

From Construction Megaproject Management to Complex Project Management: Bibliographic Analysis

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Abstract: The rapid growth of construction megaprojects worldwide has triggered a growing number of papers published in this area in the past two decades, suggesting that construction megaproject management has become an emerging area in the field of construction engineering and management (CEM). This study aims to investigate the status and the trends in megaproject research by conducting a structured literature review. A total of 85 relevant articles identified from eight peer-reviewed CEM journals between 2000 and 2010 were analyzed based on the number of articles published annually, institutional and regional contributions, citations, and categorization of research interests and methodologies. Analysis results indicated that developed countries, such as the United Kingdom, the United States, and Australia, have enjoyed significant advantages in megaproject research because of their greater experience, while megaproject research in developing countries, such as Russia, India, Turkey, and Vietnam, remains weak or lacking. These results also revealed that many theory-based findings have been reported in five subareas; namely, construction and site management, cost and schedule management, risk analysis and management, innovation and utilization of information technology, and leadership and professional development. The subareas of organization and stakeholder management, project planning and procurement, and project monitoring and control remain to be promising domains for future research, particularly in developing countries which have yet to develop a research tradition. Incorporating the complexity theory and institutional theory as the theoretical foundation in these subareas can develop megaproject research further through strengthened global collaboration in the future. DOI: [10.1061/\(ASCE\)ME.1943-5479.0000254](https://doi.org/10.1061/(ASCE)ME.1943-5479.0000254). © 2014 American Society of Civil Engineers.

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Introduction

Rapid global urbanization has triggered another round of investment boom in construction megaprojects. From 1990 to 2008, the global urban population grew at an annual rate of 2.2% (World Bank 2010). Thus, the ever-increasing demand for infrastructure, primarily in developing countries, yielded huge investments in urban and infrastructure megaprojects, such as in water and sewage, electricity, transportation, and telecommunications. Major developing countries are predicted to invest another US\$22 trillion in infrastructure from 2008 to 2017 (Economist 2008). Meanwhile, infrastructure systems in major developed countries have deteriorated and are under renewal (Scott et al. 2011). Thus, a global megaproject boom is under way (Economist 2008).

Since the early 2000s, construction megaprojects have become an emerging area in the field of construction engineering and management (CEM). This emergence originated from research initiatives on the issues of megaproject investment in the urban United States during the 1950s and 1960s (Altshuler and Luberoff 2003). These issues received increased attention from the academic

community, as civic and infrastructure megaprojects continued to grow in major developed countries since the 1970s, and later emerged in developing countries (Merrow 1988; Flyvbjerg et al. 2003). Flyvbjerg et al. (2003) observed that megaprojects in developing countries also face risks, such as cost overruns, safety incidents, and quality defects, similar to those in developed countries. Thus, the management of megaprojects is a global challenge common to both developed and developing countries.

The fast growth of megaprojects worldwide has been accompanied by a growing number of relevant papers published in peer-reviewed CEM journals. This paper aims to review the megaproject literature in the CEM field published between 2000 and 2010, assess the state of megaproject research, and identify future trends in this area. This paper aims to address the following questions:

1. What was the coverage of megaproject research published in CEM journals from 2000 to 2010?
2. What did authors from different countries (regions) contribute to megaproject research during the same period?
3. How did the interests, methodologies, and research trend of megaproject-related papers evolve during this period?

Definition of Construction Megaprojects

Viewpoints of Governments and Industries

The term *construction megaproject* is a social construct referring to a large-scale and complex construction project (Altshuler and Luberoff 2003). Most definitions of megaprojects are provided by governments and industry directives. One of the most widely accepted definitions is the one given by the U.S. Department of Transportation: namely, a *megaproject* is a project with at least a US\$1 billion budget (DIOG 2001). The U.S. Federal Highway

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Administration (FHA) later gave a detailed definition of megaprojects:

“...major infrastructure projects that cost more than 1 billion USD, or projects of a significant cost that attract a high level of public attention or political interest because of substantial direct and indirect impacts on the community, environment, and state budgets” (Capka 2006).

The project cost threshold of US\$1 billion is increasingly advocated worldwide as the key criterion for defining a megaproject (Flyvbjerg et al. 2003; van Marrewijk et al. 2008). In countries in the European Union (EU), the International Project Management Association (IPMA 2011) designated a cost threshold of 100 million euros as the basis for defining megaprojects across all industries.

Major project or *major program(me)* is another term frequently used to define large public projects in several countries, such as the United States, the United Kingdom, and China. These terms sometimes are used interchangeably with *megaproject* (Haynes 2002). Even in the United States, where megaprojects originated, the FHA designated “major project” as a separate category and “megaproject” as its subcategory in a new act, Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users, which took effect in 2005. Thus, a major project is defined as “a project with a total estimated cost of USD 500 million or more that is receiving financial assistance” (FHA 2005). South Korea also adopted this threshold in defining an urban renewal megaproject (Hyun et al. 2009). In China, major national projects usually involve government-funded projects approved by the National Development and Reform Commission (NDRC), with a total investment of RMB 5 billion, or approximately US\$754 million (NDPC 2002; NDRC 2004). This amount is near the widely accepted US\$1 billion megaproject threshold.

Flyvbjerg (2009) estimated the cost of a megaproject to be within the range of US\$500 million–1 billion when specific factors, such as scale, economy, and income, are considered. However, this cost threshold applies only to major developed countries because its application may be difficult for several developing countries whose gross domestic products (GDPs) are only a few billion U.S. dollars. Thus, the relationships between the megaproject cost threshold and GDP in these countries were examined further in terms of cost-GDP ratios (Table 1). Most megaproject cost-GDP ratios are between 0.01 and 0.02%. Therefore, 0.01% of GDP is suggested worldwide as a reasonable criterion to replace the criterion of Flyvbjerg (2009) in defining megaprojects.

