This is the accepted version of the publication Wu H, Xue X, Zhao Z, Wang Z, Shen GQ, Luo X. Major Knowledge Diffusion Paths of Megaproject Management: A Citation-Based Analysis. Project Management Journal (Volume 51, Issue Number 3) pp. 242-261. Copyright © 2000 (Project Management Institute, Inc.). DOI: 10.1177/8756972819850232.

Major Knowledge Diffusion Paths of Megaproject Management: A Citation-Based Analysis

Hengqin Wu, PhD student, School of Management, Harbin Institute of Technology, Harbin, China. Email: hengqin.wu@connect.polyu.hk

Xiaolong Xue, Professor, School of Management, Guangzhou University, Guangzhou, China; School of Management, Harbin Institute of Technology, Harbin, China; Email: xlxue@hit.edu.cn

*Zebin Zhao, Associated professor, School of Management, Harbin Institute of Technology, Harbin, China (corresponding author). Email: zhaozebin@hit.edu.cn.

Zeyu Wang, Associated professor, School of Management, Guangzhou University, Guangzhou, China. Email: wangzeyu@gzhu.edu.cn

Geoffrey Qiping Shen, Chair Professor of Construction Management, Department of Build and Real Estate, The Hong Kong Polytechnic University, Hong Kong, China. Email: geoffrey.shen@polyu.edu.hk

Xiaowei Luo, Assistant Professor, Department of Architecture and Civil Engineering, City University of Hong Kong, Hong Kong, China. Email: xiaowluo@cityu.edu.hk

Abstract

This article integrates social network analysis and main path analysis to investigate progress in megaproject management (MPM) from the perspective of knowledge diffusion. After measuring three major knowledge diffusion paths of MPM, the authors find that MPM is mainly driven by a set of problems and puzzles. The findings provide an exciting opportunity to advance existing understanding of MPM from an alternative angle of knowledge diffusion that considers the underlying associations among publications. Moreover, this article employs

quantitative methods to examine citation data of publications, thus providing more unbiased and in-depth analysis to illustrate the development of MPM.

Keywords

knowledge diffusion, main path analysis, megaproject management, modularity optimization

Introduction

Megaprojects have been known to bring about severe problems, including cost overruns, poor performance, environmental damage, and conflicts of interest between stakeholders (Aaltonen, Kujala, Havela, & Savage, 2015; Flyvbjerg, 2014), leading to considerable challenges for project managers. Since 2000, megaproject management (MPM) has emerged and developed as a separate research field (Hu, Chan, Le, & Jin, 2015). However, the current body of knowledge in MPM does not provide enough support to meet the challenges in the management practice of megaprojects (Flyvbjerg, Landman, & Schram, 2016; Li, Lu, Taylor, & Han, 2017). The "tension point" of MPM has attracted increasing attention and thus researchers have been compelled to review the MPM body of knowledge (Flyvbjerg et al., 2016) to address the challenges. Scholars have devoted a lot of effort to extend MPM knowledge from different perspectives, such as civil engineering and construction (Levitt, 2007; Love, Holt, & Li, 2002), social and economic impacts (Cicmil, Williams, Thomas, & Hodgson, 2006; Flyvbjerg, Bruzelius, & Rothengatter, 2003), project management (Van Marrewijk, Clegg, Pitsis, & Veenswijk, 2008), and sustainable and urban development (Kennedy, 2015). MPM is also recognized as an academic field in the social sciences and characterized by a cumulative and combinatory nature (Nemet, 2012), which progress highly depends on transfer of knowledge across other fields (Flyvbjerg & Turner, 2018). . In this way, one can expect that MPM, similar to other fields in the social sciences, embodies diversified theories, ideas, and methods from different fields to improve and extend knowledge (Schoenmakers & Duysters, 2010). In general, progress in a field heavily depends on prior knowledge (Battke, Schmidt, Stollenwerk, & Hoffmann, 2016), and MPM is no exception. This highlights the role of the diffusion process (Chen & Hicks, 2004; Sorenson & Fleming, 2004), in which new knowledge is advanced by a combination of existing knowledge (Fleming, 2001; Grant, 1996; Schilling & Green, 2011). Without effective diffusion, knowledge would be worthless (Yu, Wang, & Yu, 2010). Knowledge diffusion has been an active research area in several fields (Argote & Ingram, 2000; Luo, Du, Liu, Xuan, & Wang, 2015; Ma & Liu, 2016; Park & Magee, 2017). This article aims to ascertain the knowledge diffusion process of MPM by looking into MPM's development trajectories, revealing MPM research interlinkage and its development from the past to the present.

Certain empirical studies have been conducted to investigate knowledge diffusion, and citation-based approaches are frequently used in those studies to quantitatively measure the diffusion process (Chen & Hicks, 2004; Jaffe & Trajtenberg, 1999; Lu & Liu, 2014; Sorenson & Fleming, 2004; Xiao, Lu, Liu, & Zhou, 2014). The trajectories of knowledge diffusion are too impalpable to follow, but they form citation patterns between academic publications (Jaffe, Trajtenberg, & Henderson, 1993), providing a measurable way to trace knowledge flows. In this way, citations indicate unidirectional links that connect publications from the past to the present (Small & Griffith, 1974), revealing the process by which knowledge is diffused from the original publications to the latter ones (Lucio-Arias & Leydesdorff, 2008). The authors perform a citation-based approach by integrating citation analysis, modularity optimization, and main path analysis to trace the major knowledge diffusion paths of MPM. Specifically, the citation analysis models the knowledge flows of MPM in a citation network; the cluster analysis, using modularity optimization, divides the citation network into several groups; and the main path analysis identifies the major knowledge diffusion paths in each group.

To date, the review works of MPM have tended to focus on finding future research directions (Hu et al., 2015), identifying important articles, and analyzing current research topics (Gemunden, 2015; Li et al., 2017). However, there is little discussion about how MPM emerged and developed, and it is unclear what specific knowledge contributes to enlightening and inspiring MPM research. This study fills those gaps and makes two contributions to MPM research. First, this article investigates research progress in MPM from the perspective of knowledge diffusion, considering social connections between the publications. Most of the previous research findings are based on reviewing a set of literature, which is selected based on personal judgments with potential biases (Silva, Amancio, Bardosova, Costa, & Oliveira, 2016). It is hard to reveal the social interactions and knowledge flows when the volume of the literature set is large (Stone & Lavine, 2014). Second, this study provides readable and objective outputs to illustrate the development trajectories of MPM through a citation-based approach. The results could assist scholars in better understanding the evolutionary history of MPM, and especially in understanding the current status based on the connections and research streams from the past to present.

Framework: The Conceptual Background on Knowledge Diffusion

Knowledge diffusion has been investigated from several perspectives, and currently, three of them have gained increased attention: regions, firms, and academic fields. Table 1 summarizes these perspectives in terms of research content, diffusion channels, and methods adopted. In the context of regions and firms, due to the crucial role that knowledge diffusion plays in economic growth and innovation, more attention has been given to the factors that affect knowledge diffusion, highlighting the externalities or spillovers of knowledge (Orazbayev, 2017; Roper & Hewitt-Dundas, 2015). Some of the studies measured the knowledge diffusion through a variety of indicators, such as the number of patents, scientists' immigration, and research expenditure (Appleyard & Kalsow, 1999; Hoetker & Agarwal, 2007; Nelson, 2009), and empirically analyzed the relationship between knowledge and the explored factors. However, the process of knowledge diffusion has been rarely studied because it is difficult to measure the virtual flows between the stakeholders in the network. In addition, the knowledge could be diffused through various channels, such as supply chains (Roper & Hewitt-Dundas, 2015), scientists' immigration (Orazbayev, 2017), training programs (Hoetker & Agarwal, 2007; Roper & Hewitt-Dundas, 2015), and so on, making it more difficult to measure the diffusion process of knowledge.

In recent years, the process of knowledge diffusion between and within different academic fields or scientists seems to have been powerful (Yu et al., 2010), owing to the inherent openness of and accessibility to academic knowledge. Modern science highlights the role of representative publications, such as books and journal articles, in which knowledge is archived to avoid disappearance (Sorenson & Fleming, 2004), making the knowledge public property, which is available to all and could not be diminished in the diffusion process(Arrow, 1962). Therefore, scholars may disseminate their knowledge to others (Jaffe, 1986), as well as acquire knowledge from others with less effort (Foray & Lundvall, 1998). This may considerably accelerate knowledge diffusion among different scientists and disciplines (Wojick, Warnick, Carroll, & Crowe, 2006). As mentioned above, this article focuses on the knowledge transfer process within academic fields, in which the knowledge can be diffused through several channels, such as student training, public and private communications, and conferences (Bernal, 1939). This article investigates the knowledge diffusion of MPM through publications, which convey knowledge with high-level openness and reduce the restrictions of locations and private social networks, thus diffusing the knowledge in a much broader scope and accelerating the diffusion process (Sorenson & Fleming, 2004).

Table 1. Research Perspectives of Knowledge Diffusion

Research perspectives	**Research content**	**Channels whereby the knowledge was diffused**	**Methods**
Between and within regions	Factors that impact knowledge diffusion across regions (Jaffe & Trajtenberg, 1999; Orazbayev, 2017; Singh & Marx, 2013); approaches to reduce geographic constraints (Singh & Marx, 2013) and policies that help to facilitate knowledge diffusion; patterns of knowledge diffusion within different regions (Wu & Mathews, 2012); the mechanism that knowledge diffusion affects the productivity growth (Hu & Jaffe, 2003)	Scientists' immigration; purchasing patents; international collaborations; imported capital goods, and so on	Social network analysis ; questionnaire survey; structural equation model; regression

Between organizations	Factors that impact knowledge diffusion between organizations (Darr & Kurtzberg, 2000; Luo et al., 2015; Szulanski, 2000; Wang, Guo, Yang, & Liu, 2015); how knowledge diffusion affects organizational performance (Argote & Ingram, 2000; Cavusgil, Calantone, & Zhao, 2003); methods and tools to foster knowledge transfer within organizations (Bartol & Srivastava, 2002)	Internal social networks (such as internal training programs, online official systems, etc.); face-to-face contact; supply chains, and so on	Social network analysis; questionnaire survey; citation analysis
Between and within academic fields	Knowledge diffusion paths shedding light on the overall development trajectories for an academic field (Chuang et al., 2017; Liang, Wang, Xue, & Cui, 2016; Lu, Hsieh, & Liu, 2016; Lucio-Arias & Leydesdorff, 2008; Tu & Hsu, 2016; Yu et al., 2010)	Publications; patents	Social network analysis; citation analysis; main path analysis; text mining

Methodology

The citation-based approach embodied in this study integrates three methods: citation analysis, modularity optimization, and main path analysis (Figure 1 shows the four steps in the analysis procedure, and Appendix E describes the tools used for the method implementation). The citation link between two publications is a good indicator of knowledge flow, providing a lasting reflection of the social interactions between publications (Fujigaki, 1998; Sorenson, Rivkin, & Fleming, 2006). In addition, the citation activities (citing and being cited) provide directional information between the publications, revealing what knowledge is codified and diffused dynamically (Lucio-Arias & Leydesdorff, 2008; Small & Griffith, 1974). As a result, the citation relations have been widely investigated to trace the research progress in different academic fields (Chuang et al., 2017; Ho, Liu, & Chang, 2017; Liang et al., 2016; Lu & Liu, 2014; Xiao et al., 2014). Although some scholars point out that citations between publications may not accurately reflect the process of knowledge diffusion

(Alcacer & Gittelman, 2006; Roach & Cohen, 2012), citation is recognized as one of the best measurements available due to the lack of alternative and comparable methods (Nelson, 2009; Orazbayev, 2017; Roach & Cohen, 2012). The four steps in the analysis procedure are further elaborated in the following subsections.

