of categories of research topics

Based on the nine topics in the field of megaproject management proposed by Themistocleous and Wearne (2000) and then adopted by Hu et al. (2015), as well as considering the contents of 155 selected articles, a total of ten topics were identified in this study, including: (1) organization and stakeholder management; (2) cost and schedule management;(3) megaproject management in general; (4) megaproject sustainability; (5) decision-making and planning;(6) megaproject governance; (7) risk analysis and management; (8) complexity management; (9) innovation in megaproject; (10) project monitoring and control.

Table 4 lists the annual number of publications across different research topics in the selected period. The most research effort has been paid to the section of 'organization and stakeholder management', which had a total of 32 articles and accounted for 20.65% of total selected papers. The topic of 'cost and schedule management' had 27 articles (17.42%), and the 'megaproject management in general' had 26 articles (16.67%); and meanwhile, the topics of 'megaproject sustainability' and 'decision-making and planning' all had 13 selected articles (8.39%). The last five topics were 'megaproject governance' (7.74%), 'risk analysis and management' (7.10%), 'complexity management' (7.10%), 'innovation in megaproject' (4.52%) and 'project monitoring and control' (1.94%).

The topic of organization and stakeholder management, with 32 selected articles, was at the first place. As mentioned above, megaprojects are very different from normal construction projects, usually involving many stakeholders, and having long period in

planning and construction. These unique characteristics create challenges in megaprojects' organization and stakeholder management (Söderlund et al. 2017). Table 4 shows that relevant papers focusing on activities and stakeholders could cross different organizations and disciplinarians to improve performance of megaproject management in organization and stakeholder area, mainly including analysis of stakeholder management (Ng et al. 2014; Di Maddaloni and Davis 2017), relationships between stakeholders (Mazur et al. 2014; Mazur and Pisarski 2015), coordinative and/or collaborative management (Chang and Shen 2014; van Marrewijk et al. 2014; van Marrewijk et al. 2016) and analysis of organizational characteristics (Szentes and Eriksson 2016; Brookes et al. 2017; Eriksson and Kadefors 2017).

Cost and schedule management ranked at second place among the ten topics, with a total of 27 articles in the selected period. The performance of megaproject management is extremely poor, and the cost overruns and delays are common in construction megaprojects, which was described by Flyvbjerg (2017) as 'the iron law of megaproject management'. Thus, the topic of 'cost and schedule management' has received great attention in the research area of megaproject management. Table 4 shows that the relevant articles have gone through nearly the whole period and witnessed an increasing trend of interest. Research interests in this topic were mainly classified into the following categories: causes and reasons for cost overruns or delays (Flyvbjerg et al. 2007; Jennings 2012; Oyegoke and Kiyumi 2017); schedule optimization and modeling (Menesi et al. 2013; Nguyen et al. 2017); assessment of schedule or cost overruns (Chevroulet et al. 2012; Sharma et al. 2013; Ronnle 2017). It is interesting to note that in recent years, some studies concentrated on analysing the relationships between project characteristics and cost & schedule performance, such as Locatelli, Invernizzi, et al. (2017), the research results of which would provide new insights for cost and schedule management in future.

Researches in the topic of megaproject management in general ranked the third out of the 155 selected articles. This topic is essential for clients in managing megaprojects successfully. Studies in this topic can be classified into two aspects. One is the analysis of megaproject management, including status quo and strategies of megaproject management (Dimitriou et al. 2013; Söderlund et al. 2017; Shenhar and Holzmann 2017) and experience and lessons from case study (Lopez del Puerto and Shane 2014; Sturup and Low 2015). The other one is performance of megaproject management, mainly including strategies for improving the performance (Toor and Ogunlana 2010; Hu et al. 2012) and success of megaproject management (Patanakul et al. 2016; Caldas and Gupta 2017).