Viewpoints of Academics

Construction megaprojects intrinsically exhibit highly complex characteristics and are theoretically viewed as complex projects.

Table 1. Ratios of Megaproject Cost Threshold in GDP in Different Countries and Regions

| Country | Cost threshold ^a (million USD) | GDP ^b (million \$) | Ratio (%) |
|---------------------|--|----------------------------------|--------------|
| United States | 1,000 | 14,582,400 | 0.01 |
| EU countries (IPMA) | 133 | 601,817 ^c | 0.02 |
| China | 754 | 5,878,629 | 0.01 |
| Hong Kong | 26 | 224,458 | 0.01 |
| South Korea | 500 | 1,014,483 | 0.05 |

^aBased on the exchange rates on December 30, 2010, retrieved from the website of the International Monetary Fund. Exchange rate is HKD 7.8 = US\$1.

^bData from World Bank (2010).

^cThe average GDP of 27 EU membership countries in 2010.

The management of complex projects originated from complexity theory (Whitty and Maylor 2009), a well-known physical theory developed by the Santa Fe Institute in the 1980s to solve complex, real-world, cross-discipline problems, such as those in astronomy, biology, and economy (Waldrop 1992; Ziemelis 2001). This theory has been applied to project management since the late 1990s (Baccarini 1996; Williams 2003). A growing number of complex projects are emerging nowadays because of the increasing complexity of the project scope and environment (Fiori and Kovaka 2005; Remington and Pollack 2008). Complex projects can be viewed as complex systems formed from many components with emergent behavior. One of the most popular frameworks for complex projects is that provided by Remington and Pollack (2007). In this framework, project complexity is classified into four categories: structural, technical, directional, and temporal.

A megaproject is a typical example of a complex project (Remington and Pollack 2008). Thus, the theory on complex project management can be applied to megaproject research as well. Fiori and Kovaka (2005) developed a five-criterion framework to define megaprojects: cost, complexity, risk, ideals, and visibility. Case studies of six megaprojects constructed in the United States, Japan, and Taiwan that used this framework revealed that construction megaprojects are primarily characterized by huge cost, high complexity, and uncertainty. Brockmann and Girmscheid (2007) further categorized the complexity of megaprojects into three groups: task, social, and cultural complexity. Bruijn and Leijten (2008) provided a similar framework by citing technical complexity, social complexity, and complexities from implementation management to define the complexity of megaprojects.

The term *megaproject* also can refer to a program that includes two or more projects and requires close cooperation among these projects (Archibald 2003). Shehu and Akintoye (2010) noted that a construction megaproject is a typical example of a program in the construction industry. Remington and Pollack (2008) stated that programs also can be typical forms of complex projects.

Research Methodology

This work adopted a structured method advocated by Ke et al. (2009) to identify and assess the major outputs of megaproject research published in peer-reviewed journals. The entire research process included three phases.

In Phase 1, comprehensive exploratory desktop searches were conducted through the Web of Science (WoS) and Scopus search engines to identify the peer-reviewed journals with the most megaproject articles published in the CEM field. These search engines are the world's largest web sources of peer-reviewed literature, covering over 10,000 journals. Based on the abovementioned definitions of construction megaprojects, the common keywords of *megaproject*, *mega project*, *large project*, *major project*, and *complex project* were used in the Title/Abstract/Keyword field under the Engineering, Environment, Energy, and Business subarea of the search engines. Six journals in the CEM field were identified as the ones with the most megaproject articles published. These journals include the *International Journal of Project Management (IJPM)*, *Journal of Construction Engineering and Management (JCEM)*, *Construction Management and Economics (CME)*, *Proceedings of the Institution of Civil Engineers—Civil Engineering (PICE-CE)*, *Leadership and Management in Engineering (LME)*, and *Project Management Journal (PMJ)*. Most of these journals were among the top eight journals in the ranking done by Chau (1997). Two journals from this ranking were also added to this list of selected journals: *Engineering, Construction, and Architectural*

Management (ECAM) and *Journal of Management in Engineering (JME)*. Thus, the final list of target journals includes eight peer-reviewed construction journals: *IJPM*, *JCEM*, *CME*, *PICE-CE*, *LME*, *PMJ*, *ECAM*, and *JME*.

In Phase 2, megaproject articles in each selected journal were searched thoroughly. Two other databases [namely, EBSCO (for *PMJ*) and Informaworld (for *ECAM*)] were used because Scopus and WoS did not contain a full record of papers published in *PMJ* and *ECAM* between 2000 and 2010. A total of 85 articles published in the eight selected journals between 2000 and 2010 were identified as valid.

In Phase 3, the 85 articles were quantitatively analyzed to determine their contribution by year, country, author, institution, and citation. The scoring method developed by Howard et al. (1987) was used to assess the contribution value of each author in multi-authored articles. In this method, the credit of authors listed in the same article is calculated based on the order of authorship, as shown in [Eq. (1) Howard et al. (1987)]:

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

where n is the number of authors in the article and i is the order of the specific author.

The detailed score matrix for the authors is provided in Table 2. This scoring method was also adopted by Ke et al. (2009) and Hong et al. (2012).

Citations of journal articles were used as a key index to assess research quality (Hong et al. 2012). Given that both Scopus and WoS did not cover all 85 articles identified in the eight selected journals, Google Scholar was used to determine the citation status of the journal articles identified. Although Google Scholar provides only an indirect citation report, its powerful search function is a simple yet thorough channel used to acquire such citation reports. Research interests and methods then were categorized to identify their evolutions in the past decade, and the relationships between research topics and methods were examined. Future research directions were also discussed. Although these analyses do not provide all the details on the 85 megaproject papers, they present an overall picture of megaproject research from 2000 to 2010 and thus are expected to guide and benefit future research.