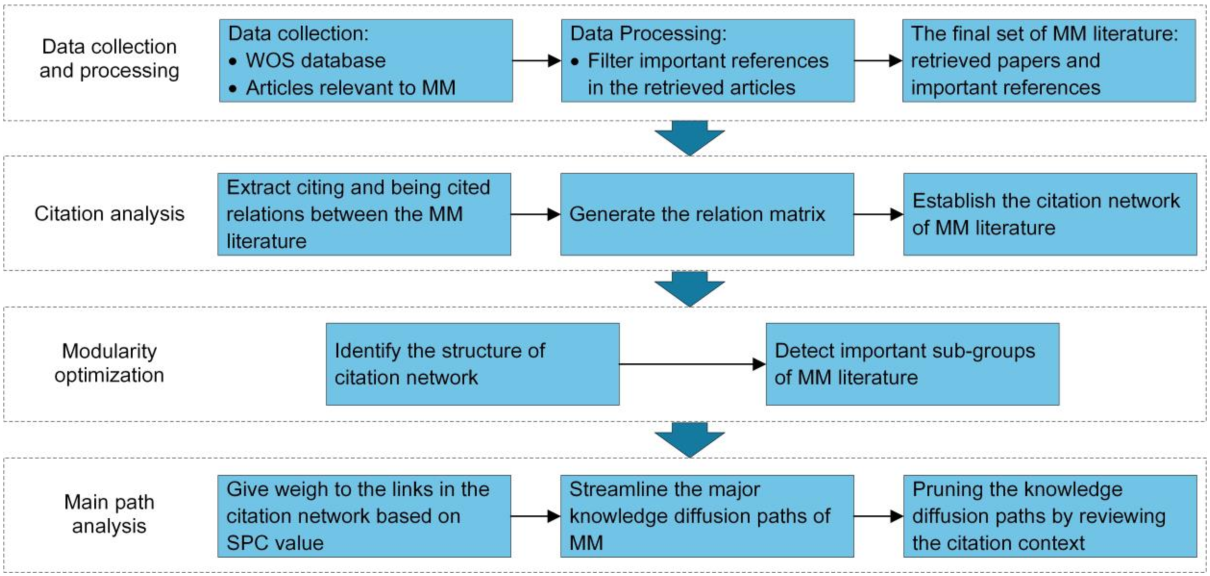

Figure 1. The analysis procedure

Data Collection and Processing

Data Collection

Data collection is a crucial step that significantly affects the citation analysis results. To achieve precise and robust results, a four-step procedure was adopted to retrieve the most relevant data for defining the MPM domain (Figure 2). The authors retrieved the data from the core collection of the Web of Science because it is considered the largest accessible academic citation database that provides representative academic journal articles with their citation information (Boyack, Klavans, & Borner, 2005).

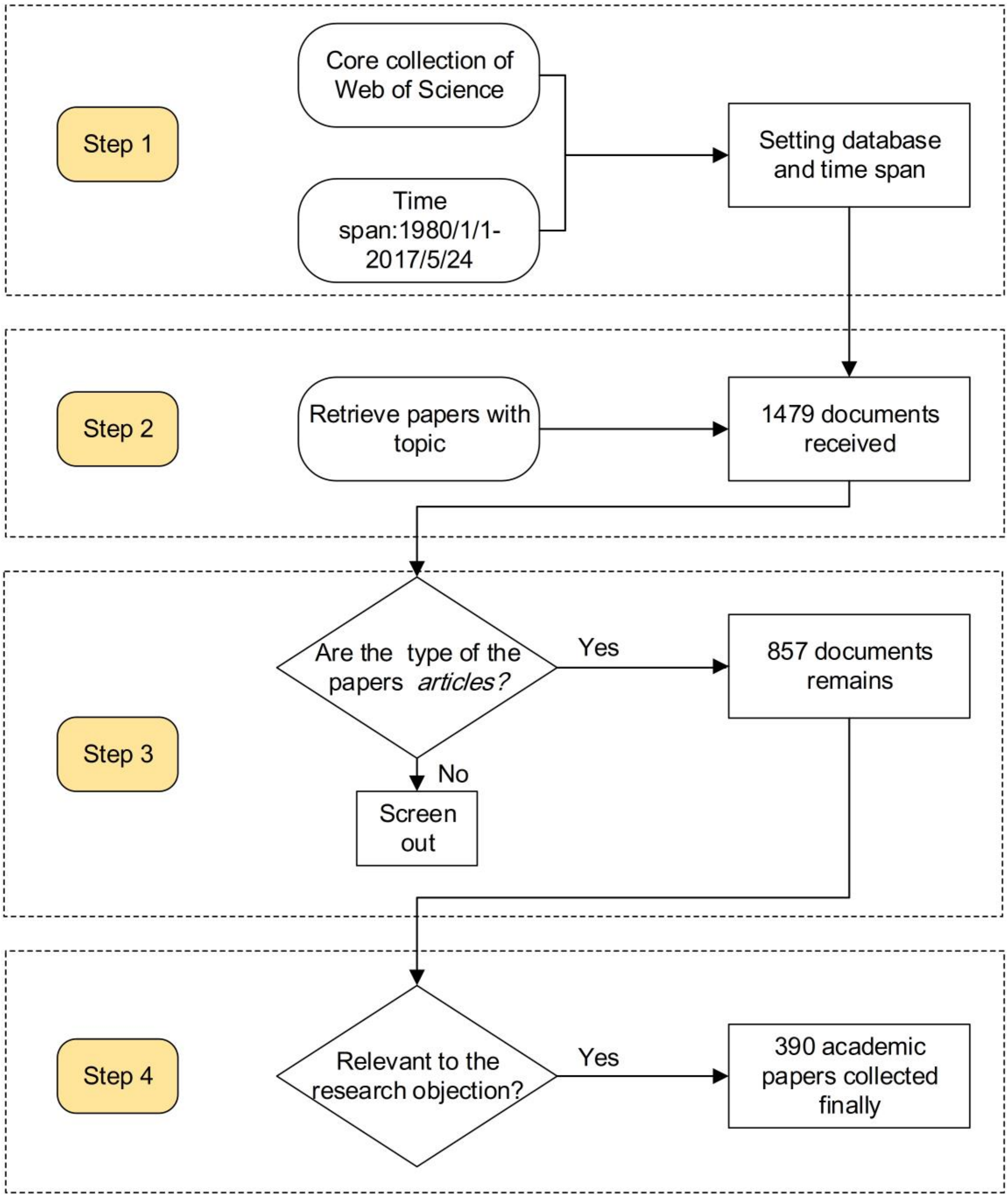

Figure 2. Detailed steps of data collection

The searching criteria strongly depend on the definition of megaprojects. Researchers have defined megaprojects from different perspectives (Flyvbjerg, 2014; Miller, Lessard, Michaud, & Floricel, 2000). In this article, the authors consider megaprojects to be large-scale construction or infrastructure projects that transform the landscape considerably (Gellert &

Lynch, 2003), significantly impacting the politics, economy, society, technology progress, environmental preservation, public welfare, and national security (Flyvbjerg, 2014; Flyvbjerg et al., 2003; Gellert & Lynch, 2003). Therefore, this study identifies appropriate keywords for searching by referring to some review articles of megaprojects (Flyvbjerg, 2014; Greiman, 2013; Mok, Shen, & Yang, 2015; Zidane, Johansen, & Ekambaram, 2013). With the definition of megaprojects summarized in those articles, the searching criterion used in this paper is: "Topic" = *(("mega project*" or "mega-project*" or "large-scale project*" or "complex project*" or "major project*") and ("construction" or "civil engineering" or "infrastructure" or "urban")) or "mega-project*" or "major infrastructure project*" or "mega infrastructure project*" or "large construction project*" or "complex construction project*".*

In addition, only publications within the category of "article" were retrieved. "Review paper," "proceedings paper," "editorial material," and so on are excluded because they do not always contain well-defined research questions and problems, and lack a rigid research methodology and regular citation patterns. Furthermore, the authors reviewed the contents of the articles to filter out the ones irrelevant to MPM, reducing the size of the data set from 857 to 390. Those 390 articles make up the primary data set.

Data Processing

This step adds some important but missing literature back to the primary data set. Most previous studies identified important literature from the retrieved articles (Ho, 2014; Martinez, Herrera, Lopez-Gijon, & Herrera-Viedma, 2014; Powell, 2016), and this may have caused some of the literature to be missed due to the limitations of the citation databases (i.e., Web of Science) because: (1) only journal articles are included in the database, but other document types such as books and reports are not included regardless of their significance in the research fields; (2) the searching criteria restricts the retrieved articles in the scope of MPM. However, research from other fields, not directly about MPM, may impact MPM. Therefore, the relevant literature should not be excluded from the primary data set. (3) Some articles published in earlier years may not be included in the database. The authors address those limitations by considering the references of the 390 articles as the candidates to be included into the primary data set because the references do not have the restrictions above, and more importantly, high-impact literature always appears in the references, not as the articles (Seglen, 1998). To select the appropriate articles from the candidates to be included in the primary data set, H-index is used as the selection criterion because it is relatively objective and unbiased (Hirsch, 2005; Martinez et al., 2014). This may avoid the arbitrary results that have occurred in previous studies when setting fixed values to extract significant publications from the candidates, such as setting a minimum value (e.g.,100 or 50) for the number of citations (Ho, 2014; Ibrahim, Snead, Rutka, & Lozano, 2012; Powell, 2016), or a percentage or a number of highly cited publications (e.g., the top 0.5% of highly cited publications; or the top 50 of highly cited publications) (Aminian, Hinckson, & Stewart, 2015; Joyce, Sugrue, Joyce, Kelly, & Regan, 2014; Lo, Wong, Tam, & Ho, 2016). In this case, based on the local citation count (i.e., the LCC, the number of citations by the MPM articles), the threshold of H-index is computed as six. The authors selected the articles with

LCCs larger than six from the candidates and added those selected articles to the expanded primary data set for the citation network generation. Finally, 449 publications (390 MPM articles and 59 references that are cited by some of the 390 articles with LCC greater than six) comprise the final data set.

Citation Analysis

Citation analysis is normally utilized by social network analysis (de Solla Price, 1965). When modeling a set of publications by a citation network, a correlation matrix C is always used to measure the citation relations among the publications (Hummon & Doreian, 1989; Verspagen, 2007). An element c_{ij} of C has a value of 1 or 0, which indicates whether publication j cites publication i or not. Therefore, there is no link between node i and node j when $c_{ij} = 0$, and there exists a directed link from node i to node j if $c_{ij} = 1$. The citation network converted from the correlation matrix C is a directed acyclic graph because any publication cannot cite a later-published publication (Small & Griffith, 1974). Because the citation network is a directed acyclic graph, the nodes in the network can be divided into three categories: source (a publication that never cites any publications in the network), sink (a publication that has never been cited by any publications in the network), and intermediate nodes (Dohleman, 2006; Tu & Hsu, 2016). Intermediate nodes are those publications that have cited others as well as have been cited by others. In the citation network, the knowledge flows from the sources to the sinks directly or through intermediate nodes.

In this case, the authors developed the citation network of MPM with 449 nodes (corresponding to the publications in the final data set) and directed edges using the citation relationship extracted from the references lists of each article. The authors further removed the nodes that were not included in the giant component (an independent subnetwork that includes a significant portion of nodes in the network). In this way, irrelevant publications were pruned out because proper and relevant publications always cite and are cited with each other (Shibata, Kajikawa, Takeda, & Matsushima, 2008).