The topic of megaproject sustainability and decision-making & planning both included 13 articles, accounting for 8.39% out of all selected papers. Sustainability of megaproject management has received increasing attention especially since the 2010s. Relevant papers in this topic were grouped into the following categories: studies on environmental impacts (Xu et al. 2013; Martin et al. 2016); social responsibility (Lin et al. 2017; Zhou and Mi 2017); social conflict management (Jia et al. 2011; Lee C et al. 2017). The topic of decision-making and planning has been founded in the whole inventoried articles from 2007 to 2018. This topic plays an essential role in megaproject management, and relevant articles were concentrated on the problems, causes and policies in decision-making or planning (Flyvbjerg 2007b). Then followed by the topic of megaproject governance, with 12 articles and accounting for 7.74%. Megaproject governance is a relatively new theme in megaproject management since the relevant articles published within five years Table 4. There is an increasing interest in the research of megaproject governance, and researchers have already recognized governance as a useful tool to improve megaproject performance (Brunet and Aubry 2016). The interest

in this area primarily included principles and practices of governance (van Marrewijk and Smits 2016; Volden and Samset 2017), organizational governance (Lu et al. 2015), governmental governance (Zhai et al. 2017) and strategies for governance framework or process (Robbins 2015; Brunet and Aubry 2016; Klakegg et al. 2016; Locatelli, Mariani, et al. 2017).

Risk analysis and management with a total of 11 articles took the seventh place. This topic has been advocated as a critical aspect in megaproject management (Flyvbjerg et al. 2003). Specific topics of the identified articles included analysis of risk factors (Cheung and Chan 2011; Wang et al. 2011) and strategies for risk mitigation (Liu et al. 2016; Dyer 2017). The topic of complexity management also involved 11 articles. Complexity management has been increasingly suggested as the main theory of megaproject management (Hu et al. 2015), and many scholars made great efforts to do research on analysis of uncertainty and complexity (Giezen 2013), identification of characteristics of complexity (Chapman 2016) and strategies for managing complexity (Giezen 2012; Brady and Davies 2014).

Innovations are indispensable to the success of megaproject delivery. In this study, seven papers were related to this topic. These papers mainly analysed strategies for practices of making innovations in megaprojects, such as Davies et al. (2014), Brockmann et al. (2016) and Gao et al. (2018). Project monitoring and control also play an important role in project management, but they received very limited attention in the selected period. Here, only three papers were identified, namely Lee et al. (2012), Eriksson (2015) and Dimitriou et al. (2016).

(Insert Table 4. Here)

Implications for future research

Based on the results and discussions above, the main gaps in current megaproject management research, as well as three corresponding research directions in this field, are displayed in Figure 3.

(Insert Figure 3. Here)

Construction megaproject research in developing areas

According to the research results, considerable effort has been conducted on construction megaproject research in developed countries/regions, such as United Kingdom and United States. However, effort for researching on relevant studies has been insufficiently addressed in developing areas, such as China and India, which have vast markets in investment and construction of megaprojects. Additionally, the differences in the social and cultural contexts among countries can result in different outcomes of construction practice and research. Taking China as an example, a centralized leadership strategy is generally used in the organizational structure of construction megaprojects, which significantly differs from that in western countries. Therefore, implications for future research directions include identifying differences in the success criteria and critical success factors between developing and developed countries, and identifying the barriers and strategies for improving the likelihood of project success in developing areas.

Human factors in construction megaproject research

The identified categories of research topics primarily focus on managerial and technical aspects. Studies on human factors are rather limited. However, human-related factors, such as Organizational Citizenship Behavior (OCB), have already been demonstrated to contribute to project success (He et al. 2019). Although scholars have already recognized the existence of such positive behavior in construction and their positive impacts on

megaproject performance, relevant research is still rather limited and urgent attention is needed to address this issue. Research questions in this direction are as follows: What drives construction participants to enhance initiative behavior in megaproject management from external organization? How to quantify the impact of such positive behavior on performance of megaproject management? How to cultivate such positive behavior in construction practice?

External complexity in construction megaproject research

As stated by Sheng (2018), construction megaproject management is a systematic practice whose major task is to solve complex management problems. Normally, complexity can be divided into intra-organizational complexity and external-organizational complexity. The external complexity mainly includes temporal complexity, social complexity and cultural complexity. Neglecting management of external complexity could bring about disastrous consequences to megaproject management or even lead to a failure. As reviewed in this paper, most existing studies were conducted on internal complexity issues, and research on managing external complexity is quite insufficient in this regard. Future research can be done as follows: What are characteristics of external complexity in developing countries? What are the differences in characteristics of complexity between developed and developing areas? What are strategies for reducing the external complexity?

Conclusions

Megaproject management in CEM has been drawing great attention from scholars and practitioners. This paper systematically reviewed relevant articles published in academic journals from 2007 to 2018 to assess the status quo of this specific area and to identify the research implications in future. To be specific, a total of 155 academic papers were

selected and analysed in terms of publication numbers in major journals, research regions/countries contributions, and categorizations of research interests.