Discussions of Search Results

Annual Productivity of Construction Journals Based on Megaproject Articles

The total number of megaproject articles identified by Scopus and WoS in Phase 1 was 685 and 200, respectively. Scopus identified a greater number of megaproject papers than WoS because WoS has a more detailed subarea classification system than Scopus. More specific searches in each of the selected journals revealed that among

the 4,459 articles published in the eight selected journals, 85 (1.9%) addressed megaproject topics or associated issues, and this was an obviously increasing trend, from 3 in 2000 to 12 in 2010. The data in Table 3 suggest that by the 21st century, megaproject research has emerged as an increasingly important area in the CEM field. In particular, the number of megaproject papers published between 2006 and 2010 (49) was nearly double the number of those published between 2000 and 2004 (27). Table 3 indicates the consistent growth of interest research as a result of the fast growth of megaprojects.

The number of megaproject articles published in the eight selected journals between 2000 and 2010 is also indicated in Table 3. Four journals (namely, *IJPM*, *PMJ*, *JCEM*, and *ECAM*), published the most megaproject articles within the selected period (25, 18, 14, and 11 articles, respectively, representing 80% of all 85 papers identified in the journals). The number of papers published in each of the four journals was greater than the average number (10.6) of papers published in the eight journals. *IJPM* published 25 megaproject articles, which accounted for nearly 30% of all 85 papers and contributed the most to megaproject research in the past decade. Table 3 also reflects that megaproject papers published in *PMJ* accounted for 5.7% of the total number of papers published in *PMJ* during the selected period, higher than that in any of the other selected journals. *IJPM* and *ECAM* followed with a percentage of 3.3% and 2.8% respectively. Therefore, these four journals can be regarded as the most important sources to publish and acquire megaproject papers.

Contributions of Countries/Regions and Institutions to Megaproject Research

Hong et al. (2012) stated that the number of academic research publications in a country or region implies the extent to which industrial development and practices in the research areas are progressing in that particular location. Thus, the analysis of research contributions of a country or region and its affiliated institutions can obtain a collective view of the current status of industry development and practices in that particular location. In this study, the research contributions of each country or region and research institutions (universities) were analyzed by accumulating the score of each researcher's contributions to megaproject research. The method to compute the score of each researcher's contribution (as mentioned in the "Research Methodology" section earlier in this paper) was the primary tool used to conduct this analysis. The sum of the contribution values of all researchers within identical origins was used as the final score of that origin. In addition, the contribution value of one researcher with two origins from different countries was divided into two equal parts pertaining to two origins.

In Table 4, the countries or regions of origin of megaproject articles are outlined with the numbers of research institutions and their affiliated researchers, the total number of megaproject papers published, and the score for each origin. The 85 papers identified involved 31 countries and regions, of which 22 were developed countries and regions (including Taiwan) and 9 were developing countries (UNDP 2010), which also include major construction markets and most emerging construction markets in the world (GCP and OE 2009). This finding reinforces the observation by Flyvbjerg et al. (2003) that megaprojects have become a global phenomenon. On average, each country/region published 2.7 papers. The 22 developed countries and regions published 70 papers (82%), with a total score of 75.2, and a mean of 3.4 (75.2/22) papers per country; this value is higher than the average level of all 31 countries and regions. By contrast, the 9 developing countries published only 15 papers (18%), with a total score of 9.8 and a

Table 2. Score Matrix for Multiauthor Papers

| Number of authors | Order of specific authors | | | | |
|-------------------|---------------------------|------|------|------|------|
| | 1 | 2 | 3 | 4 | 5 |
| 1 | 1.00 | N/A | N/A | N/A | N/A |
| 2 | 0.60 | 0.40 | N/A | N/A | N/A |
| 3 | 0.47 | 0.32 | 0.21 | N/A | N/A |
| 4 | 0.42 | 0.28 | 0.18 | 0.12 | N/A |
| 5 | 0.38 | 0.26 | 0.17 | 0.11 | 0.08 |

Note: Source of data is Ke et al. (2009).