Modularity Optimization

Before employing the main path analysis, the authors use modularity optimization to divide the citation network into groups. Modularity optimization is an algorithm to explore the structure of the network to deliver high-quality results in less time, especially for the densely connected networks (Vincent, Jean-Loup, Renaud, & Etienne, 2008). Modularity optimization has been widely applied to detect the structure in networks with weighted links. Modularity Q can be calculated using the following equation (Newman, 2004):

$$Q = \frac{1}{2m}\sum_{i,j}\left[A_{ij} - \frac{k_i k_j}{2m}\right]\delta(c_i, c_j) \quad (1)$$

Where A_{ij} is the weight of the link from node i to j, c_i is the group to which node i belongs, k_i is the degree of node i, and m denotes the number of links in the network. The δ -function δ (u, v) is 1 if u = v and 0 otherwise. The value of Q is a good index to indicate whether a division of a network into groups is a good one. The division that has the largest Q value is the optimum solution. Modularity optimization is one of the most popular algorithms to detect the underlying structure that is a common property in most social networks, in which nodes aggregate into groups with solid connections. In a citation network, the publications in the same group tend to share similar topics, methods, or ideas (Small, 1973).

Main Path Analysis

Main path analysis is one of the citation-based approaches that is widely used to identify the most valuable paths of knowledge diffusion by streamlining a significant citation route from a huge and complex citation network (Hummon & Doreian, 1989). In the extracted route, only significant links can appear to highlight the academic achievements in a dynamic sequence (Lucio-Arias & Leydesdorff, 2008). In specific, the main path analysis converts the binary correlation matrix of a citation network to a weighted matrix by computing the traversal counts that capture the times a link has been passed through by all the possible routes from all sources to all sinks. To date, scholars have preferred the search path count to measure the traversal counts (Batagelj, 2003; Chuang et al., 2017; Liang et al., 2016; Lu & Liu, 2016). For example, in Figure 3, all the possible routes from the sources (A and B in Figure 3) to the sinks (X, Y and Z in Figure 3) are AZ, AFZ, BDFZ, BDEZ, BDY, BDEY, BCY, and BCX. Therefore, the search path count value for link BD is four, because four routes (BDFZ, BDEZ, BDY, and BDEY) pass link BD. A larger search path count value of a link indicates that this link plays a more important role in the path of knowledge diffusion (Batagelj, 2003).

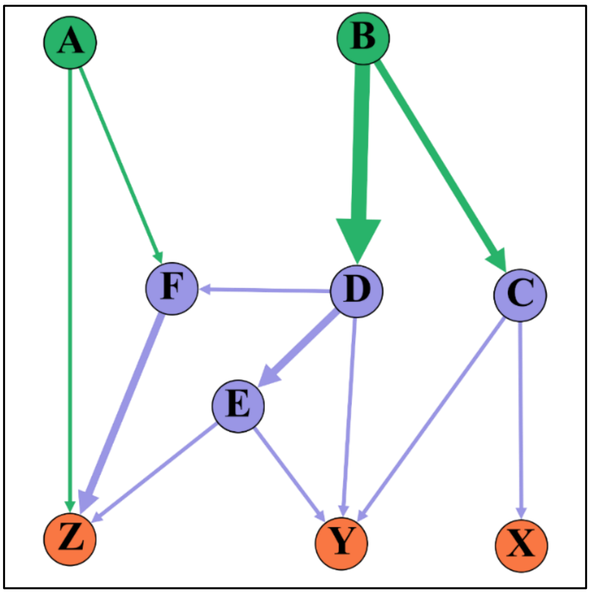

Figure 3. A citation network with search path count value as weights.

Several algorithms, including local, global, and key route have been developed to search the main paths. Traditionally, the local algorithm follows a "priority-first search" manner (Hummon & Doreian, 1989), which starts from a source by choosing the link with the highest search path count outgoing from the source node, and repeats the searching from the node that the chosen link goes to until a sink is reached. In fact, the local search algorithm identified the main paths with progressive focuses and may not produce the main path with the highest sum of search path counts, whereas the global search algorithm suggests the main path with the highest sum of search path counts (Liu & Lu, 2012). Key-route search algorithm, as an advanced one, considers both the developing path and the long-term influence (Liu & Lu, 2012).

This study uses the key-route algorithm to trace the major knowledge diffusion paths of MPM. Such an algorithm gives an opportunity to provide a more objective outcome in which significant publications and diffusion routes can appear because being cited is more important than citing in this method. There can be a number of knowledge diffusion routes in the citation network, but only the publications with a higher LCC have a better chance to appear in the main path.

The last step is pruning the main paths by reviewing the citation context. The purpose is to remove the peripheral paths and retain the significant ones. If the references were cited to provide relevant information supporting a specific but not important argument, the citation links would be pruned out (Liang et al., 2016). On the other hand, if the references were cited to stand for basic viewpoints or concepts, such as research questions or ideas, basic methodology or hypotheses, the citation links would be retained (Appendix D interprets this function with an example).

Results

In this section, the authors report the obtained structure of the network and the major knowledge diffusion paths . Figure 4 illustrates the procedure that the authors used to obtain the major knowledge diffusion paths of MPM from the primary citation network. In specific, Figure 4(a) shows the primary citation network established based on the collected 449 publications and their citation relations. Figure 4(b) shows the clustered groups and further identified major knowledge diffusion paths of the top three groups. Table 2 reports the number of nodes in the groups in the giant component.

The Citation Network and the Clustered Groups

In the citation network, the links between the nodes indicate the citation relations, and the arrow of a link indicates the citation direction. A total of 449 nodes and 865 links comprise the citation network of MPM. The average degree of the network is 3.589, which means each publication has 3.589 citation links with others on average, indicating a relatively high association of MPM regardless of the well-recognized fragmental nature of MPM (Flyvbjerg & Turner, 2018; Li et al., 2017).

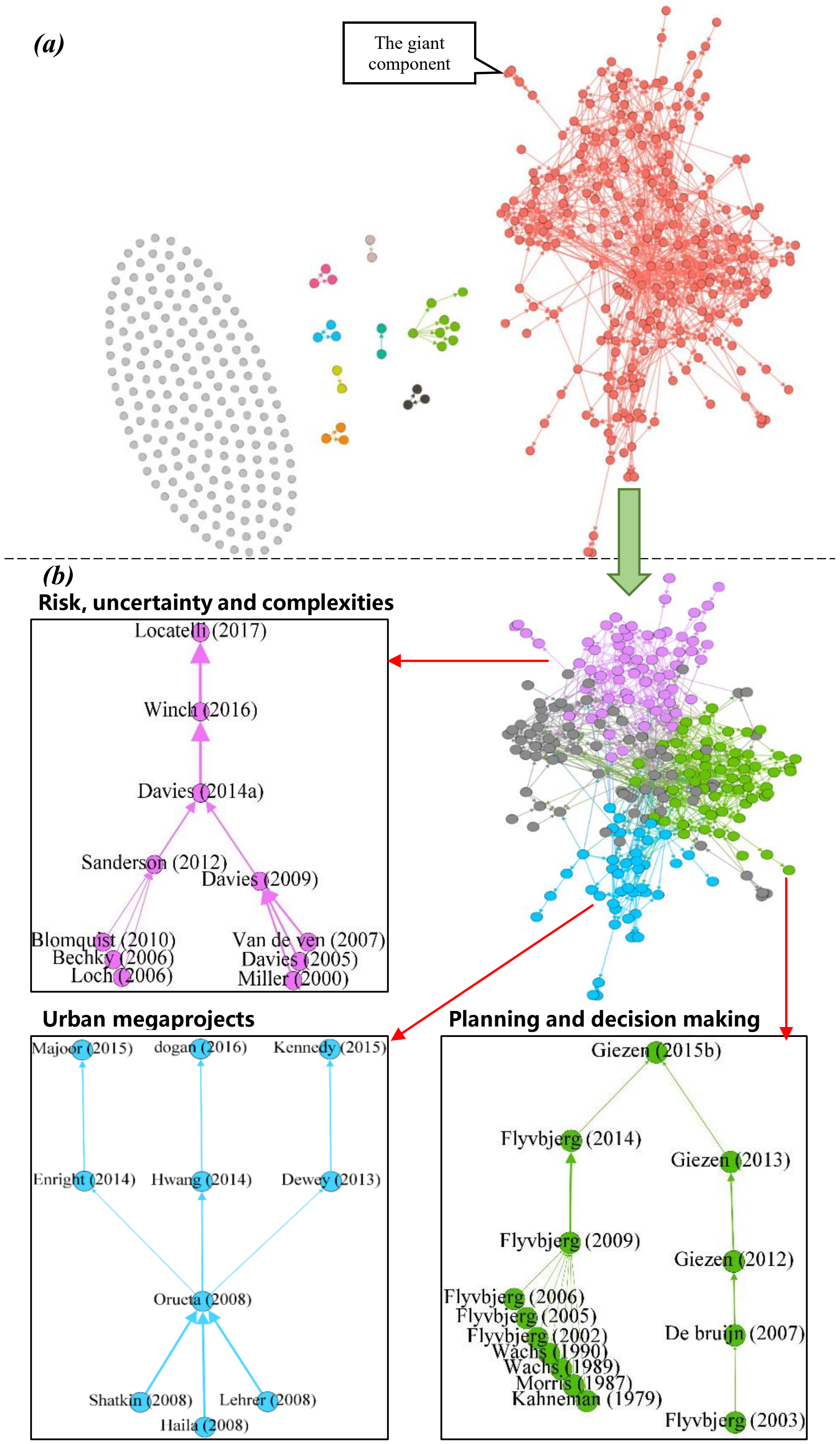

Figure 4. Identifying the major knowledge diffusion paths from the primary citation network: (a) the primary citation network; (b) the structure and major knowledge diffusion paths.

In specific, the giant component in Figure4(a) contains 236 nodes and 847 links, accounting for 52.6% and 97.91% of the network, respectively. The algorithm of modularity optimization identifies the structure within the giant component, dividing the component into seven groups. As shown in Table 2, since publications from the top three groups account for 69% of publications of the giant component, the authors choose the top three groups in the giant component for further analysis, separating the groups with colors/shadeslabeling the nodes in those groups with . Consequently, the authors extract MPM's major knowledge diffusion paths in those three groups. As shown in Figure 4(b), a link connects a cited publication to a citing one, and the thickness of a link denotes the normalized search path count value, which represents the importance of the diffusion channel of MPM knowledge.

Table 2. The Distribution of Nodes in Seven Groups

No.	Number of publications	Percent of the sum of publications	Cumulative percent of the sum of publications
1	64	27.119%	27.119%
2	59	25.000%	52.119%
3	42	17.797%	69.915%
4	26	11.017%	80.932%
5	25	10.593%	91.525%
6	13	5.508%	97.034%
7	7	2.966%	100.000%

Major knowledge diffusion paths of MPM

The proposed approach identified three major knowledge diffusion paths of MPM with 38 publications (32 journal articles and six books). Unlike some review works that identified important literature only from journal articles (Aksnes, 2003; Garfield, 1976; Y. S. Ho, 2012; Y. Hu et al., 2015; Kelly, Glynn, O'Briain, Felle, & McCabe, 2010), this study covers some critical books by adding important references into the citation network (as mentioned in *Data Collection section*). Moreover, some classic publications from other fields are also incorporated in the major knowledge diffusion paths (see Appendix A, B, and C for details), which is consistent with the nature of MPM, that MPM is associated with other fields (Flyvbjerg & Turner, 2018). The authors report the results on the three identified major knowledge diffusion paths as follows and interpret the implications in the discussion section.

