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Mapping the Knowledge Structure in Megaproject Management Research Using Complex Network Analysis

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ABSTRACT

The megaprojects boomed in recent years, which have significant impacts on the economy, social issues, technology innovation, and environment. Therefore, specific knowledge is needed to support the management activities of megaproject management (MM). This paper aimed to explore and visualize the knowledge structure of the research domain in megaproject management using the keyword network analysis. By retrieving the journal papers relevant to megaproject management, the data of keyword and the relation between them are further extracted, and the keyword network is built up. Employed by the scientific knowledge structure of megaproject management has been measured by complex network analysis. The results showed that the topic network of Mega Engineering Management served the features of high clustering coefficient and scale-free and total 40 topic communities existed in the topic network. Megaproject, Project Management, and Construction Management were general research fields whereas risk, complexity infrastructure and scheduling were core research directions.

INTRODUCTION

Megaprojects are defined as major public construction projects which have considerable influences on the economy, society, public policy, technology innovation, national safety and environment preservation (Flyvbjerg, 2014; Flyvbjerg et al., 2003; Gellert and Lynch, 2003). Until Dec 15th, 2016, China have 1.1157 trillion dollars US debt totally, which is less than twice amount of money of the largest megaprojects: The high-speed rail of China and Joint Strike Fighter aircraft. Many studies have shown that reasonable investment for megaprojects can bring a higher level of productivity, boost economic growth, improve productivity and land values, overflow value,

stimulate economic growth, as well as improve energy efficiency and public health. Therefore, it is urgent to develop specific knowledge to support the management activities embodied in megaprojects.

The main feature of megaproject is the so-called "complexity" in perspectives of technology, organizational structure (Baccarini, 1996), vast stakeholders involved (Mok et al., 2015), the complex procedure of design and construction and complex financing patterns (Flyvbjerg et al., 2003). Consequently, complicated management issues within the megaprojects such as decision making, organization, coordination among stakeholders, resource consumption, environmental and social effects can not be simply explained by the knowledge of general project management such PMBOK (PMI, 2013). In this way, it needs to evaluate the knowledge of megaproject management deeply.

Against this background, the aim of this study is to map the knowledge structure in megaproject management research using complex network analysis, which provides visualized results. This paper tried to provide insights on the following questions:

(1) what exact research issues do the scholars prefer in the megaproject management?

(2) what the relationships between those research topics?

In order to answer the questions above, this paper employed keyword co-occurrence analysis which combined methods of complex network and bibliometrics. The outputs help to recognize the knowledge of research trend and structure.

METHODOLOGY

(1) Data collection

In group to identify the knowledge structure of megaproject management, this paper collect journal papers related to Engineering Management. The first step is to select the most important and relevant journals. It is challenging to decide which is one the top journals due to the dispute of origin, development and evolution of Engineering Management. This paper select top journals of Engineering Management based on two criteria:(1) The selected journal should be retrieved in the web of science, which is regarded as significant research database and retrieve tool in the world (Meho and Yang, 2007); and (2) The selected journal should be recognized as no doubt in the scientific community (Li et al., 2000; Xue et al., 2012; Xue et al., 2010). obeying the rules above, 13 journals are selected as top journals of megaprojects (Table 1).

Table 1. Top journals of megaproject management

	Category	Journal	2015 Impact Factor	Publisher
1	Theory, method and application	Building Research and Information(BRI)	2.196	Taylor & Francis
2	Theory, method and application	IEEE Transactions on Engineering Management (IEEE M)	1.454	IEEE Xplore
3	Theory, method and application	Journal of Civil Engineering and Management(JCEM)	1.530	Taylor & Francis

4	Theory, method and application	Journal of Infrastructure Systems(JIS)	1.234	ASCE
5	Theory, method and application	Journal of Management in Engineering(JME)	1.840	ASCE
6	Theory, method and application	Journal of Construction Engineering and Management(CEM)	1.152	ASCE
7	Theory, method and application	Journal of Professional Issues in Engineering Education and Practice(PIEDP)	0.538	ASCE
8	Information & technology	Computer-Aided Civil and Infrastructure Engineering(CCIE)	5.288	John Wiley & Sons
9	Information & technology	Automation in Construction(AIC)	2.442	Elsevier
10	Information & technology	Advanced Engineering Informatics(AEI)	2.000	Elsevier
11	Information & technology	Journal of Computing in Civil Engineering(CCE)	1.855	ASCE
12	Project management	International Journal of Project Management(IJPM)	2.885	Elsevier
13	Project management	Project Management Journal(PM)	1.765	John Wiley & Sons

The retrieval strategy is following: (Topics= mega or “Macro project*” or “macro engineering*” or “macro infrastructure*” or “large scale project*” or “large scale engineering*” or “large scale infrastructure*” or “major project*” or “complex project*” or “large engineering*” or “large project*” or megaproject*）and （PUBLICATION NAME= “Top journals of Engineering Management”）. The publication types include ARTICLE, EDITORIAL MATERIAL, PROCEEDINGS PAPER and REVIEW. Total 234 journal papers have been retrieved, and 61 of them are discarded due to its irrelevant to megaproject management. Finally, 173 papers and 511 keywords data are achieved.