Table 3. Megaproject Papers Published in Selected Journals

| Amount/ratio | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | Total |
|--------------------------|------|------|------|------|------|------|------|------|------|------|------|-------|
| Scopus | | | | | | | | | | | | |
| Megaproject papers | 47 | 52 | 46 | 51 | 55 | 59 | 61 | 78 | 81 | 66 | 89 | 685 |
| WoS | | | | | | | | | | | | |
| Megaproject papers | 12 | 17 | 16 | 15 | 15 | 18 | 15 | 22 | 13 | 26 | 31 | 200 |
| Selected journals | | | | | | | | | | | | |
| Total | 335 | 333 | 348 | 363 | 406 | 432 | 469 | 434 | 438 | 454 | 447 | 4,459 |
| Megaproject papers | 3 | 4 | 5 | 7 | 8 | 9 | 7 | 11 | 8 | 11 | 12 | 85 |
| Percentage (%) | 0.9 | 1.2 | 1.4 | 1.9 | 2.0 | 2.1 | 1.5 | 2.5 | 1.8 | 2.4 | 2.9 | 1.9 |
| IJPM | | | | | | | | | | | | |
| Total | 45 | 45 | 68 | 66 | 66 | 69 | 72 | 85 | 85 | 79 | 79 | 759 |
| Megaproject papers | 1 | 2 | 2 | 1 | 2 | 1 | 2 | 6 | 2 | 3 | 3 | 25 |
| Percentage (%) | 2.2 | 4.4 | 2.9 | 1.5 | 3.0 | 1.5 | 2.8 | 7.1 | 2.4 | 3.8 | 3.8 | 3.3 |
| PMJ | | | | | | | | | | | | |
| Total | 24 | 22 | 23 | 22 | 20 | 22 | 36 | 31 | 41 | 33 | 40 | 314 |
| Megaproject papers | 0 | 1 | 0 | 1 | 0 | 5 | 2 | 2 | 2 | 2 | 3 | 18 |
| Percentage (%) | 0.0 | 4.6 | 0.0 | 4.6 | 0.0 | 22.7 | 5.6 | 6.5 | 4.9 | 6.1 | 7.5 | 5.7 |
| JCEM | | | | | | | | | | | | |
| Total | 62 | 61 | 60 | 80 | 101 | 139 | 132 | 109 | 103 | 132 | 131 | 1,110 |
| Megaproject papers | 1 | 1 | 1 | 0 | 2 | 3 | 2 | 1 | 0 | 1 | 2 | 14 |
| Percentage (%) | 1.6 | 1.6 | 1.7 | 0.0 | 2.0 | 2.2 | 1.5 | 0.9 | 0.0 | 0.8 | 1.5 | 1.3 |
| ECAM | | | | | | | | | | | | |
| Total | 37 | 37 | 38 | 36 | 39 | 35 | 36 | 37 | 36 | 33 | 35 | 399 |
| Megaproject papers | 0 | 0 | 0 | 2 | 3 | 0 | 0 | 1 | 1 | 3 | 1 | 11 |
| Percentage (%) | 0.0 | 0.0 | 0.0 | 5.6 | 7.7 | 0.0 | 0.0 | 2.7 | 2.8 | 9.1 | 2.9 | 2.8 |
| CME | | | | | | | | | | | | |
| Total | 87 | 74 | 60 | 72 | 89 | 86 | 105 | 101 | 94 | 90 | 91 | 949 |
| Megaproject papers | 1 | 0 | 2 | 0 | 1 | 0 | 0 | 1 | 2 | 0 | 2 | 9 |
| Percentage (%) | 1.2 | 0.0 | 3.3 | 0.0 | 1.1 | 0.0 | 0.0 | 1.0 | 2.1 | 0.0 | 2.2 | 1.0 |
| LME | | | | | | | | | | | | |
| Total | N/A | 33 | 36 | 27 | 17 | 8 | 12 | 8 | 27 | 19 | 16 | 203 |
| Megaproject papers | N/A | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 3 |
| Percentage (%) | N/A | 0.0 | 0.0 | 3.7 | 0.0 | 0.0 | 8.3 | 0.0 | 0.0 | 0.0 | 6.3 | 1.5 |
| PICE-CE | | | | | | | | | | | | |
| Total | 37 | 36 | 38 | 37 | 52 | 50 | 52 | 39 | 24 | 44 | 31 | 440 |
| Megaproject papers | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 4 |
| Percentage (%) | 0.0 | 0.0 | 0.0 | 5.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.6 | 0.0 | 0.9 |
| JME | | | | | | | | | | | | |
| Total | 43 | 25 | 25 | 23 | 22 | 23 | 24 | 24 | 28 | 24 | 24 | 285 |
| Megaproject papers | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| Percentage (%) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.6 | 0.0 | 0.0 | 0.4 |

Note: The total number of papers in these journals is calculated by excluding articles under the categories of editorial; book review; forum; discussion/closure; letter to editor; article in press; index; foreword; introduction; conference/seminar report; briefing sheet; miscellany; comment; erratum; and announcement.

mean of 1.1 papers per country. The huge difference between the developing and developed countries (regions) may be because most developed countries and regions have practiced megaproject research for longer than developing countries. In addition, the total score of the 9 developing countries (9.8) is much lower than that of the 22 developed countries (15.0). Moreover, approximately, 60% (9/15) of the papers were coauthored with researchers from developed countries, indicating that a number of developing countries were trying to establish megaproject research through international collaborations in response to the gradual emergence of construction megaprojects in these locations. Among the 8 developing countries that published fewer papers than the average level (2.7 papers), India, Turkey, and Vietnam are predicted to be among the top six construction markets to experience the highest growth in 2009–2014. Thus, these countries should strengthen their megaproject research. Five countries listed among the 15 biggest construction markets but excluded in the list of involved countries in Table 4 (GCP and OE 2009) (i.e., Spain, Russia, South Korea, Brazil, and Indonesia) need to establish megaproject research in their research institutions. An imbalance in megaproject research also was observed among developed countries and regions.

The contribution of countries and regions were examined further. Among all the countries and regions, the United Kingdom, the United States, and Australia (with scores of 17.6, 11.1, and 8.9, respectively) published the greatest number of megaproject articles in the eight journals within the selected period. Among the 46 papers published by these countries, 36 were published with the first authorship in these countries, accounting for 78% of all the papers. Thus, these countries are considered the main centers of megaproject research. These findings can be considered logical and understandable when the construction market scales in the world are examined (GCP and OE 2009). The fast growth of megaproject practices has boosted the development of megaproject research greatly in major developed countries.

Table 5 shows the top 10 research institutions with the highest number of megaproject papers published in the selected period. These research institutions represented 13% of all 76 research institutions involved. However, their overall contribution score was 26% of all megaproject papers published in the target journals between 2000 and 2010. The total number of researchers in the 10 universities represented 26% of all researchers involved. The average number of researchers in the 10 universities was 4.4, twice that