Knowledge Diffusion Path 1 for Group 1 (Risk, Uncertainty, and Complexity)

The identified path 1 contains 11 publications (four books and seven articles, see Appendix A for details), mainly reflecting the knowledge diffusion progress in risk, uncertainty, and complexity that causes poor performance in megaprojects. As shown in Figure 5, path 1 shows a convergence pattern, where two diffusion streams congregated in Davies and Mackenzie's (2014) article, proposing an organizational rationale coping with complexity in megaprojects: The organizational structure of a megaproject should be constructed to integrate complexities rather than to break them into small subprojects. This rationale inspired the later research, which focuses on the "strong owner" (Winch & Leiringer, 2016) and corruption (Locatelli, Mariani, Sainati, & Greco, 2017). While tracking back to the upstream of path 1, the progress heavily depends on two streams of knowledge: the recognition of the nature of megaprojects (in Figure 5, the left stream under Davies & Mackenzie, 2014) and the system integration model (in Figure 5, the right stream under Davies & Mackenzie, 2014).

In the left stream, three publications process the source positions and offer the fundamental knowledge, providing a "projects-as-practice" approach (Bechky, 2006; Blomquist, Hallgren, Nilsson, & Soderholm, 2010), and knowledge of the relation between inappropriate governance and poor performance of megaprojects (Loch, DeMeyer, & Pich, 2006). Sanderson (2012) analyzed the unique features of megaprojects and summarized the possible factors that cause performance problems that frequently occurred in megaprojects. In the right stream, three publications provide the source knowledge in terms of general understanding for complex problems, project performance, and risks (Miller et al., 2000), managing the risk and innovation (Davies & Hobday, 2005) in projects, and rationales for complex social problems (Van de Ven Andrew, 2007). That knowledge diffused into Davies, Gann, and Douglas (2009), who proposed a "system integration model" to cope with poor performance in megaprojects.

It is noticeable that a few scholars heavily influenced MPM over time and their work repeatedly appeared on the major knowledge diffusion paths. As the path is identified using the key-route search algorithm, the publications, which not only rely on prior works but also play important roles in reference to later ones, would have higher probabilities to be included on the main paths (Lucio-Arias & Leydesdorff, 2008).

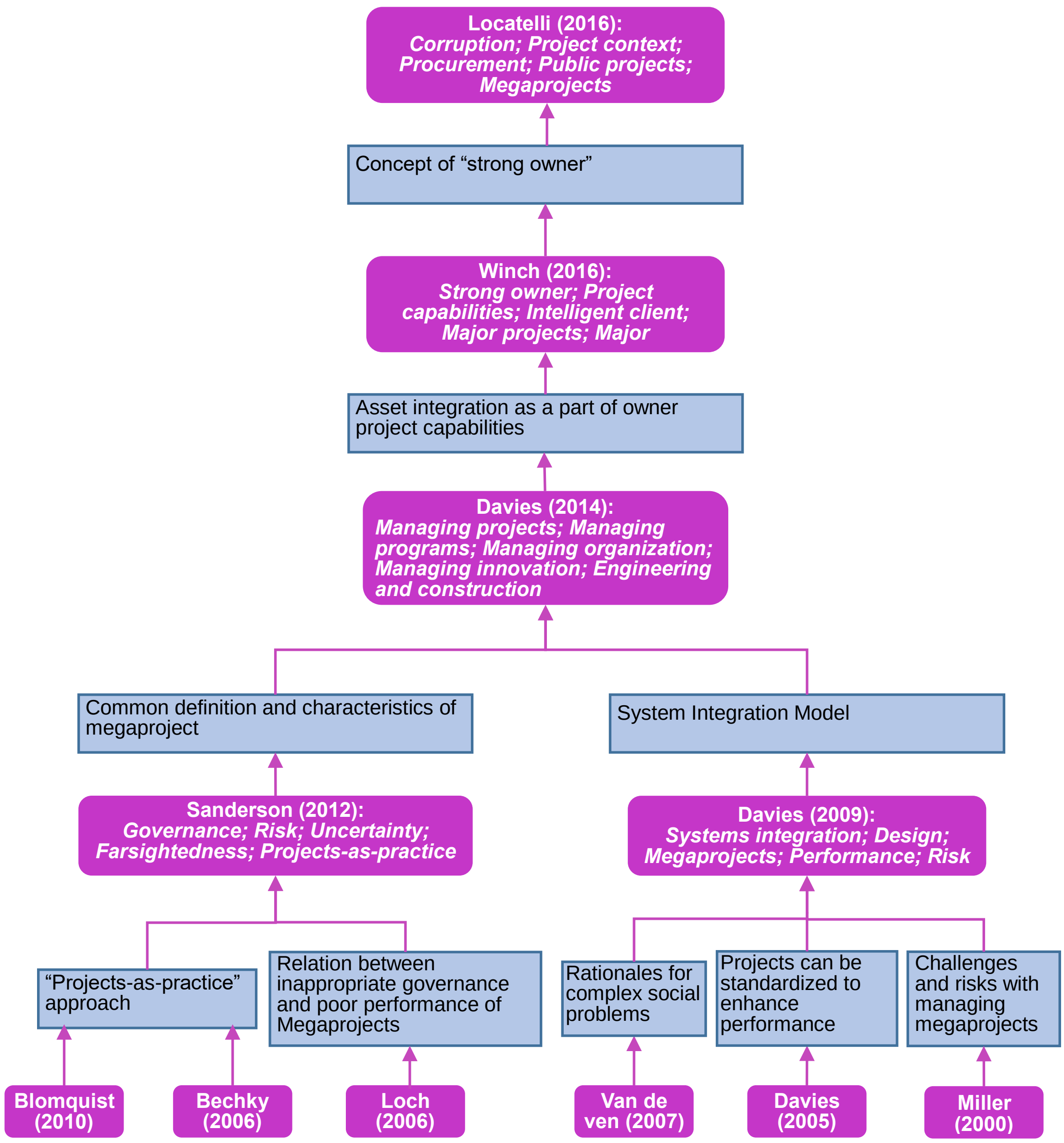

Figure 5. Knowledge diffusion path 1 for group 1 (risk, uncertainty, and complexity).

Notes for Figures 5, 6, and 7): Each publication is displayed with the top five keywords provided by the authors (for some publications without keywords, the authors displayed the five topic terms with most frequency of occurrence in the context); the content represents the detailed knowledge that diffused through the citation link.

Knowledge Diffusion Path 2 for Group 2 (Planning and Decision Making)

Planning and decision making of megaprojects are challenging due to the high complexity of megaprojects. The identified path 2 shows MPM's progress in terms of "planning" and "decision making" for megaprojects. Figure 6 presents the major knowledge diffusion path of this group. Similar to path 1, this group shows a convergence pattern.

In the beginning, as shown in the right stream, Flyvbjerg et al. (2003) contributed to the body of knowledge in two perspectives: on the one hand, Flyvbjerg and his colleagues summarized the risk environment that the megaprojects are always in. On the other hand, they proposed an advanced decision-making approach, named BOT (build-operate-transfer) or SOE (state-owned enterprise) model that consider "accountability." The decision-making model for megaprojects inspires the later research on decision making in megaprojects. In 2007, De Bruijn and Leijten proposed the concept of negotiated knowledge, which is a better strategy than objective information for decision making. After 2012, complexities in planning and decision making were highlighted. Although reduction of the complexity in the planning of megaprojects may help the project team prevent cost overruns, the reduction in complexity may result in some disadvantages in megaprojects, because the target of a megaproject may also include strategic goals regardless of cost and time control (Giezen, 2012). Then adaptive capacity and strategic capacity were introduced to analyze the processes of planning and decision making (Giezen, 2013).

The other stream focuses on the cost overrun issue of megaprojects. Many studies have been conducted to investigate the reasons why the cost-benefit analysis in megaprojects were always misleading. Flyvbjerg integrated the factors that caused the poor cost-benefit analysis in megaprojects, and many of the factors were supported by the previous studies, including technical factors (Flyvbjerg, Holm, & Buhl, 2002; Flyvbjerg, Holm, & Buhl, 2005; Morris & Hough, 1987; Wachs, 1989; Wachs, 1990) and psychological factors (Kahneman &

Tversky, 1979). The later works summarized the features of megaprojects (Flyvbjerg, 2009) and highlighted that cost-overrun is the “iron law” (Flyvbjerg, 2014). The publications in the two streams converged into Giezen, Bertolini, and Salet’s (2015) recent work, which introduces three concepts to investigate strategies in decision making in megaprojects.

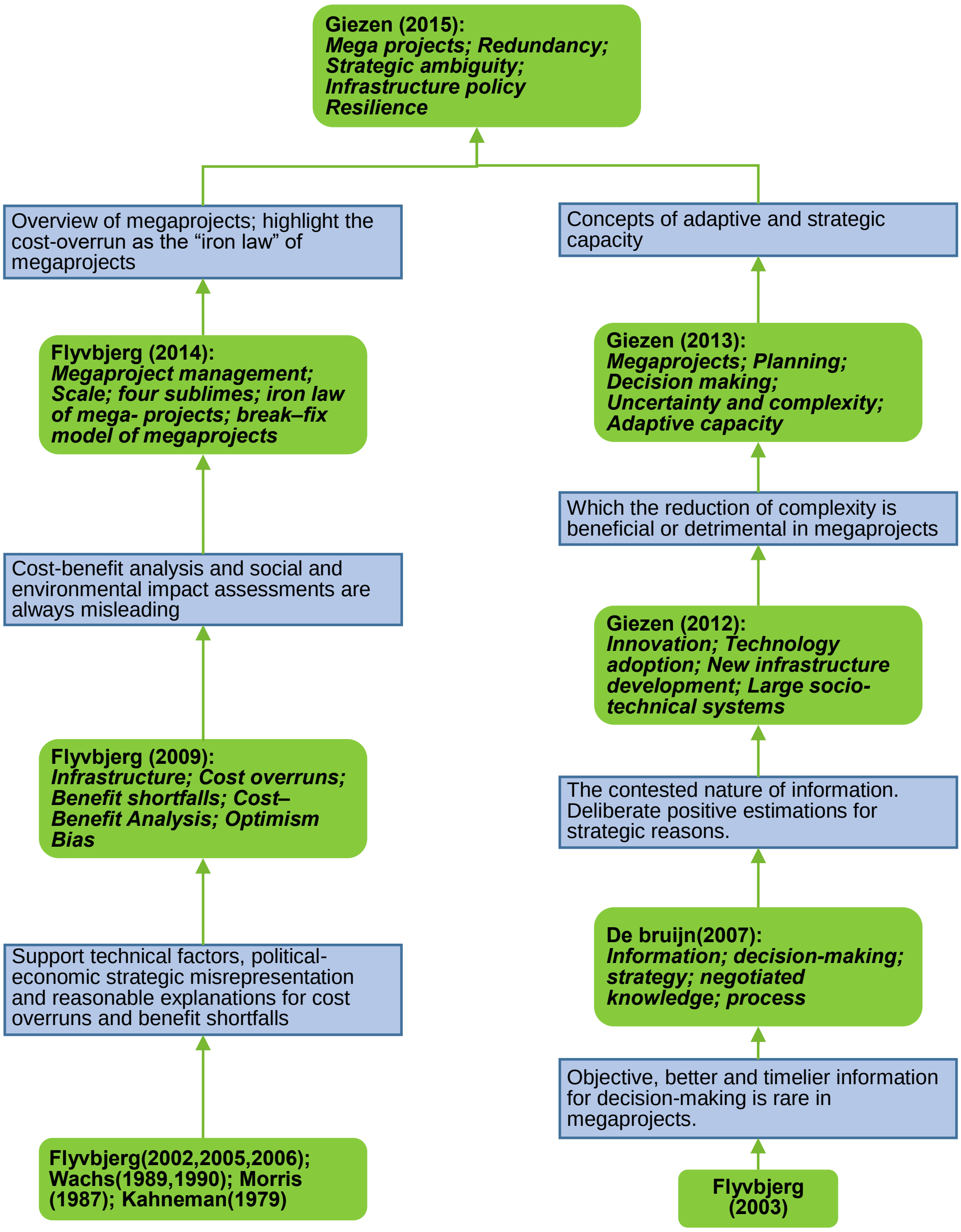

Figure 6. Knowledge diffusion path 2: Planning and decision making.