(2) Keyword network analysis

The keywords of literature reflect the fundamental elements of the scientific knowledge, which denote the relations and structure of a given research domain (Su and Lee, 2010). To draw and analyze the keyword network of megaproject management, this paper computes the relation metric base on the keyword co-occurrence pairs, which make sense to analyze the network properties and the structure.

(3) Complex network analysis

A number quantitative methods involved in the complex network analysis. This paper measures the overall feature of the keyword network by computing the prosperities including indexes of average degree, density, the number of nodes, number of links, the clustering coefficient and the average distance.

To measure the importance of each topic of megaproject management, between centrality is computed. For each node, between centrality is the number of shortest

paths pass by the node divide by the sum number of all the shortest paths within the network, which reflect the degree of the closeness of every node. The equation is following:

$$C_k = \frac{\sum_{i,j \neq k} \frac{p_k(\mathrm{i},\mathrm{j})}{p(\mathrm{i},\mathrm{j})}}{\frac{(\mathrm{n}-1)(\mathrm{n}-2)}{2}} \quad (1)$$

To model the knowledge structure, this paper applies the algorithm of Modularity Optimization on the network. Base on this algorithm, a network can be divided into several groups. The links within the same group are much more than between groups (Newman, 2006).

RESULTS

(1) The basic properties of keyword network

Two different keywords serve a link when they are listed as author keywords in the same paper. Then the correlation metric is built up and the correlation coefficients are calculated by the weight of links. As shown in Table 2, the properties are analyzed with this metric.

Total 511 different keywords with 697 occurrence frequency and 1595 links constitute the keyword network. The average degree is 5.934 which means every keyword have co-occurrence relation with other 5.934 keywords. The density is 0.012, which is much higher than general social networks. The clustering coefficient is 0.918, and the average distance is 3.587. The most strike feature of the keyword network is the high level of aggregation, with a clustering coefficient of 0.918. This index denotes that the probability that two neighbors of each keyword are also linked is 0.918, which demonstrates many triangle relations exist in the keywords.

Table 2 The properties of the keyword network of megaproject management

Average Degree	Density	Number of Nodes	Number of Links	Clustering Coefficient	Average Distance
5.934	0.012	511	1593	0.918	3.587

(2) Measurement of the properties of each node

As the Table 3 shown, “project management” is the most popular keyword, with the highest occurrence frequency (30) and largest between centrality (0.301). Some other keywords, such as megaproject(s), construction management, risk management, complexity, scheduling, uncertainty(ies), and infrastructure. Most of the important keywords are the research objectives of megaproject management.

Table 3 The measurement of the node in the keyword network (Top 20 keywords by occurrence)

No.	Keywords	Frequency	Degree	Betweeness centrality
1	project management	30	118	0.301
2	megaproject(s)	18	65	0.170
3	construction management	9	39	0.054
4	risk management	8	37	0.040
5	complexity	8	37	0.037
6	scheduling	7	32	0.064
7	uncertainty(ies)	7	26	0.037
8	infrastructure	6	29	0.029
9	risk	6	27	0.037
10	case study (case studies)	6	29	0.023
11	construction	5	28	0.021
12	building information modeling(BIM)	5	22	0.041
13	simulation	4	17	0.026
14	complex projects	4	14	0.019
15	construction industry	4	13	0.005
16	complex project management	4	18	0.034
17	strategy	4	20	0.059
18	stakeholder(s)	4	16	0.036
19	major project(s)	3	11	0.014
20	cost overrun	3	13	0.000

(3) Measuring the structure and mapping the knowledge network of megaproject management

Base on the relation metric of the keywords, the map of the keyword network is drawn by visualizing tool (Fig. 1).

All the 511 keywords of megaproject management aggregate into 40 subgroups based on the algorithm of Modularity Optimization. The Fig.1 depicts the most giant component, in which each single keyword has at least one path to any other keyword.