The main results reveal an increasing interest in the research of megaproject management in the context of CEM during the selected period. Eight journals were identified as the most popular on this selected research topic, namely IJPM, JME, PMJ, FEM, JCEM, Sustainability, PICE-MPL, and ECAM. Major developed regions/countries such as the United Kingdom, the United States, and Australia have played the dominant role in research of megaproject management; and meanwhile, megaproject research in developing countries such as mainland China, which are vast markets in megaprojects' investment and construction, remains weak. Additionally, the research interests were categorized to study the states of this field and facilitate identification of future directions, and the categorization results are as follows: (1) organization and stakeholder management, (2) cost and schedule management, (3) megaproject management in general, (4) megaproject sustainability, (5) decision-making and planning, (6) megaproject governance, (7) risk analysis and management, (8) complexity management, (9) innovations in megaproject, and (10) project monitoring and control.

Based on our consideration of state-of-the-art research on megaproject management, three research directions were highlighted, including construction megaproject research in developing areas, human factors in construction megaproject research and external complexity in construction megaproject research. However, two main limitations cannot be ignored. One refers to the databases of analysis and the twelve-year time horizon previously defined in this study. The identified articles could not cover all the papers related to megaproject management in CEM since the research design, tools and time horizon constraints. The other is that the possibility of some subjectivity would exist in the filter of literature, although the classification of papers was based on well-

designed procedures that aim to improve objectivity. Given these limitations, significant contributions are still exerted in this study. On the one hand, this study provides a critical perspective of construction megaproject management in the academic field over the selected period, in which an overall presentation of related articles, main contributors, research topics and leading directions will support academic efforts into key issues in megaproject research. On the other hand, a relatively comprehensive understanding of the research trend in construction megaproject management may enable practitioners in construction industry (such as owners, consultants, contractors and suppliers), especially those involved in megaprojects, to keep up with the frontiers of megaproject research and be aware of problems or strategies once ignored in industrial practice, as well as gaining support from researchers via cooperation or consulting relationships to improve the performance of megaprojects. Hence, scholars and practitioners are expected to work together on facilitating faster development in this field.

Declaration of interest statement

There is no conflict of interest. The authors wish to express gratitude to the National Natural Science Foundation of China (Grant No. 71971161) for the financial support of this research.

References

Amadi A. 2018. A cross-sectional snapshot of the insider view of highway infrastructure delivery in the developing world. International Journal of Construction Management. 19(6):472-491.

Ansar A, Flyvbjerg B, Budzier A, Lunn D. 2014. Should we build more large dams? The actual costs of hydropower megaproject development. Energy Policy. 69:43-56.

Bjorvatn T, Wald A. 2018. Project complexity and team-level absorptive capacity as drivers of project management performance. International Journal of Project Management. 36(6):876-888.

Brady T, Davies A. 2014. Managing Structural and Dynamic Complexity: A Tale of Two Projects. Project Management Journal. 45(4):21-38.

Brockmann C, Brezinski H, Erbe A. 2016. Innovation in Construction Megaprojects. J Constr Eng Manage. 142(11):1-9.

Brookes N, Sage D, Dainty A, Locatelli G, Whyte J. 2017. An island of constancy in a sea of change: Rethinking project temporalities with long-term megaprojects. International Journal of Project Management. 35(7):1213-1224.

Brunet M, Aubry M. 2016. The three dimensions of a governance framework for major public projects. International Journal of Project Management. 34(8):1596-1607.

Caldas C, Gupta A. 2017. Critical factors impacting the performance of mega-projects. Engineering, Construction and Architectural Management. 24(6):15.

Chang AS, Shen F-Y. 2014. Effectiveness of Coordination Methods in Construction Projects. Journal of Management in Engineering. 30(3):04014008.

Chapman RJ. 2016. A framework for examining the dimensions and characteristics of complexity inherent within rail megaprojects. International Journal of Project Management. 34(6):937-956.

Chau KW. 1997. The ranking of construction management journals. Construction Management and Economics. 15(4):387-398.

Cheung E, Chan APC. 2011. Risk Factors of Public-Private Partnership Projects in China: Comparison between the Water, Power, and Transportation Sectors. Journal of Urban Planning and Development. 137(4):409-415.

Chevroulet T, Giorgi L, Reynaud C. 2012. New Approach for the Assessment of High-Speed Rail Projects and How to Contain Cost Overruns: Lessons from the EVA-TREN Project. Journal of Infrastructure Systems. 18(4):297-304.