Table 4. Research Origins of Megaproject Articles Published

| Country | University/organization | Researchers | Papers | Score |
|----------------|-------------------------|-------------|--------|-------|
| United Kingdom | 20 | 33 | 23 | 17.6 |
| United States | 20 | 26 | 16 | 11.1 |
| Australia | 8 | 19 | 11 | 8.9 |
| Canada | 9 | 11 | 8 | 5.3 |
| Hong Kong | 2 | 10 | 5 | 4.8 |
| China | 8 | 12 | 5 | 3.6 |
| Norway | 4 | 9 | 5 | 3.3 |
| Taiwan | 3 | 6 | 4 | 3.3 |
| Singapore | 1 | 5 | 3 | 2.6 |
| Netherlands | 1 | 4 | 3 | 2.5 |
| Sweden | 3 | 5 | 3 | 2.3 |
| Thailand | 1 | 2 | 4 | 2.0 |
| Finland | 1 | 6 | 2 | 2.0 |
| Switzerland | 2 | 7 | 2 | 2.0 |
| Saudi Arabia | 3 | 3 | 3 | 1.9 |
| Germany | 3 | 2 | 2 | 1.6 |
| Bahrain | 1 | 1 | 1 | 1.0 |
| Belgium | 1 | 3 | 1 | 1.0 |
| Denmark | 1 | 1 | 1 | 1.0 |
| India | 1 | 1 | 1 | 1.0 |
| Italy | 1 | 3 | 1 | 1.0 |
| Algeria | 1 | 5 | 1 | 0.8 |
| France | 2 | 3 | 3 | 0.8 |
| Japan | 2 | 2 | 1 | 0.7 |
| Israel | 2 | 2 | 1 | 0.7 |
| Pakistan | 1 | 1 | 1 | 0.6 |
| Sudan | 1 | 1 | 1 | 0.5 |
| Portugal | 1 | 1 | 1 | 0.3 |
| New Zealand | 1 | 1 | 1 | 0.3 |
| Turkey | 1 | 1 | 1 | 0.2 |
| Vietnam | 1 | 1 | 1 | 0.2 |
| Total | 76 | 168 | 85 | 85.0 |

of researchers in all research institutions involved (2.2). As shown in Table 4, the University of Hong Kong (with four articles published) ranked first among all the identified research institutions, with a score of 2.8. The National University of Singapore and Vrije Universiteit of the Netherlands ranked second and third, respectively. These universities have played essential roles in megaproject research in their geographic locations and throughout the world. However, the contribution of each of the 10 universities remained very limited. For instance, the University of Hong Kong published only four articles and obtained a contribution score of only 2.8, which was a small margin relative to those of other research institutions. In addition, a growing number of top universities in different countries and regions have established separate research centers to strengthen megaproject research. For instance, Stanford

Table 6. Number of Citations of Papers from Eight Selected Journals

| Journal | Total cited times of relevant papers | Total number of relevant papers | Times per paper |
|----------------|--------------------------------------|---------------------------------|-----------------|
| <i>IJPM</i> | 354 | 25 | 14.2 |
| <i>PMJ</i> | 189 | 18 | 10.5 |
| <i>JCEM</i> | 140 | 14 | 10.0 |
| <i>JME</i> | 9 | 1 | 9.0 |
| <i>CME</i> | 71 | 9 | 7.9 |
| <i>ECAM</i> | 58 | 11 | 5.3 |
| <i>LME</i> | 5 | 3 | 1.7 |
| <i>PICE-CE</i> | 3 | 4 | 0.8 |
| Total | 829 | 85 | 9.8 |

University established a multidiscipline megaproject research center in 2002 called the Collaboratory for Research on Global Projects. This center has extended the global collaborative research network not only to other universities across the United States, such as the University of Pennsylvania and the University of Colorado at Boulder, but also to those outside the United States, such as Aalto University and the University of Oulu in Finland and the Indian Institute of Technology (Scott et al. 2011). In 2008, the University of Oxford established the Center for Major Program Management at the Saïd Business School in partnership with British Telecom. In 2010, Manchester University established the Center for Infrastructure Development at its business school. In China, which is predicted to be the biggest investor in megaprojects in the future, Tongji University (an active participant in China's construction megaprojects) established the Research Institute for Complex Engineering Management in 2011 to strengthen megaproject research. These research institutions will play an increasingly important role in megaproject research in the future.

Although using citations as a measure of research quality has raised some controversy (Kostoff 1998), this method has been increasingly adopted as the key indicator for measuring the quality of papers published in the CEM field (Ke et al. 2009; Hong et al. 2012). Therefore, the citations of relevant papers published in the target journals were examined. Table 6 shows the citation status of the articles identified from the eight journals. *IJPM* ranked first, with 14.2 citations per article, followed by *PMJ* and *ECAM*, with 10.5 and 10.0 citations per article respectively. The average number of citations of megaproject papers (9.8 citations per paper) in each of the three journals was higher than that of citations in all 85 papers. Thus, these three journals not only published the most megaproject papers in the selected period, but also the highest-quality megaproject papers.

The top 10 articles ranked by citation are listed in Table 7. Most of these articles were published in *IJPM*, *PMJ*, *JCEM*, and *ECAM*,

Table 5. Top 10 Research Institutions Publishing Megaproject Articles

| Ranking | Research institutions | Countries | Researchers | Articles | Scores |
|---------|--|----------------|-------------|----------|--------|
| 1 | University of Hong Kong | Hong Kong | 6 | 4 | 2.8 |
| 2 | National University of Singapore | Singapore | 5 | 3 | 2.6 |
| 3 | Vrije Universiteit | Netherlands | 4 | 3 | 2.5 |
| 4 | Asian Institute of Technology | Thailand | 2 | 3 | 2.0 |
| 5 | Norwegian University of Science and Technology | Norway | 6 | 3 | 2.0 |
| 6 | Helsinki University of Technology | Finland | 6 | 2 | 2.0 |
| 7 | Queensland University of Technology | Australia | 5 | 2 | 2.0 |
| 8 | University of Reading | United Kingdom | 3 | 2 | 2.0 |
| 8 | Strathclyde University | United Kingdom | 3 | 2 | 2.0 |
| 10 | City University of Hong Kong | Hong Kong | 4 | 2 | 1.8 |
| | Total | N/A | 44 | 26 | 21.8 |

Note: Statistics were calculated based on the original formula.