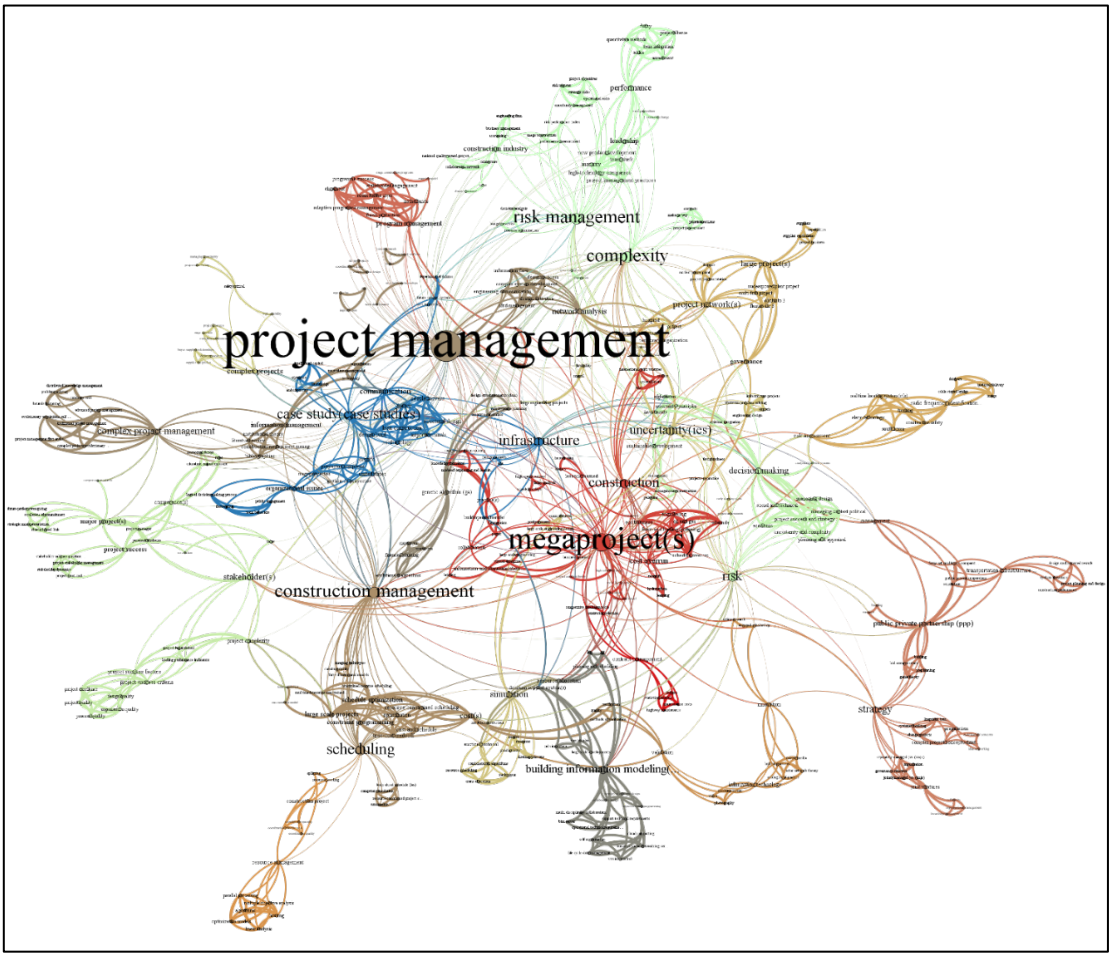

Fig 1. Mapping the knowledge network of megaproject management

This component is constituted by 395 keywords (account for 77.3% of all) with 576 occurrence times (account for 82.6% of all). Keywords within the same subgroup serve the same color, which makes the entire map very clear and discernible.

Table 4 shows the top 10 subgroups of megaprojects.

Table 4 The subgroups of keywords network of megaproject management

ID of subgroups	Keywords frequency	Number of keywords	Representative keyword
29	71	37	Project Management
2	67	40	Megaproject(S)
11	62	43	Risk Management
39	45	30	Infrastructure
5	43	33	Strategy
13	43	30	Stakeholder(S)
28	42	24	Construction Management
18	37	26	Uncertainty(Ies)
31	27	21	Bim
20	25	20	Project Network(S)

12	25	17	Risk
17	15	11	Complex Projects
24	15	13	Resource Management
25	15	12	Innovation
4	14	12	Program Management
21	13	11	Rfid
35	12	11	Selection Criteria
32	11	10	Project History
30	9	8	Genetic Algorithm
0	8	7	Contract Management

CONCLUSION

This paper characterizes the knowledge of megaproject management. The results show that the current research of megaproject management normally focuses on megaproject, construction management, and project management because those three keywords stand on the central position of the network. From Table 3 we can see that those three keywords rank top 3 of frequency, degree and betweenness centrality. A reasonable explanation is that those three keywords encompass a large range of topics and the scholars always list them as author keywords in the papers.

The core research issues of megaproject management are risk (including risk management and uncertainty), complexity, infrastructure, and scheduling. Those keywords reach the top 10 with frequency, have a better position in the map.

The subgroups of stakeholders, BIM, strategy, resource management, innovation, and RFID are the important research areas of megaproject management. Those topic subgroups stand on the edge of the map and process few links with other subgroups.

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