EVOLUTIONARY COLLABORATION NETWORK AND ORGANIZATIONAL COMPETITIVENESS IN MEGAPROJECTS

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The collaboration network is a compilation of relationships among multiple stakeholders within and across organizations. In a megaproject that involves with hundreds of organizations, these organizations may dynamically collaborate for a sub-project while compete for a new sub-project. However, who are the organizations that have competitive advantages to win more tenders and the reason of how these companies are emerged haven't been fully investigated yet. Thus, to study the network-based organizational competitiveness in a megaproject is critical for its execution and future success. This study analyses the organizational competitiveness and evolution of collaboration network by social network analysis (SNA) and a 6-years (2008-2013) case study of district development in Wuxi, China with a total of 1,897 construction projects. The constructed megaproject collaboration network consists of four parties: owners, contractors, designers and quality supervisors. The analytical result shows several key observations and trends of stakeholders in the evolution of the network. Contractors and designers who have a higher normalized degree and are in K-core are more competitive when bidding for a new project. This study enriches the existing research for the organizational competitiveness in megaprojects, helping us to better understand the mechanism of collaboration and competition in megaprojects and to offer effective and dynamic governing strategies for megaprojects.

Keywords: megaprojects; collaboration network; network evolution; governance strategies

INTRODUCTION

Large-scale city infrastructure construction has become a critical supporting pillar for social development. As the scale of a project increases from single project to city-level or regional level megaprojects, the project requires higher investment (Flyvbjerg, 2014), greater amount of stakeholders (Lu, Li, Pang, and Zhang, 2015), and higher complexity than the project ever before. Given the complexity in a megaproject, the close collaboration among different stakeholders is a must to fulfil the megaprojects task instead of relying on the capacity of single stakeholder. A compilation of these collaborations among multiple stakeholders within and across organizations in a megaproject constitutes a collaboration network. Meanwhile, during the process of implementation and dynamic evolution, contractors also need to compete for new

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project opportunities. Thus, study on evolution of megaproject collaboration network and organizational competitiveness will help to improve performance and management of megaprojects. Current studies mainly use a static perspective to analyse a single megaproject, but ignore the dynamic collaboration and its influence to a megaproject. Understanding such a collaboration network can indeed help better identify the organizational competitiveness.

This study aims to investigate the organizational competitiveness (herein refers to bidding competitiveness) in a collaboration network. Specifically, four objectives will be explored, including 1) to analyse the collaboration network, its dynamic evolution, and organizational competitiveness in a megaproject; 2) to investigate the tender selection strategies by owners; and 3) to identify effective governance strategies for different types of megaprojects. The results can enrich current megaprojects study by providing better understanding of dynamic evolution and organizational competitiveness of organizations and by providing practical strategies for governing megaprojects.

The paper is structured in six sections. The next section reviews pertinent studies, followed by section three that explains the research design. Section four explains data processing and operationalization of hypothesis. The results of the organizational competitiveness and owners' tender strategies are discussed in section five. The last section summarizes this study.

LITERATURE REVIEW

Megaprojects

The definition of "megaprojects" has a long term debate without a universal agreement. A megaproject could be defined and characterized in different aspects, such as by its investment expenditures which is higher than $1 billion USD (Bruzelius, Flyvbjerg, and Rothengatter, 2002), by its duration longer than one political dispensation (O Oliomogbe and J Smith, 2013), by its scale that involve colossal in size and scope (Sturup, 2009), or by its complexity with multiple owners (Haynes, 2002) and organizations that seek success with different objectives (Ruuska, Artto, Aaltonen, and Lehtonen, 2009).

Considering megaprojects' characteristics and its complexity, megaprojects management (MPM) faces tremendous challenges (Zhai, Xin, and Cheng, 2009). Currently, most of current research on megaprojects management focus primarily on several aspects, such as stakeholders' value (Zhai et al., 2009), performance (Kwak and Smith, 2009), risk management (Locatelli and Mancini, 2010) and governance (Müller, Pemsel, and Shao, 2014).

In sum, most of existing studies investigate the management of megaproject by providing a static snapshot analysis, however, the literature hasn't studied the dynamic evolution of megaproject during its different phases. Given that the megaproject is highly complex and evolves along the time, there is a research need to investigate the dynamic evolution of megaprojects.

Network analysis

Research on "network" has grown extensively in past decades, such as organizational network, collaboration network and social network and so on. In a construction project, all organizations are social networks and can be addressed in terms of a set of nodes linked by social relationships (Liu, Han, and Xu, 2015). Studying the network can allow scholars better understand the position, power and trajectory of an organization. For instance, Chowdhury, Chen, and Tiong (2011) applied network theory to identify and to distinguish potential stakeholders in Public Private Partnership (PPP) affiliation. Recently, collaboration network analysis has been widely adapted in the construction field. Park, Han, Rojas, Son, and Jung (2010) produced a collaboration network model to investigate a variety of collaboration patterns and their impacts on the level of profit performance. Liu (2015) investigated evolutionary analysis of the collaboration networks within National Quality Award Projects of China by using SNA.

However, several limitations exist in the existing studies of social network and collaboration network in the construction field. First, most of the construction project network were identified through objective judgement, such as questionnaires and interviews from stakeholders, but haven't used subjective measurement based on real data collected from projects. Second, most of the studies focused on the static network in a particular year, but ignored the dynamic evolution of the collaboration network that is constantly expanded by additional stakeholders and their relationships. These two research gaps will be fulfilled in this study.