Table 7. Top 10 Journal Articles Ranked by the Citation

| Rank | Author(s)/year | Journal | Volume (issue) | Times |
|------|------------------------------|-------------|----------------|-------|
| 1 | Von Branconi and Loch (2004) | <i>IJPM</i> | 22(2) | 46 |
| 2 | Thorpe and Mead (2001) | <i>JCEM</i> | 127(5) | 44 |
| 3 | Lampel (2001) | <i>IJPM</i> | 19(8) | 34 |
| 4 | Berggren et al. (2001) | <i>PMJ</i> | 32(3) | 32 |
| 4 | Flyvbjerg (2006) | <i>PMJ</i> | 37(3) | 32 |
| 6 | Crawford et al. (2006) | <i>IJPM</i> | 24(8) | 31 |
| 6 | Miller and Hobbs (2005) | <i>PMJ</i> | 36(3) | 31 |
| 8 | Ivory and Alderman (2005) | <i>PMJ</i> | 36(3) | 29 |
| 9 | Williams (2003) | <i>IJPM</i> | 21(1) | 28 |
| 10 | Molenaar (2005) | <i>JCEM</i> | 131(3) | 23 |
| 11 | Nguyen et al. (2004) | <i>ECAM</i> | 11(6) | 23 |

Note: Data obtained from Google Scholar.

reinforcing the observation that these four journals published not only the most number of megaproject papers, but also the most important and influential articles in the selected period. The paper by van Marrewijk et al. (2008) ranked seventh, with a citation of 30 times in the list of the most cited *IJPM* papers given by Scopus (retrieved on March, 11, 2013). Although these analyses may not fully reflect the citation status of journal articles published recently, megaproject research can be construed as an increasingly important area in the CEM field.

Categories of Research Interests in Megaproject Research

CEM publications have witnessed an increasing trend in megaproject research, with topics covering a wide scope from theoretical development to practical application. Megaproject research interests involve nine topics suggested by Themistocleous and Wearne (2000).

Organization and stakeholder management ranked first among the nine topics, with 17 papers involved. Morris et al. (2011) stressed the importance of the new paradigm of viewing projects as organizations in project management studies and that this new research paradigm is the principal shift of the focus on project management studies. Table 8 shows that relevant papers focused on integrating activities and stakeholders across different organizational and disciplinary domains to improve megaproject performance, including stakeholder management (Awakul and Ogunlana 2002; Leung et al. 2004; Helm and Remington 2005; Ruuska et al. 2009); project partnership (Cathcart 2003; Anderson et al. 2006; Alderman and Ivory 2007; van Marrewijk et al. 2008); communication management (Murtoaro and Kujala 2007; Tai et al. 2009); team management (Dzeng and Wen 2005; van Marrewijk 2007); organizational governance and integration (Berggren et al. 2001; Klakegg et al. 2008; Miller and Hobbs 2005); and organizational learning and innovation (Lê and Brønn 2007; Winch 2000).

Scope and project planning and management also received the highest ranking with 17 papers involved. This topic is essential for clients in managing megaproject success. Relevant papers primarily dealt with the tasks of defining project scope, breaking down the megaproject into several manageable packages and outsourcing these work packages to contractors, including objective and scope management (Ahmad et al. 2003; Nguyen et al. 2004; Beheiry et al. 2006; Zhai et al. 2009; Toor and Ogunlana 2010); decision management (Kumaraswamy et al. 2004; Jergeas 2008; Genadio and Singh 2010; Williams and Samset 2010); procurement methods (such as design and build, engineering procurement construction, and build-operate-transfer; Tam 2000; Lampel 2001; Kumaraswamy and Morris 2002; Ling and Lau 2002; Algarni et al. 2007); and contract management (von Branconi and Loch 2004; Badenfelt 2008; Rose and Manley 2010). Table 7 shows that the relevant studies have gone through nearly the entire period and received an increasing level of interest.

The number of papers on cost and schedule management ranked third out of the 85 megaproject papers. For example, Flyvbjerg et al. (2003) stated that cost overruns and time delay are the primary risks faced by construction megaprojects. Thus, this topic has received great attention in the past decade. Research interest in this aspect was grouped into the following categories: cost overrun analysis (Eden et al. 2005; Creedy et al. 2010); delay analysis (Williams 2003; Toor and Ogunlana 2008); optimization and modeling (Wang and Demsetz 2000; Hardie 2001; Liu and Rahbar 2004; Vanhoucke et al. 2005; Touran and Lopez 2006; Bonnal et al. 2006; Yang 2007; Zammori et al. 2009); and performance management (Walker and Shen 2002; Yang et al. 2006).

Construction and site management ranked fourth (with 10 papers) among all megaproject papers. The interest in this area primarily included safety management (Chua and Goh 2005; Rajendran and Gambatese 2009); labor and construction productivity (Elhakeem and Hegazy 2005; Aziz 2008; Helen et al. 2010); quality and material management (Ibn-Homaid 2002; Keeling 2003); and construction technology and management (Attar et al. 2009; Chakraborty 2009; Hassanain 2009). These studies addressed the practical issues in the megaproject construction; these issues are indispensable to the execution management of construction megaprojects.

Risk analysis and management took fifth place, with eight papers involved. This topic has been advocated as a critical aspect in managing megaprojects (Miller and Lessard 2000; Flyvbjerg et al. 2003; Fiori and Kovaka 2005). Specific topics of the identified papers included risk identification (Santoso et al. 2003; Busby and Hughes 2004; de Camprieux et al. 2007; Krane et al. 2010); risk measurement (Molenaar 2005; Sun et al. 2008); and risk control methods (Schexnayder et al. 2004; Flyvbjerg 2006). Table 8 shows that research interest in this area has grown since 2003.