Darko A, Chan APC, Ameyaw EE, Owusu EK, Pärn E, Edwards DJ. 2018. Review of application of analytic hierarchy process (AHP) in construction. International Journal of Construction Management. 19(5):436-452.

Davies A, MacAulay S, DeBarro T, Thurston M. 2014. Making Innovation Happen in a Megaproject: London's Crossrail Suburban Railway System. Project Management Journal. 45(6):25-37.

De Jong M, Annema JA, Van Wee GP. 2013. How to Build Major Transport Infrastructure Projects within Budget, in Time and with the Expected Output; a Literature Review. Transport Reviews. 33(2):195-218.

Di Maddaloni F, Davis K. 2017. The influence of local community stakeholders in megaprojects: Rethinking their inclusiveness to improve project performance. International Journal of Project Management. 35(8):1537-1556.

Dimitriou HT, Ward EJ, Dean M. 2016. Presenting the case for the application of multi-criteria analysis to mega transport infrastructure project appraisal. Research in Transportation Economics. 58:7-20.

Dimitriou HT, Ward EJ, Wright PG. 2013. Mega transport projects—Beyond the 'iron triangle': Findings from the OMEGA research programme. Progress in Planning. 86:1-43.

Dyer R. 2017. Cultural sense-making integration into risk mitigation strategies towards megaproject success. International Journal of Project Management. 35(7):1338-1349.

Eriksson T. 2015. Developing Routines in Large Inter-organisational Projects: A Case Study of an Infrastructure Megaproject. Construction Economics and Building. 15(3):4-18.

Eriksson T, Kadefors A. 2017. Organisational design and development in a large rail tunnel project—Influence of heuristics and mantras. International Journal of Project Management. 35(3):492-503.

Eweje J, Turner R, Müller R. 2012. Maximizing strategic value from megaprojects: The influence of information-feed on decision-making by the project manager. International Journal of Project Management. 30(6):639-651.

EYGM. 2014. Spotlight on oil and gas megaprojects. Ernst and Young; [accessed 2019 Sep 10]. http://www.ey.com/GL/en/Industries/Oil---Gas/EY-spotlight-on-oil-and-gas-megaprojects.

Flyvbjerg B. 2006. From Nobel Prize To Project Management: Getting Risks Right. Project Management Journal. 37(3):5-15.

Flyvbjerg B. 2007a. Cost Overruns and Demand Shortfalls in Urban Rail and Other Infrastructure. Transportation Planning and Technology. 30(1):9-30.

Flyvbjerg B. 2007b. Curbing Optimism Bias and Strategic Misrepresentation in Planning: Reference Class Forecasting in Practice. European Planning Studies. 16(1):3-21.

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

Flyvbjerg B. 2017. The Iron Law of Megaproject Management. The Oxford Handbook of Megaproject Management.1-18.

Flyvbjerg B, Holm MS, Buhl S. 2007. Underestimating Costs in Public Works Projects:Error or Lie? Journal of the American Planning Association. 68(3):279-295.

Flyvbjerg B, Hon CHK, Rothengatter W. 2003. Megaprojects and Risk: An Anatomy of Ambition. Cambridge: Cambridge University Press.

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

Giezen M. 2012. Keeping it simple? A case study into the advantages and disadvantages of reducing complexity in mega project planning. International Journal of Project Management. 30(7):781-790.

Giezen M. 2013. Adaptive and Strategic Capacity: Navigating Megaprojects through Uncertainty and Complexity. Environment and Planning B: Planning and Design. 40(4):723-741.

He Q, Wang T, Chan APC, Li H, Chen Y. 2019. Identifying the gaps in project success research: A mixed bibliographic and bibliometric analysis. Engineering, Construction and Architectural Management. 26 (08): 1553-1573.

Hong Y, Chan DWM, Chan APC, Yeung JFY. 2012. Critical Analysis of Partnering Research Trend in Construction Journals. Journal of Management in Engineering. 28(2):82-95.

Howard GS, Cole DA, Maxwell SE. 1987. Research productivity in psychology based on publication in the journals of the American Psychology Association. American Psychologist. 42(11):975-986.

Hu Y, Chan APC, Le Y, Jiang W-P, Xie LL, Hon CHK. 2012. Improving Megasite Management Performance through Incentives: Lessons Learned from the Shanghai Expo Construction. Journal of Management in Engineering. 28(3):330-337.