Knowledge Diffusion Path 3 for Group 3 (Urban Megaprojects)

The publications on this path address urban megaprojects, showing a major path with a convergence-divergence pattern, and Orueta and Fainstein's (2008) publication occupies the most dominant position in this main path. From Figure 7, the authors find that before Orueta and Fainstein's article, three publications provided the basic information about urban megaprojects in Canada (Lehrer & Laidley, 2008), Western Europe (Haila, 2008), and Southeast Asia (Shatkin, 2008). They inspired Orueta and Fainstein's work to make an in-depth comparison between cities in several regions, by pointing out the revival of urban megaprojects in developed countries after 2000. Orueta and Fainstein investigated the revival of urban megaprojects and their impact on environmental sustainability in the view of the private sector, and the major findings are that the urban megaprojects in North America and Europe become similar in terms of physical forms, financing, and targets. This publication motivated the later research through three streams.

The first stream, in the upper left of Figure 7, focuses on research about the impact of the global economic crisis in 2008 on the development of urban megaprojects, drawn from two cases: Grand Paris (Enright, 2014) and Ørestad (Majoor, 2015). They mainly concluded that although the global economic crisis was caused by subprime mortgage bubble in United States, the urban megaprojects were still worth developing.

The upper middle stream emphasizes the research on the development of urban megaprojects. Hwang's work (Hwang, 2014) found that the development of an urban megaproject in Seoul was the result of interactions between different factors. This study emphasized that local factors play important roles for urban megaprojects, which is inconsistent with Orueta and Fainstein's work (2008), which considers global factors to be the main ones for the development of urban megaprojects. This finding supported Dogan and Stupar's (2017) later research, which underlines the contradiction between the anticipation of economic growth and drawbacks according to urban megaprojects in Istanbul.

The third stream in the upper right in this group focuses on the mechanism between political factors and the development of urban megaprojects. Dewey and Davis (2013) illustrated how political and economic transition influence the development of urban megaprojects. Consequently, Kennedy (2015) concluded that the pattern of urban megaproject development is shaped by institutional context, policy instruments, and social dynamics.

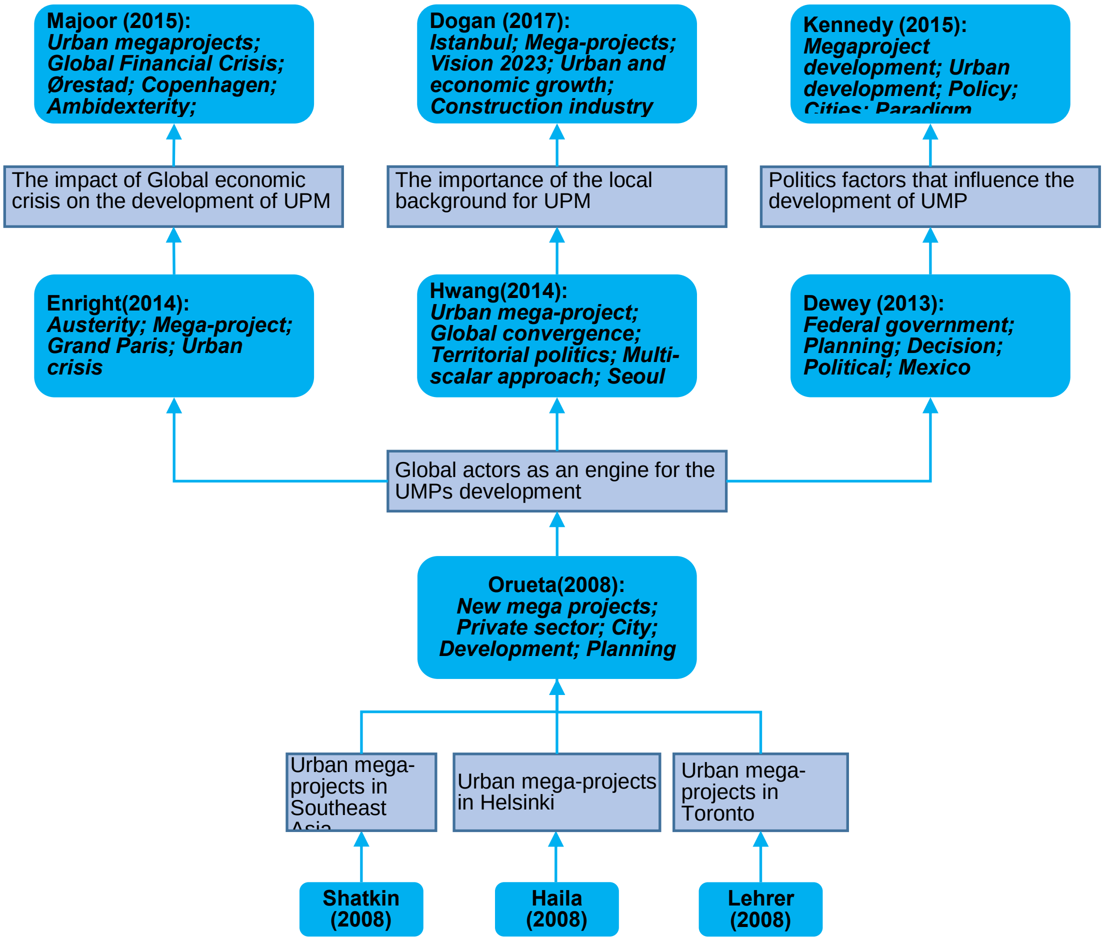

Figure 7. Knowledge diffusion path 3: Urban megaprojects.

Discussion

This article identifies the major knowledge diffusion paths to shed light on the development process of MPM. This section elaborates on and discusses the implications of the results. Traditionally, it is a complex task for scholars to perceive a field’s progress by reviewing a number of studies. The approach of reviewing the articles one by one could consume a considerable amount of time and energy. This may also lead to the inevitable personal preference and bias in recognizing the importance of the publications and the associations between them (Silva et al., 2016). In the context of MPM, such work may be more difficult, since it is recognized as an emerging academic field (Flyvbjerg & Turner, 2018; Stephan et al., 2017) involving diversified theories, ideas, and methods form different fields to conduct new knowledge (Schoenmakers & Duysters, 2010), which may cause complex knowledge flows. This study proposes a quantitative approach that can identify the major knowledge diffusion paths by using citation analysis and social network analysis techniques, which could offer more convincing results by reducing personal bias and improving efficiency.

The findings in this article have practical implications, which suggest that MPM still lacks fundamental theories and successive research topics. This can be manifested by the uncommon pattern of MPM's major knowledge diffusion paths. Most of the identified major knowledge diffusion paths in other fields are characterized with divergence patterns, such as technological forecasting (Lu et al., 2016), resource-based theory (Lucio-Arias & Leydesdorff, 2008), data envelopment analysis (DEA) (Liu, Lu, Lu, & Lin, 2013), and technology acceptance (Hsiao, Tang, & Liu, 2015). Those paths were initiated by a single piece of work, providing theoretical frameworks, assumptions, or models. For example, in the field of technology acceptance, the major knowledge diffusion paths started from a single node (Davis (1989), which introduced the basic theoretical foundations for technology acceptance, illuminating later research work on this topic (Hsiao et al., 2015). However, in the context of MPM, the paths share a convergence or convergence-divergence pattern, in which more than one node initializes the MPM's knowledge development (see Figures 5, 6, and 7). Most of the MPM paths convey novel concepts, ideas, and information, rather than basic methodology or hypotheses, especially in the early stages. This means, even though the knowledge progresses considerably and several rationales and concepts are proposed, MPM's development does not follow a unified and widely recognized theoretical framework.

The findings also indicate that theoretical frameworks, models and concepts from a wide range of other fields, such as organization science (Bechky, 2006; Van de Ven Andrew, 2007), project management (Blomquist et al., 2010), public policy (Wachs, 1990), prospect theory (Kahneman & Tversky, 1979), innovation management (Davies & Hobday, 2005), and strategy management (Miller et al., 2000) contribute to the development of MPM. Currently, Internet Plus, artificial intelligence, and industrialization may provide new knowledge in the practice of MPM, facilitating solutions to cope with the complexities and to achieve the sustainable development goals of megaprojects.

The findings help to clarify the roles that some important publications have played in the development of MPM. Although important academic achievements can be easily identified by simply setting a number of top-cited publications (Li et al., 2017), it is still unknown how those publications influence the later research of MPM. For example, the works of Miller and Flyvbjerg have been identified as significant publications, but which parts of the knowledge of them impacted the development of MPM are still unclear. This can be addressed from the main knowledge diffusion paths identified by this research: The major contribution of the works of Flyvbjerg and Miller are the new models for megaproject decision making and challenges and risks associated with managing megaprojects, respectively.

Flyvbjerg et al. (2016) defined three types of research approaches in the social sciences: problem-driven, theory-driven, and data-driven. Problem-driven research observes the confused phenomenon or puzzle by investigating the experience separately from the practice. The main work is to find out plausible explanations for the puzzle. The results in this article show that the development of MPM's research is mainly driven by a set of problems and facts but not theories, although some classic theories have contributed to the development of MPM. At the beginning of the three knowledge diffusion paths, the scholars tried to explain interesting phenomena of megaprojects: poor performance (Flyvbjerg, 2009), risk environment (Sanderson, 2012), and recovery of urban megaprojects. By highlighting MPM's practical problems, those works contribute to better understanding the unique properties of megaprojects, stimulating the later scholars to propose new theoretical frameworks, models, and concepts to facilitate the management of megaprojects. As time goes by, the academic works that introduce management rationales and concepts to cope with these problems may have a higher probability to appear in the major knowledge diffusion paths, such as Davies et al. (2009) in path 1, and Flyvbjerg (2014) and Giezen (2013) in path 2. Therefore, the authors suggest that research that could link the current problems of megaprojects and theories or tools of other disciplines, such as smart construction (links the complexity and internet-based techniques) and social responsibility (links the challenge of sustainability and theory of business ethics), may play an important role in later progress of the MPM knowledge.

Conclusions

Traditionally, review works are mainly conducted based on personal judgment, cognition, and preference. Even though some professional researchers review the works comprehensively and systematically, there exists unintentional bias in selecting significant publications (Silva et al., 2016). This article, rather than drawing a big picture of MPM progress from personal viewpoints and by qualitative methods, aims to identify the major knowledge diffusion paths by means of quantitative methods using a relatively large amount of data, providing not broad, but clarified and objective findings to highlight MPM's progress. Those results can help scholars have a better understanding of MPM research.