Information technology (IT) is an indispensable aspect of managing megaprojects. Harty et al. (2007) emphasized the increasing

Table 8. Major Research Interests of Megaproject Articles in the Eight Selected Journals

| Topics | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | Total | % |
|---|------|------|------|------|------|------|------|------|------|------|------|-------|----|
| Organization and stakeholder management | 1 | 1 | 1 | 1 | 1 | 3 | 1 | 4 | 2 | 2 | 0 | 17 | 20 |
| Project planning and procurement | 1 | 1 | 2 | 1 | 3 | 0 | 1 | 1 | 2 | 1 | 4 | 17 | 20 |
| Cost and schedule management | 1 | 1 | 1 | 1 | 1 | 2 | 3 | 1 | 1 | 1 | 1 | 14 | 16 |
| Construction and site management | 0 | 0 | 1 | 1 | 0 | 2 | 0 | 0 | 1 | 4 | 1 | 10 | 12 |
| Risks analysis and management | 0 | 0 | 0 | 1 | 2 | 1 | 1 | 1 | 1 | 0 | 1 | 8 | 9 |
| IT innovation and utilization | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 2 | 7 | 8 |
| Leadership and professional development | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 2 | 1 | 5 | 6 |
| Complex project management | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 4 | 5 |
| Project monitoring and control | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 3 | 4 |

trend in utilizing ITs in construction. In this study, seven papers were identified to be relevant to this area. These papers primarily involved IT application issues in different phases and aspects of megaproject management, including design management (Harty and Whyte 2010; Whyte and Lobo 2010); communication management (Thorpe and Mead 2001; Underwood and Watson 2003; Rowlinson 2007); and workflow and process management (Badir et al. 2003; Boersma et al. 2007).

The development of megaproject management as a new area of project management has increased the attention given to leadership and professional development in megaproject research since 2006. Relevant papers concentrated on two specific topics: namely, capability assessment (Yasin et al. 2009; Müller and Turner 2010) and professional development (Crawford et al. 2006; Toor and Ogunlana 2009; Frank et al. 2007). This topic is expected to receive greater research attention in the future because of the rapid growth of megaprojects.

Complex project management has been increasingly advocated as the main theory for megaproject research since the mid-2000s. A growing number of scholars stressed the importance of applying this theory to megaproject research, pointing out that it not only contributes to the establishment of a knowledge body for megaprojects (Ivory and Alderman 2005; Saynisch 2010), but also improves the capability of professionals who manage megaprojects (Thomas and Mengel 2008; Whitty and Maylor 2009).

Central monitoring and control plays an essential role in project management research, although this topic has received very limited research attention in the past decade. Only three papers on this topic were identified: Brady and Davies (2010), Edum-Fotwe et al. (2004), and Jaafari (2007).

Categories of Research Methods in Megaproject Research

Table 9 shows the relationships between eight research topics and methods of the 85 articles in the eight selected journals in the selected period. In general, qualitative methods (including mixed methods) were employed at a high frequency (62%) in the relevant

Table 9. Categories of Research Methods of Megaproject Articles in the Eight Selected Journals

| Topics | Number | Types of research methods | | |
|---|--------|---------------------------|--------------|-------|
| | | Qualitative | Quantitative | Mixed |
| Organization and stakeholder management | 17 | 14 | 3 | 0 |
| Project planning and procurement | 17 | 11 | 4 | 2 |
| Cost and schedule management | 14 | 4 | 8 | 2 |
| Construction and site management | 10 | 4 | 6 | 0 |
| Risks analysis and management | 8 | 3 | 4 | 1 |
| IT innovation and utilization | 7 | 3 | 3 | 1 |
| Leadership and professional development | 5 | 1 | 4 | 0 |
| Complex project management | 4 | 4 | 0 | 0 |
| Project monitoring and control | 3 | 2 | 0 | 1 |
| Total | 85 | 46 | 32 | 7 |

studies, indicating that megaprojects constitute an intermediate research area (Edmondson and Mcmanus 2007).

Table 9 further shows the results of the detailed examinations of research methods employed in each topic. Quantitative methods (including mixed methods) were employed at a high frequency employing as primary research methods (60–80%) in each of the five topics: namely, cost and schedule management, construction and site management, risk analysis and management, IT innovation and utilization, and leadership and professional development. Thus, these topics are intermediate or mature topics in megaproject research (Edmondson and Mcmanus 2007). In these studies, many optimization models and tools were developed and used to resolve real-life problems. The primary quantitative methods and models employed in these studies consisted of the following:

1. Empirical survey (e.g., Müller and Turner 2010; Santoso et al. 2003; Yasin et al. 2009)
2. Delphi survey (Dzeng and Wen 2005; Sun et al. 2008)
3. Correlation analysis (Helen et al. 2010)
4. Regression analysis (Creedy et al. 2010)
5. Fuzzy analysis (Zammori et al. 2009; Dzeng and Wen 2005)
6. Particle swarm optimization (Yang 2007)
7. Markov analysis (Hardie 2001)
8. Integer programming analysis (Rajendran and Gambatese 2009)
9. Loss causation analysis (Chua and Goh 2005)
10. Nomograph theory (Elhakeem and Hegazy 2005)
11. Maximal flow theory (Liu and Rahbar 2004)
12. Social network analysis (Thorpe and Mead 2001)
13. Monte Carlo simulation analysis (Touran and Lopez 2006)
14. Networks under the correlated uncertainty simulation model (Wang and Demsetz 2000)

Among the four remaining topics (namely, organization and stakeholder management, project planning and procurement, project monitoring and control, and complex project management), a high percentage of qualitative methods (including mixed methods) as primary research methods (77–100%) was observed in each of these topics (Table 9). This result indicates that these topics are nascent research areas (Edmondson and Mcmanus 2007). A triangulation of multiple qualitative methods, such as interviews, case studies, and content analyses, were employed frequently in these studies to explore the theories behind real cases (e.g., von Branconi and Loch 2004; Murtoaro and Kujala 2007; Thomas and Mengel 2008; Ruuska et al. 2009; Toor and Ogunlana 2010; Brady and Davies 2010).

Assessing Megaproject Research in a Project Complexity Framework

As shown in Fig. 1, a dual-dimension framework is proposed to assess previous megaproject research and identify its future direction.