Hu Y, Chan APC, Le Y, Jin RZ. 2015. From Construction Megaproject Management to Complex Project Management: Bibliographic Analysis. Journal of Management in Engineering. 31(4):1-11.

Jennings W. 2012. Why costs overrun: risk, optimism and uncertainty in budgeting for the London 2012 Olympic Games. Construction Management and Economics. 30(6):455-462.

Jia G, Yang F, Wang G, Hong B, You R. 2011. A study of mega project from a perspective of social conflict theory. International Journal of Project Management. 29(7):817-827.

Ke YJ, Wang SQ, Chan APC, Cheung E. 2009. Research trend of public-private-partnership (PPP) in construction journals. Journal of Construction Engineering and Management. 135(10):1076-1086.

Klakegg OJ, Williams T, Shiferaw AT. 2016. Taming the 'trolls': Major public projects in the making. International Journal of Project Management. 34(2):282-296.

Kovaka M. 2005. Defining mega-projects, learning from construction at the edge of experience. Construction Research Congress, ASCE, Reston, VA.

Lee C, Won JW, Jang W, Jung W, Han SH, Kwak YH. 2017. Social conflict management framework for project viability: Case studies from Korean megaprojects. International Journal of Project Management. 35(8):1683-1696.

Lee HW, Tommelein I, Ballard G. 2012. Design of an Infrastructure Project Using a Point-Based Methodology. Journal of Management and Engineering. 28(3):291-299.

Lin H, Zeng S, Ma H, Zeng R, Tam VWY. 2017. An indicator system for evaluating megaproject social responsibility. International Journal of Project Management. 35(7):1415-1426.

Liu ZZ, Zhu ZW, Wang HJ, Huang J. 2016. Handling social risks in government-driven mega project: An empirical case study from West China. International Journal of Project Management. 34(2):202-218.

Locatelli G, Invernizzi DC, Brookes NJ. 2017. Project characteristics and performance in Europe: An empirical analysis for large transport infrastructure projects. Transportation Research Part A: Policy and Practice. 98:108-122.

Locatelli G, Mariani G, Sainati T, Greco M. 2017. Corruption in public projects and megaprojects: There is an elephant in the room! International Journal of Project Management. 35(3):252-268.

Lopez del Puerto C, Shane JS. 2014. Keys to Success in Megaproject Management in Mexico and the United States: Case Study. Journal of Construction Engineering and Management. 140(4):1-7.

Lu Y, Li Y, Pang D, Zhang Y. 2015. Organizational Network Evolution and Governance Strategies in Megaprojects. Construction Economics and Building. 15(3):19-33.

Luo L, He Q, Jaselskis EJ, Xie J. 2017. Construction Project Complexity: Research Trends and Implications. Journal of Construction Engineering and Management. 143(7):1-10.

Martin N, Evans M, Rice J, Lodhia S, Gibbons P. 2016. Using offsets to mitigate environmental impacts of major projects: A stakeholder analysis. Journal of environmental management. 179:58-65.

Mazur A, Pisarski A, Chang A, Ashkanasy NM. 2014. Rating defence major project success: The role of personal attributes and stakeholder relationships. International Journal of Project Management. 32(6):944-957.

Mazur AK, Pisarski A. 2015. Major project managers' internal and external stakeholder relationships: The development and validation of measurement scales. International Journal of Project Management. 33(8):1680-1691.

MGI. 2013. Infrastructure productivity: How to save $1 trillion a year. McKinsey Global Institute; [accessed 2019 Sep 10]. https://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/infrastructure-productivity.

MGI. 2016. Bridging Global Infrastructure Gaps. McKinsey Global Institute; [accessed 2019 Sep 10]. https://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/bridging-global-infrastructure-gaps.

Menesi W, Golzarpoor B, Hegazy T. 2013. Fast and Near-Optimum Schedule Optimization for Large-Scale Projects. Journal of Construction Engineering and Management. 139(9):1117-1124.

Merrow EW. 2011. Industrial Megaprojects: Concepts, Strategies and Practices for success. John Wiley & Sons.

Miller R, Lessard DR. 2000. The Strategic Management of Large Engineering Projects — Shaping Institutions, Risks and Governance. MIT Press, Cambridge, MA.

Nguyen T, Cook S, Ireland V. 2017. Application of System Dynamics to Evaluate the Social and Economic Benefits of Infrastructure Projects. Systems. 5(4):1-21.

Oyegoke AS, Kiyumi NA. 2017. The causes, impacts and mitigations of delay in megaprojects in the Sultanate of Oman. Journal of Financial Management of Property and Construction Economics and Building. 22(3):286-302.