Similar to all scientometric studies, this study is not without limitations. On the one hand, because this study performs a citation-based approach, the scholars' citation motivation may influence accuracy. This article measures the knowledge diffusion paths using key-route search algorithm, which can address the limitation to some extent because this algorithm computes the importance of each link using search path count value. On the other hand, the authors only retrieved the relevant articles from Web of Science, which may omit some important research that is not included in this database. The authors make efforts to address this limitation, by adding some significant references to the citation network (as mentioned in *Data Collection section*), which may cover the most important publications of MPM.

Acknowledgments

This research was supported by the National Natural Science Foundation of China (NSFC) (No. 71390522, No. 71671053, No. 71271065, No. 71771067). The work described in this article was also funded by the National Key R&D Program of China (No. 2016YFC0701800 and No. 2016YFC0701808).

Appendix A

Label	Title (books are displayed in italics)	Journal/Publisher	LCC	WCC	GCC	Added references
Locatelli (2017)	Corruption in public projects and megaprojects: There is an elephant in the room!	*International Journal of Project Management*	0	0	0	/
Winch (2016)	Owner project capabilities for infrastructure development: A review and development of the "strong owner" concept	*International Journal of Project Management*	2	7	23	/
Davies (2014)	Project complexity and systems integration: Constructing the London 2012 Olympics and Paralympics games	*International Journal of Project Management*	5	18	60	/
Sanderson (2012)	Risk, uncertainty and governance in megaprojects: A critical discussion of alternative explanations	*International Journal of Project Management*	6	49	126	/
Blomquist (2010)	Project-as-practice: In search of project management research that matters	*Project Management Journal*	6	67	217	/
Davies (2009)	Innovation in megaprojects: Systems integration at London Heathrow Terminal 5	*California Management Review*	10	40	128	/
van de ven (2007)	*Engaged scholarship: A guide for organizational and social research*	Oxford University Press	9	\	2051	✓
Loch (2006)	*Managing the unknown: A new approach to managing high uncertainty and risk in projects*	John Wiley & Sons	7	\	290	✓
Bechky (2006)	Gaffers, gofers, and grips: Role-based coordination in temporary organizations	*Organization Science*	6	242	630	✓
Davies (2005)	*The business of projects: Managing innovation in complex products and systems*	Cambridge University Press	6	\	449	✓
Miller et al. (2000)	*The strategic management of large engineering projects: Shaping institutions, risks, and governance*	MIT press	11	\	558	✓

Table A1: Publications in the main path of *risk and uncertainty.*

Note: Label refers to first author and the publication year; LCC stands for local citation count; WCC stands for citation count in Web of Science; GCC stands for citation count in Google Scholar; Added references show whether the publication is added from the references (Data Collection section).

Appendix B

Label	Title (books are displayed in italics)	Journal/Publisher	LCC	WCC	GCC	Added references
Giezen (2015)	Adding value to the decision-making process of mega projects: Fostering strategic ambiguity, redundancy, and resilience	*Transport Policy*	1	2	3	/
Flyvbjerg (2014)	What you should know about megaprojects and why: An overview	*Project Management Journal*	15	63	220	/
Giezen (2013)	Adaptive and strategic capacity: Navigating megaprojects through uncertainty and complexity	*Environment and Planning B: Planning & Design*	4	6	12	/
Giezen (2012)	Keeping it simple? A case study into the advantages and disadvantages of reducing complexity in mega project planning	*International Journal of Project Management*	13	31	87	/
Flyvbjerg (2009)	Survival of the unfittest: Why the worst infrastructure gets built—And what we can do about it	*Oxford Review of Economic Policy*	10	75	299	/
De Bruijn (2007)	Megaprojects and contested information	*Transportation Planning and Technology*	6	10	54	/
Flyvbjerg (2006)	From nobel prize to project management: Getting risks right	*Project Management Journal*	10	80	320	/
Flyvbjerg (2005)	How (in) accurate are demand forecasts in public works projects? The case of transportation	*Journal of the American Planning Association*	11	204	631	/
Flyvbjerg (2003)	*Mega-projects and risk: An anatomy of ambition*	Cambridge University Press	66	\	2580	✓
Flyvbjerg (2002)	Underestimating costs in public works projects—Error or lie?	*Journal of the American Planning Association*	25	330	1286	✓
Wachs (1990)	Ethics and advocacy in forecasting for public policy	*Business & Professional Ethics Journal*	10	63	204	✓
Wachs (1989)	When planners lie with numbers	*Journal of the American Planning Association*	8	76	215	✓
Morris (1987)	*The anatomy of major projects—A study of the reality of project management*	John Wiley & Sons	21	\	1129	✓
Kahneman (1979)	Prospect theory: An analysis of decision under risk	*Econometrica*	6	\	46359	✓

Table A2: Publications in the main path of *planning and decision making*.

Note: Label refers to first author and the publication year; LCC stands for local citation count; WCC stands for citation count in Web of Science; GCC stands for citation count in Google Scholar; Added references show whether the publication is added from the references (Data Collection section).

Appendix C

Label	Title (books are displayed in italics)	Journal/Publisher	LCC	WCC	GCC	Added references
Dogan (2017)	The limits of growth: A case study of three megaprojects in Istanbul	*Cities*	0	0	0	/
Majoor (2015)	Urban megaprojects in crisis? Ørestad Copenhagen revisited	*European Planning Studies*	1	2	3	/
Kennedy (2015)	The politics and changing paradigm of megaproject development in metropolitan cities	*Habitat International*	1	2	12	/
Hwang (2014)	Territorialized urban megaprojects beyond global convergence: The case of Dongdaemun Design Plaza & park project, Seoul	*Cities*	2	4	10	/
Enright (2014)	The great wager: Crisis and mega--project reform in 21st-century Paris	*Cambridge Journal of Regions Economy and Society*	1	3	7	/
Dewey (2013)	Planning, politics, and urban mega-projects in developmental context: Lessons from Mexico City's airport controversy	*Journal of Urban Affairs*	1	1	8	/
Orueta (2008)	The new mega-projects: Genesis and impacts	*International Journal of Urban and Regional Research*	9	40	160	/
Shatkin (2008)	The city and the bottom line: Urban megaprojects and the privatization of planning in southeast Asia	*Environment and Planning A*	4	55	142	/
Haila (2008)	From Annankatu to Antinkatu: Contracts, development rights and partnerships in Kamppi, Helsinki	*International Journal of Urban and Regional Research*	1	7	18	/
Lehrer (2008)	Old mega-projects newly packaged? Waterfront redevelopment in Toronto	*International Journal of Urban and Regional Research*	10	56	172	✓

Table A3: Publications in the main path of *urban megaprojects.*

Note: Label refers to first author and the publication year; LCC stands for local citation count; WCC stands for citation count in Web of Science; GCC stands for citation count in Google Scholar; Added references show whether the publication is added from the references (Data Collection section).

Appendix D

The authors provide a figure to illustrate the pruning process of the main paths. As a rule, this article keeps meaningful links when the citations are used to support fundamental theories, models, or assumptions. Citation analysis is always criticized because it does not distinguish the negative and positive citations. This limitation can be largely addressed through the pruning process, which makes the remaining citation links more convincing (Liang et al., 2016). Through examining the citing behavior in context, the pruning process keeps the important paths whereby knowledge is diffused in a meaningful manner. In this way, the major diffusion paths are streamlined to show important information. As shown in Figure A1, in the citation network, two publications have cited Davies et al. (2009) (the arrows indicate the citing direction, from the cited publication to the citing one). The authors review the context of how this piece of work is cited by the two publications. Brady and Davies (2014) cited Davies et al's (2009) publication for supporting a general saying, whereas Davies and Mackenzie (2014) cited this work as a theoretical foundation. Therefore, the authors retain link 2 and remove link 1.

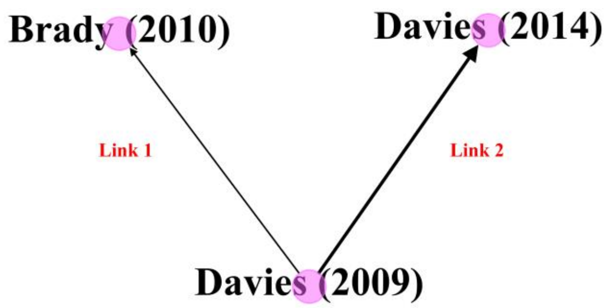

Figure A1: The example for pruning the main paths.

Appendix E

The retrieved 390 articles and the references in the articles were collected from Web of Science in a text format file (*Data Collection section*). A Python program developed by the authors was used to enumerate the references, count the times they appeared in the articles , identify the citation relations, and generate the directional citation network ( ). Four packages were mainly used to code the program: Regular Expression (RE), Pandas, Numpy, and NetworkX. Gephi (Bastian, Heymann, & Jacomy, 2009) and Pajek (Dohleman, 2006) are used to perform the modularity optimization and calculate the search path count value, respectively.

References

Aaltonen, K., Kujala, J., Havela, L., & Savage, G. (2015). Stakeholder dynamics during the project front-end: The case of nuclear waste repository projects. *Project Management Journal, 46*(6), 15–41.

Aksnes, D. W. (2003). Characteristics of highly cited papers. *Research Evaluation, 12*(3), 159–170.

Alcacer, J., & Gittelman, M. (2006). Patent citations as a measure of knowledge flows: The influence of examiner citations. *Review of Economics and Statistics, 88*(4), 774–779.

Aminian, S., Hinckson, E. A., & Stewart, T. (2015). Modifying the classroom environment to increase standing and reduce sitting. *Building Research and Information, 43*(5), 631–645.

Appleyard, M. M., & Kalsow, G. A. (1999). Knowledge diffusion in the semiconductor industry. *Journal of Knowledge Management, 3*(4), 288–295.

Argote, L., & Ingram, P. (2000). Knowledge transfer: A basis for competitive advantage in firms. *Organizational Behavior and Human Decision Processes, 82*(1), 150–169.

Arrow, K. (1962). Economic welfare and the allocation of resources for invention. In Universities-National Bureau Committee for Economic Research, Committee on Economic Growth of the Social Science Research Council (Eds.), *The rate and direction of inventive activity: Economic and social factors* (pp. 609–626). Princeton, NJ: Princeton University Press. Retrieved from http://www.nber.org/chapters/c2144

Bartol, K. M., & Srivastava, A. (2002). Encouraging knowledge sharing: The role of organizational reward systems. *Journal of Leadership & Organizational Studies, 9*(1), 64–76.

Bastian, M., Heymann, S., & Jacomy, M. (2009). Gephi: An open source software for exploring and manipulating networks. Third international AAAI conference on weblogs and social media. 2009.

Batagelj, V. (2003). Efficient algorithms for citation network analysis. University of Ljubljana, Institute of Mathematics, Physics and Mechanics, Preprint series, 41, 897.

Battke, B., Schmidt, T. S., Stollenwerk, S., & Hoffmann, V. H. (2016). Internal or external spillovers—Which kind of knowledge is more likely to flow within or across technologies. *Research Policy, 45*(1), 27–41.

Bechky, B. A. (2006). Gaffers, gofers, and grips: Role-based coordination in temporary organizations. *Organization Science, 17*(1), 3–21.

Bernal, J. D. (1939). The social function of science. The Social Function of Science. London, UK: George Routledge & Sons Ltd.

Blomquist, T., Hallgren, M., Nilsson, A., & Soderholm, A. (2010). Project-as-practice: In search of project management research that matters. *Project Management Journal, 41*(1), 5–16.

Boyack, K. W., Klavans, R., & Borner, K. (2005). Mapping the backbone of science. *Scientometrics, 64*(3), 351–374.