The fast emergence of construction projects worldwide has improved significantly in the built environment. However, the execution of these megaprojects has pushed the limits of scope, experience, and technology (Fiori and Kovaka 2005). These megaprojects are usually characterized by high internal complexity, such as task complexity (Brockmann and Girmscheid 2007), structural and directional complexity (Remington and Pollack 2008), technical complexity, and organizational complexity (Baccarini 1996). Most previous megaproject studies focused on these internal complexity issues (Fig. 1). Many studies have been conducted on relevant topics, such as construction and site management, cost and schedule management, risk analysis and management, IT

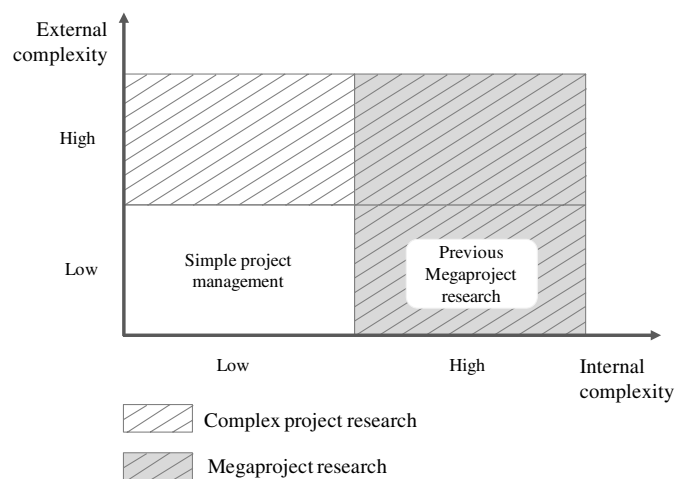


Fig. 1. A framework of project complexity for positioning megaproject research

innovation and utilization, and leadership and professional development. However, the frequent use of qualitative methods (including mixed methods) in the three additional topics (namely, organization and stakeholder management, project planning and procurement, project monitoring and control) indicates their possible lack of a main theory. This lack reinforces the argument of Pellegrinelli et al. (2011) that a great research opportunity exists in megaproject organization. A growing number of researchers suggest that complex project management serves as a theoretical foundation in megaproject research, particularly in these nascent topics (Ivory and Alderman 2005; Whitty and Maylor 2009; Thomas and Mengel 2008).

Construction megaprojects also need to deal with the complexity from contextual uncertainty, namely external complexity. Construction projects operate in the uncertain context because of widespread economic fluctuation (Shehu and Akintoye 2010). In major developing countries, such as China, India, and Russia, which are new investors in megaprojects, megaproject management faces even more uncertainty from social and cultural transitions. This contextual uncertainty has greatly increased the external complexity in managing megaprojects, which includes temporal complexity (Remington and Pollack 2008) and social and cultural complexity (Brockmann and Girmscheid 2007). This complexity affects several relevant topics, such as organization and stakeholder management, project planning and procurement, project monitoring and control, and risk analysis and management. This issue has been discussed in Miller and Hobbs (2005), de Camprieux et al. (2007), and Klakegg et al. (2008), but it deserves greater attention in future megaproject research. Miller and Hobbs (2005) proposed that megaprojects can reconcile this uncertainty through good interaction with the institutional environment. Mahalingam and Levitt (2007) indicated that institutional theory can help practitioners classify the issues from institutions that they encounter, determine the causes of these problems, and judge with relative ease the best way to resolve each problem. Only recently has institutional analysis been increasingly advocated as the main tool to examine the contextual effect on the management of megaprojects (e.g., Grigg 2005; Mahalingam and Levitt 2007). For instance, Chi and Javernick-Will (2011) used institutional analysis to examine project management arrangements in high-speed rail projects between Taiwan and China. Mahalingam and Levitt (2007) also used this theory to analyze the source of conflicts in metro railway projects in India. Remington and Pollack (2008) enumerated

several methods for researching into the external uncertainty of megaprojects, such as mapping complexity, system anatomy, and multimethodology in parallel. Most of the relevant studies mentioned were conducted either in developed countries or as a collaboration between developed and developing countries. Major developing countries that are new investors in megaprojects but lack a research tradition are considering that research collaborations with developed countries that have merit in megaproject research are advantageous. Several collaborative studies have been completed, but they remain insufficient.

Conclusions

Megaproject management has emerged as a separate research area, drawing extensive attention from scholars and practitioners. As a practice-driven research area, megaproject management will experience a fast level of development in the near future because of the anticipated investment boom in construction megaprojects (Economist 2008). This paper systematically reviewed relevant articles published between 2000 and 2010 to assess the state of this field and identify the research trends in megaproject research. A total of 85 relevant papers identified from eight peer-reviewed construction journals were analyzed in terms of the number of articles published annually, institutional and regional contributions, citations, and categorization of research interests and methodologies.

The analysis results reveal a growing interest in megaproject research, particularly in the past five years, and that major developed countries such as the United Kingdom, the United States, and Australia have enjoyed a huge advantage in megaproject research because of their greater experience. Meanwhile, megaproject research in developing countries such as Russia, India, Turkey, and Vietnam, which are new investors in megaprojects, remains weak or lacking. In addition, several developed countries, such as Spain, South Korea, and Brazil, have yet to establish megaproject research in their research institutions.

The research interests and methodologies in megaproject research are categorized to assess the state of this field and identify the future directions. Many important theory-based contributions to megaprojects have been made in the five subareas of cost and schedule management, construction and site management, risk analysis and management, IT innovation and utilization, and leadership and professional development. Meanwhile the subareas of organization and stakeholder management, project planning and procurement, and project monitoring and control have been identified as rich domains for future research. An assessment using the project complexity framework confirms that greater research efforts incorporating new theories, such as complexity theory and institutional theory, should be directed to these topics through strengthened global collaboration.

This study provides a critical overview of megaproject development in the academic field by presenting an overall theoretical picture for researchers to acquire useful insights into the megaproject issue. A better understanding of this research trend may enable scholars and practitioners to appreciate the key issues in megaproject research to facilitate faster development in this area.

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