Patanakul P, Kwak YH, Zwikael O, Liu M. 2016. What impacts the performance of large-scale government projects? International Journal of Project Management. 34(3):452-466.

Robbins G. 2015. The Dube TradePort-King Shaka International Airport mega-project: Exploring impacts in the context of multi-scalar governance processes. Habitat International. 45:196-204.

Ronnle E. 2017. A novel approach to economic evaluation of infrastructure?—Examining the benefit analyses in the Swedish high-speed rail project. Case Studies on Transport Policy. 5(3):492-498.

Sharma JR, Najafi M, Qasim SR. 2013. Preliminary Cost Estimation Models for Construction, Operation, and Maintenance of Water Treatment Plants. Journal of Infrastructure Systems. 19(4):451-464.

Sheng ZH. 2018. Fundamental Theories of Mega Infrastructure Construction Management: Theoretical Considerations from Chinese Practices. Switzerland: Springer.

Shenhar AJ, 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.

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

Sturup S, Low N. 2015. Storylines, Leadership and Risk, Some Findings from Australian Case Studies of Urban Transport Megaprojects. Urban Policy and Research. 33(4):490-505.

Sykes A.1998. Megaprojects: Grand Schemes Need Oversight, Ample Funding. Forum for Applied Research and Public Policy. 13(1):6–47.

Szentes H, Eriksson PE. 2016. Paradoxical Organizational Tensions between Control and Flexibility When Managing Large Infrastructure Projects. Journal of Construction Engineering and Management. 142(4):1-10.

Themistocleous G, Wearne SH. 2000. Project management topic coverage in journals. International Journal of Project Management. 18(1):7–11.

Thomas Ng S, Skitmore M, Tam KY, Li THY. 2014. Public engagement in major projects: the Hong Kong experience. Proceedings of the Institution of Civil Engineers - Municipal Engineer. 167(1):22-31.

Toor S-u-R, Ogunlana SO. 2010. Beyond the ‘iron triangle’: Stakeholder perception of key performance indicators (KPIs) for large-scale public sector development projects. International Journal of Project Management. 28(3):228-236.

van Marrewijk A, Smits K. 2016. Cultural practices of governance in the Panama Canal Expansion Megaproject. International Journal of Project Management. 34(3):533-544.

van Marrewijk A, Veenswijk M, Clegg S. 2014. Changing collaborative practices through cultural interventions. Building Research & Information. 42(3):330-342.

van Marrewijk A, Ybema S, Smits K, Clegg S, Pitsis T. 2016. Clash of the Titans: Temporal Organizing and Collaborative Dynamics in the Panama Canal Megaproject. Organization Studies. 37(12):1745-1769.

Volden GH, Samset K. 2017. Governance of Major Public Investment Projects-Principles and Practices in Six Countries. Project Management Journal. 48(3):90-108.

Wang S, Wahab MIM, Fang L. 2011. Managing construction risks of AP1000 nuclear power plants in China. Journal of Systems Science and Systems Engineering. 20(1):43-69.

Winch GM. 2013. Escalation in major projects: Lessons from the Channel Fixed Link. International Journal of Project Management. 31(5):724-734.

Xu X, Tan Y, Yang G. 2013. Environmental impact assessments of the Three Gorges Project in China: Issues and interventions. Earth-Science Reviews. 124:115-125.

Yang IT. 2007. Performing complex project crashing analysis with aid of particle swarm optimization algorithm. International Journal of Project Management. 25(6):637-646.

Yuan H, Shen L. 2011. Trend of the research on construction and demolition waste management. Waste management. 31(4):670-679.

Zhai L, Xin Y, Cheng C. 2009. Understanding the Value of Project Management from a Stakeholder's Perspective: Case Study of Mega-Project Management. Project Management Journal. 40(1):99-109.

Zhai Z, Ahola T, Le Y, Xie J. 2017. Governmental Governance of Megaprojects_ The Case of EXPO 2010 Shanghai. Project Management Journal. 48(1):37-50.

Zheng X, Le Y, Chan APC, Hu Y, Li Y. 2016. Review of the application of social network analysis (SNA) in construction project management research. International Journal of Project Management. 34(7):1214-1225.

Zhou Z, Mi C. 2017. Social responsibility research within the context of megaproject management: Trends, gaps and opportunities. International Journal of Project Management. 35(7):1378-1390.