Brady, T., & Davies, A. (2014). Managing structural and dynamic complexity: A tale of two projects. *Project Management Journal, 45*(4), 21–38.

Cavusgil, S. T., Calantone, R. J., & Zhao, Y. (2003). Tacit knowledge transfer and firm innovation capability. *Journal of Business & Industrial Marketing, 18*(1), 6–21.

Chen, C. M., & Hicks, D. (2004). Tracing knowledge diffusion. *Scientometrics, 59*(2), 199–211.

Chuang, T. C., Liu, J. S., Lu, L. Y. Y., Tseng, F. M., Lee, Y., & Chang, C. T. (2017). The main paths of eTourism: Trends of managing tourism through Internet. *Asia Pacific Journal of Tourism Research, 22*(2), 213–231.

Cicmil, S., Williams, T., Thomas, J., & Hodgson, D. (2006). Rethinking project management: Researching the actuality of projects. *International Journal of Project Management, 24*(8), 675–686.

Darr, E. D., & Kurtzberg, T. R. (2000). An investigation of partner similarity dimensions on knowledge transfer. *Organizational Behavior and Human Decision Processes, 82*(1), 28–44.

Davies, A., Gann, D., & Douglas, T. (2009). Innovation in megaprojects: Systems integration at London Heathrow Terminal 5. *California Management Review, 51*(2), 101–125.

Davies, A., & Hobday, M. (2005). The business of projects: Managing innovation in complex products and systems. Cambridge, UK: Cambridge University Press.

Davies, A., & Mackenzie, I. (2014). Project complexity and systems integration: Constructing the London 2012 Olympics and Paralympics Games. *International Journal of Project Management, 32*(5), 773–790.

Davis, F. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly 13*(3), 319–340.

De Bruijn, H., & Leijten, M. (2007). Megaprojects and contested information. *Transportation Planning and Technology, 30*(1), 49–69.

de Solla Price, D. J. (1965). Networks of scientific papers. *Science, 149*(3683), 510–515.

Dewey, O. F., & Davis, D. E. (2013). Planning, politics, and urban mega-projects in developmental context: Lessons from Mexico City's airport controversy. *Journal of Urban Affairs, 35(5)*, 531–551.

Dogan, E., & Stupar, A. (2017). The limits of growth: A case study of three megaprojects in Istanbul. *Cities, 60*, 281–288.

Dohleman, B. S. (2006). Exploratory social network analysis with Pajek. *Psychometrika, 71*(3), 605.

Enright, T. (2014). The great wager: Crisis and mega-project reform in 21st-century Paris. *Cambridge Journal of Regions Economy and Society, 7*(1), 155–170.

Fleming, L. (2001). Recombinant uncertainty in technological search. *Management Science, 47*(1), 117–132.

Flyvbjerg, B. (2009). Survival of the unfittest: Why the worst infrastructure gets built—And what we can do about it. *Oxford Review of Economic Policy, 25*(3), 344–367.

Flyvbjerg, B. (2014). What you should know about megaprojects and why: An overview. *Project Management Journal, 45*(2), 6–19.

Flyvbjerg, B., Bruzelius, N., & Rothengatter, W. (2003). Megaprojects and risk: An anatomy of ambition. Cambridge, UK: Cambridge University Press.

Flyvbjerg, B., Holm, M. S., & Buhl, S. (2002). Underestimating costs in public works projects—Error or lie? *Journal of the American Planning Association, 68*(3), 279–295.

Flyvbjerg, B., Landman, T., & Schram, S. F. (2016). Tension points: Learning to make social science matter. *Critical Policy Studies*, Forthcoming. Available at SSRN: https://ssrn.com/abstract=2721321.

Flyvbjerg, B., Holm, M. S., & Buhl, S. L. (2005). How (in) accurate are demand forecasts in public works projects?: The case of transportation. *Journal of the American Planning Association, 71*(2), 131–146.

Flyvbjerg, B., & Turner, J. R. (2018). Do classics exist in megaproject management? *International Journal of Project Management, 36*(2), 334–341.

Foray, D., & Lundvall, B. (1998). The knowledge-based economy: From the economics of knowledge to the learning economy. In D. Neef, G. A. Seisfeld, & J. Cefola (Eds.), *The economic impact of knowledge* (pp. 115–121). New York, NY: Routledge.

Fujigaki, Y. (1998). Filling the gap between discussions on science and scientists' everyday activities: Applying the autopoiesis system theory to scientific knowledge. *Social Science Information, 37*(1), 5–22.

Garfield, E. (1976). Citation analysis, mechanical translation of chemical nomenclature, and the macrostructure of science. *Journal of Chemical Information and Modeling, 15*(5), 153–155.

Gellert, P. K., & Lynch, B. D. (2003). Mega-projects as displacements. *International Social*

Science Journal, 55(1), 15–25.

Gemunden, H. G. (2015). The fascinating world of megaprojects. *Project Management Journal, 46*(5), 3–8.

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 & Design, 40*(4), 723–741.

Giezen, M., Bertolini, L., & Salet, W. (2015). Adaptive Capacity Within a Mega Project: A Case Study on Planning and Decision-Making in the Face of Complexity. *Transport Policy*, *44*,169–178.

Grant, R. M. (1996). Toward a knowledge-based theory of the firm. *Strategic Management Journal, 17*(S2), 109–122.

Greiman, V. A. (2013). Megaproject management: Lessons on risk and project management from the Big Dig. Hoboken, NJ: John Wiley & Sons.

Haila, A. (2008). From Annankatu to Antinkatu: Contracts, development rights and partnerships in Kamppi, Helsinki. *International Journal of Urban and Regional Research, 32*(4), 804–814.

Hwang, J.-T. (2014). Territorialized Urban Mega-projects Beyond Global Convergence: The Case of Dongdaemun Design Plaza & Park Project, Seoul. *Cities*, *40*, 82–89.

Hirsch, J. E. (2005). An index to quantify an individual's scientific research output. *Proceedings of the National Academy of Sciences of the United States of America, 102*(46), 16569–16572.

Ho, M. H. C., Liu, J. S., & Chang, K. C. T. (2017). To include or not: The role of review papers in citation-based analysis. *Scientometrics, 110*(1), 65–76.

Ho, Y. S. (2012). Top-cited articles in Chemical Engineering in Science Citation Index Expanded: A bibliometric analysis. *Chinese Journal of Chemical Engineering, 20*(3), 478–488.

Ho, Y. S. (2014). Classic articles on social work field in Social Sciences Citation Index: A bibliometric analysis. *Scientometrics, 98*(1), 137–155.

Hoetker, G., & Agarwal, R. (2007). Death hurts, but it isn't fatal: The postexit diffusion of knowledge created by innovative companies. *Academy of Management Journal, 50*(2), 446–467.

Hsiao, C. H., Tang, K. Y., & Liu, J. S. (2015). Citation-based analysis of literature: A case study of technology acceptance research. *Scientometrics, 105*(2), 1091–1110.

Hu, A. G. Z., & Jaffe, A. B. (2003). Patent citations and international knowledge flow: The cases of Korea and Taiwan. *International Journal of Industrial Organization, 21*(6), 849–880.

Hu, Y., Chan, A. P. C., Le, Y., & Jin, R. Z. (2015). From construction megaproject anagement to complex project management: Bibliographic analysis. *Journal of Management in Engineering, 31*(4), 04014052.

Hummon, N. P., & Doreian, P. (1989). Connectivity in a citation network—The development of DNA theory. *Social Networks, 11*(1), 39–63.

Ibrahim, G. M., Snead, O. C., Rutka, J. T., & Lozano, A. M. (2012). The most cited works in epilepsy: Trends in the "Citation Classics." *Epilepsia, 53*(5), 765–770.

Jaffe, A. B. (1986). Technological opportunity and spillovers of research-and-development evidence from firms patents, profits, and market value. *American Economic Review, 76*(5), 984–1001.

Jaffe, A. B., & Trajtenberg, M. (1999). International knowledge flows: Evidence from patent citations. *Economics of Innovation and New Technology, 8*(1-2), 105–136.

Jaffe, A. B., Trajtenberg, M., & Henderson, R. (1993). Geographic localization of knowledge spillovers as evidenced by patent citations*. *The Quarterly Journal of Economics, 108*(3), 577–598.

Joyce, C. W., Sugrue, C. M., Joyce, K. M., Kelly, J. L., & Regan, P. J. (2014). 100 citation classics in the melanoma literature: A bibliometric analysis. *Dermatologic Surgery, 40*(12), 1284–1298.

Kahneman, D., & Tversky, A. (1979). Prospect theory: An analysis of decision under risk. *Econometrica: Journal of the Econometric Society*, *47*(2), 263–291.

Kelly, J. C., Glynn, R. W., O'Briain, D. E., Felle, P., & McCabe, J. P. (2010). The 100 classic papers of orthopaedic surgery: A bibliometric analysis. *Journal of Bone and Joint Surgery-British Volume, 92B*(10), 1338–1343.

Kennedy, L. (2015). The politics and changing paradigm of megaproject development in metropolitan cities. *Habitat International, 45*, 163–168.

Lehrer, U., & Laidley, J. (2008). Old mega-projects newly packaged? Waterfront Redevelopment in Toronto. *International Journal of Urban and Regional Research, 32*(4), 786–803.

Levitt, R. E. (2007). CEM research for the next 50 years: Maximizing economic, environmental, and societal value of the built environment. *Journal of Construction Engineering and Management-ASCE, 133*(9), 619–628.

Li, Y., Lu, Y., Taylor, J. E., & Han, Y. (2017). Bibliographic and comparative analyses to explore emerging classic texts in megaproject management. *International Journal of Project Management, 36*(2), 342–361.

Liang, H. G., Wang, J. J., Xue, Y. J., & Cui, X. C. (2016). IT outsourcing research from 1992 to 2013: A literature review based on main path analysis. *Information & Management, 53*(2), 227–251.

Liu, J. S., & Lu, L. Y. Y. (2012). An integrated approach for main path analysis: Development of the Hirsch Index as an example. *Journal of the American Society for Information Science and Technology, 63*(3), 528–542.

Liu, J. S., Lu, L. Y. Y., Lu, W. M., & Lin, B. J. Y. (2013). Data envelopment analysis 1978-2010: A citation-based literature survey. *Omega-International Journal of Management Science, 41*(1), 3–15.

Lo, K. K. H., Wong, A. H. C., Tam, W. W. S., & Ho, S. C. (2016). Citation classics in the nutrition and dietetics literature: 50 frequently cited articles. *Nutrition & Dietetics, 73*(4), 356–368.

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.

Loch, C. H., DeMeyer, A., & Pich, M. (2006). Managing the unknown: A new approach to managing high uncertainty and risk in projects. Hoboken, NJ: John Wiley & Sons.

Love, P. E., Holt, G. D., & Li, H. (2002). Triangulation in construction management research. *Engineering Construction and Architectural Management, 9*(4), 294–303.

Lu, L. Y. Y., Hsieh, C.-H., & Liu, J. S. (2016). Development trajectory and research themes of foresight. *Technological Forecasting and Social Change, 112*, 347–356.

Lu, L. Y. Y., & Liu, J. S. (2014). The knowledge diffusion paths of corporate social responsibility—From 1970 to 2011. *Corporate Social Responsibility and Environmental Management, 21*(2), 113–128.

Lu, L. Y. Y., & Liu, J. S. (2016). A novel approach to identify the major research themes and development trajectory: The case of patenting research. *Technological Forecasting and Social Change, 103*, 71–82.

Lucio-Arias, D., & Leydesdorff, L. (2008). Main-path analysis and path-dependent transitions in HistCite(TM)-based historiograms. *Journal of the American Society for Information Science and Technology, 59*(12), 1948–1962.

Luo, S. L., Du, Y. Y., Liu, P., Xuan, Z. G., & Wang, Y. Z. (2015). A study on coevolutionary dynamics of knowledge diffusion and social network structure. *Expert Systems with*

Applications, 42(7), 3619–3633.

Ma, V. C., & Liu, J. S. (2016). Exploring the research fronts and main paths of literature: a case study of shareholder activism research. *Scientometrics, 109*(1), 33–52.

Majoor, S. (2015). Urban megaprojects in crisis? Ørestad Copenhagen revisited. *European Planning Studies, 23*(12), 2497–2515.

Martinez, M. A., Herrera, M., Lopez-Gijon, J., & Herrera-Viedma, E. (2014). H-classics: characterizing the concept of citation classics through H-index. *Scientometrics, 98*(3), 1971–1983.

Miller, R., Lessard, D. R., Michaud, P., & Floricel, S. (2000). *The strategic management of large engineering projects: Shaping institutions, risks, and governance.* Cambridge, MA: MIT Press.

Mok, K. Y., Shen, G. Q., & Yang, J. (2015). Stakeholder management studies in mega construction projects: A review and future directions. *International Journal of Project Management, 33*(2), 446–457.

Morris, P. W., & Hough, G. H. (1987). The anatomy of major projects: A study of the reality of project management. London, England: John Wiley & Sons.

Nelson, A. J. (2009). Measuring knowledge spillovers: What patents, licenses and publications reveal about innovation diffusion. *Research Policy, 38*(6), 994–1005.

Nemet, G. F. (2012). Inter-technology knowledge spillovers for energy technologies. *Energy Economics, 34*(5), 1259–1270.

Newman, M. E. J. (2004). Analysis of weighted networks. *Physical Review E, 70*(5, 056131.

Orazbayev, S. (2017). International knowledge flows and the administrative barriers to mobility. *Research Policy, 46*(9), 1655–1665.

Orueta, F. D., & Fainstein, S. S. (2008). The new mega-projects: Genesis and impacts. *International Journal of Urban and Regional Research, 32*(4), 759–767.

Park, H., & Magee, C. L. (2017). Tracing technological development trajectories: A genetic knowledge persistence-based main path approach. *PLoS ONE, 12*(1), e0170895

Powell, M. (2016). Citation classics in social policy journals. *Social Policy & Administration, 50*(6), 648–672.

Roach, M., & Cohen, W. M. (2012). Lens or prism? Patent citations as a measure of knowledge flows from public research. *Management Science, 59*(2), 504–525.

Roper, S., & Hewitt-Dundas, N. (2015). Knowledge stocks, knowledge flows and innovation: Evidence from matched patents and innovation panel data. *Research Policy, 44*(7), 1327–1340.

Sanderson, J. (2012). Risk, uncertainty and governance in megaprojects: A critical discussion of alternative explanations. *International Journal of Project Management, 30*(4), 432–443.

Schilling, M. A., & Green, E. (2011). Recombinant search and breakthrough idea generation: An analysis of high impact papers in the social sciences. *Research Policy, 40*(10), 1321–1331.

Schoenmakers, W., & Duysters, G. (2010). The technological origins of radical inventions. *Research Policy, 39*(8), 1051–1059.

Seglen, P. O. (1998). Citation rates and journal impact factors are not suitable for evaluation of research. *Acta Orthopaedica Scandinavica, 69*(3), 224–229.

Shatkin, G. (2008). The city and the bottom line: Urban megaprojects and the privatization of planning in Southeast Asia. *Environment and Planning A: Economy and Space, 40*(2), 383–401.

Shibata, N., Kajikawa, Y., Takeda, Y., & Matsushima, K. (2008). Detecting emerging research fronts based on topological measures in citation networks of scientific publications. *Technovation, 28*(11), 758–775.

Silva, F. N., Amancio, D. R., Bardosova, M., Costa, L. D., & Oliveira, O. N. (2016). Using network science and text analytics to produce surveys in a scientific topic. *Journal of Informetrics, 10*(2), 487–502.

Singh, J., & Marx, M. (2013). Geographic constraints on knowledge spillovers: Political borders vs. spatial proximity. *Management Science, 59*(9), 2056–2078.

Small, H. (1973). Co-citation in the scientific literature: A new measure of the relationship between two documents. *Journal of the American Society for Information Science, 24*(4), 265–269.

Small, H., & Griffith, B. C. (1974). The structure of scientific literatures I: Identifying and graphing specialties. *Science Studies, 4*(1), 17–40.

Sorenson, O., & Fleming, L. (2004). Science and the diffusion of knowledge. *Research Policy, 33*(10), 1615–1634.

Sorenson, O., Rivkin, J. W., & Fleming, L. (2006). Complexity, networks and knowledge flow. *Research Policy, 35*(7), 994–1017.

Stephan, A., Schmidt, T. S., Bening, C. R., & Hoffmann, V. H. (2017). The sectoral configuration of technological innovation systems: Patterns of knowledge development and diffusion in the lithium-ion battery technology in Japan. *Research Policy, 46*(4), 709–723.

Stone, R., & Lavine, M. (2014). The social life of robots. *Science, 346*(6206), 178–179.

Szulanski, G. (2000). The process of knowledge transfer: A diachronic analysis of stickiness. *Organizational Behavior and Human Decision Processes, 82*(1), 9–27.

Tu, Y.-N., & Hsu, S.-L. (2016). Constructing conceptual trajectory maps to trace the development of research fields. *Journal of the Association for Information Science and Technology, 67*(8), 2016–2031.

van de Ven, A., H. (2007). Engaged scholarship: A guide for organizational and social research. Oxford, UK: Oxford University Press.

van Marrewijk, A., Clegg, S. R., Pitsis, T. S., & Veenswijk, M. (2008). Managing public–private megaprojects: Paradoxes, complexity, and project design. *International Journal of Project Management, 26*(6), 591–600.

Verspagen, B. (2007). Mapping technological trajectories as patent citation networks: A study on the history of fuel cell research. *Advances in Complex Systems, 10*(1), 93–115.

Vincent, D. B., Jean-Loup, G., Renaud, L., & Etienne, L. (2008). Fast unfolding of communities in large networks. *Journal of Statistical Mechanics: Theory and Experiment, 2008*(10). doi: 10.1088/1742-5468/2008/10/P10008.

Wachs, M. (1989). When planners lie with numbers. *Journal of the American Planning Association, 55*(4), 476–479.

Wachs, M. (1990). Ethics and advocacy in forecasting for public policy. *Business & Professional Ethics Journal, 9*(1/2), 141–157.

Wang, J.-P., Guo, Q., Yang, G.-Y., & Liu, J.-G. (2015). Improved knowledge diffusion model based on the collaboration hypernetwork. *Physica A: Statistical Mechanics and its Applications, 428,* 250–256.

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

Wojick, D. E., Warnick, W. L., Carroll, B. C., & Crowe, J. (2006). The digital road to scientific knowledge diffusion. *D-Lib Magazine, 12*(6), 1082–9873.

Wu, C.-Y., & Mathews, J. A. (2012). Knowledge flows in the solar photovoltaic industry: Insights from patenting by Taiwan, Korea, and China. *Research Policy, 41*(3), 524–540.

Xiao, Y., Lu, L. Y. Y., Liu, J. S., & Zhou, Z. L. (2014). Knowledge diffusion path analysis of data quality literature: A main path analysis. *Journal of Informetrics, 8*(3), 594–605.

Yu, G., Wang, M. Y., & Yu, D. R. (2010). Characterizing knowledge diffusion of nanoscience & nanotechnology by citation analysis. *Scientometrics, 84*(1), 81–97.

Zidane, Y. J. T., Johansen, A., & Ekambaram, A. (2013). Megaprojects—Challenges and lessons learned. In J. P. Pantouvakis (Ed.), Selected papers from the 26th IPMA (Vol. 74, pp. 349–357).

Hengqin Wu is currently a joint doctoral student in the school of management, Harbin Institute of Technology and in the department of building and real estate, The Hong Kong Polytechnic University. His research interests include megaproject management and textual information analysis in construction based on big data and natural language processing approaches. He participated in the megaproject of the National Natural Science Foundation of China (Grant No. 71390522), "Innovative Research on the Theory, Methodology, and Application of Mega Infrastructure Engineering Management in China." He can be contacted at hengqin.wu@connect.polyu.hk

Dr. Xiaolong Xue is the dean of the school of management at Guangzhou University. He was awarded the New Century Excellent Talents Supporting Plan by the Ministry of Education of China in 2011. He also has been a postdoctoral researcher at the University of Texas at Austin and The Hong Kong Polytechnic University and a visiting scholar at Stanford University. He serves as associate chair of the construction management modernization committee of the China Construction Association. He is an associate editor of the *Journal of Engineering Management*, and an editorial board member of the *Journal of Construction Economy*. He completed many significant research projects, which were funded by the National Key Research and Development Program and the Natural Science Foundation of China. Dr. Xue has published more than 80 articles. His research areas include engineering technology innovation and management, digital management and intelligent decision making, megaproject management, smart city and sustainable development, and business behavior and environment.

Dr. Zebin Zhao is an associate professor and academic affairs coordinator of the school of management, Harbin Institute of Technology. He is the deputy secretary-general of the regional science association of Heilongjiang. His research interests include project management and sustainability, green finance and risk management, environmental economics, and management. He can be contacted at zhaozebin@hit.edu.cn

Dr. Zeyu Wang is an associate professor of construction management at Guangzhou University. He holds a doctorate in construction management from the University of Florida. His research interests cover megaproject management, sustainable construction, and smart building. His work has been published in various journals, including *Renewable and Sustainable Energy Reviews*, *Energy and Buildings*, and the *Journal of Energy Engineering (ASCE)*. He can be contacted at wangzeyu@gzhu.edu.cn

Geoffrey Qiping Shen is chair and professor of construction management in the department of building and real estate, The Hong Kong Polytechnic University. He has a proven track record of academic and research leadership in construction management with special interest in value management and collaborative working in construction, supported by information and communication technologies. He pioneered the development of an innovative interactive value management system that utilizes group decision support technologies to improve the effectiveness and efficiency of value management workshops. He has led a large number of research projects with total funding over HK$30 million, including five RGC-CERG grants in a row since the year 2002–2003, and has authored more than 380 publications including 190 articles in peer-reviewed academic journals. He is a member of the editorial boards of several leading journals, and has been invited to give keynote presentations in a number of international conferences. He has served the built environment panel of the Research Assessment Exercise in Hong Kong in 2006, and he is the current chair of the Global Leadership Forum in Construction Engineering and Management Programs.

Dr. Xiaowei Luo is currently an assistant professor in the department of architecture and civil engineering at the City University of Hong Kong. Previously, he served in a postdoctoral position in the department of civil engineering at the University of Texas at Austin. He received his doctoral degree in construction engineering and project management from the University of Texas at Austin in 2013 and his master's degree in construction management from Tsinghua University in Beijing, China in 2006. His main research interests include building information modeling, construction safety management, information technology in construction, wireless sensor technologies, and green building. His current research projects focus on the development and deployment of information and sensing technologies to advance construction safety and efficiency as well as improve the quality and sustainability of construction projects. Dr. Luo has authored and coauthored many highly cited journal publications, conference articles, and book chapters on the aforementioned topics. In addition, he has received several grants from various agencies including National Natural Science Foundation of China and Research Grants Council.