Social capital and competitiveness

In a network, it's not what you know but who you know, which sums up much of the conventional wisdom regarding social capital. The term social capital was originally used to describe the relational resources embedded in cross-cutting personal ties, which are useful for the development of individual in community social organizations (Jacobs, 1961; Loury, 1977). As the concept evolved, Coleman (1988) and Burt (2000) stated that social capital represents the ability of actors to secure benefits by virtue of membership in social networks or other social structures. At individual level, social capital is a kind of capital that can create for certain individuals a competitive advantage in pursuing their ends (Burt, 2000). Better connected actors are more competitive and gain higher returns. The competitiveness of a construction organization can be interpreted in different ways, such as the ability to obtain more resources, to win more tenders, to keep good relationship with clients, and so on. For designers and contractors, the key competitiveness can be measured by their capacity of wining new projects, also interpreted as the competitiveness in bidding in this study. During dynamic evolution of megaprojects, the analysis of network-based organizational competitiveness can facilitate the implementation of megaprojects and improve its management efficiency.

In summary, although megaprojects have been studied form different perspectives, most of current studies focused on the static analysis of a single project but ignored dynamic evolution. Thus, based on SNA and case study, this study aims to analyse the dynamic evolution and organizational competitiveness of megaprojects to provide a new perspective for the megaprojects management.

RESEARCH DESIGN

To fulfil above aim, two hypotheses were firstly proposed to analyse the network evolution and organizational competitiveness. Then, SNA conceptual model was constructed and measured by standardized degree centrality and K-core. Thirdly, two hypotheses were operationalized in the context of collaboration network and its characteristics. Hypothesis 1 and hypothesis 2 are designed to measure the social capital based on the network position. The research framework is established as follow (see Figure 1).

Hypotheses

According to the social network theory, the node with higher degree centrality normally stands in a core position of the network and possess greater power and influence (Scott and Carrington, 2011). This advantage can represent more resources, more investment opportunities (Hochberg, Ljungqvist, and Lu, 2007) and higher social prestige (Scott and Carrington, 2011).

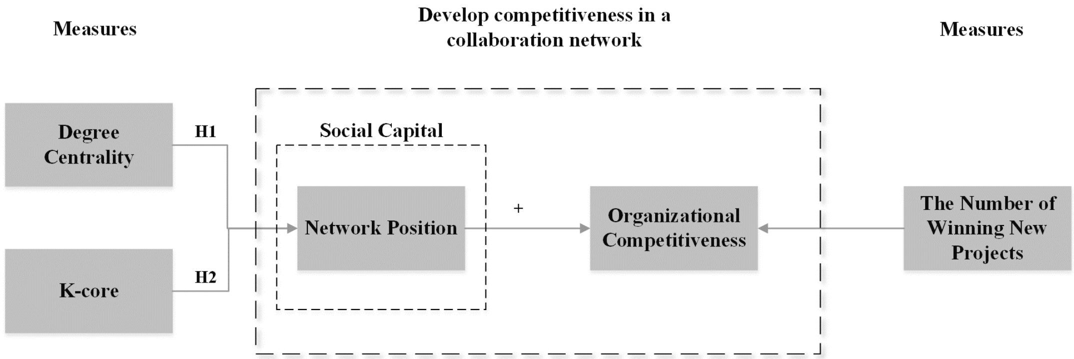

Figure 1 Research Framework and Hypotheses

In megaproject construction that includes thousands of sub-projects, this advantage can be interpreted as the capacity of winning more projects in the competitive tender. Thus, this study proposes the first hypothesis (H1):

H1: the higher degree centrality the organizations have, the more competitive they are to win more projects.

Competition and collaboration commonly coexist among organizations with equal importance. Emphasis on competitiveness should not neglect the synergy of inter-enterprise collaboration in a network (Echols and Tsai, 2005). In social network theory, K-core is commonly used to measure the cohesive subgroups in a network. The higher K-core means the nodes in this K-core have closer collaborative relationship and are more cohesive. In megaproject, various participants need to collaborate with one another to achieve project goals. Those who have closer collaboration are more likely to possess and to share more project opportunities in a network. Thus, this study proposes the second hypothesis (H2):

H2: the higher K-core the organizations are from, the more competitive they are to win more projects.

Operationalization of hypothesis

H1 and H2 are related but different concepts. H1 measure the relation of a single organization in a network while the H2 measures the relation of a subgroup and its included organizations. Specifically, H1 is used to investigate the organizational competitiveness and their network position for various contractors and designers in the collaboration network. Based on normalized degree centrality, top 30 designers and contractors were respectively selected to analyse the relation between their degree centrality ranks (in the current year) and the number of projects that designers and contractors participated (in the following year).

For H2, the study will investigate the relation between K-core (in the current year) and the average number of projects that designers and contractors participated in respective K-core (in the following year). In each year, the highest K-core, the second highest K-core, the third highest K-core, and the rest of K-core were identified from the collaboration network. The average number of a project involved with designers and contractors from each of above identified K-core was calculated and compared among one another. For instance, if the highest K-core is 4-core, the second highest K-core is 3-core. Then the average number of project participated by the organizations in 4-core was compared to that of the organizations in 3-core.

Measures

For H1, degree centrality represents the number of links that a node has in the network (Quinn, Chen, and Mulvenna, 2012), which is a critical measure to evaluate the power, influence and social prestige of a node in a social network (Scott and Carrington 2011). The study adopts the normalized degree centrality (Ndegree) proposed by Freeman (1979) to standardized the results for comparison. The formula is shown below:

$$C_{Ndi} = \frac{\sum_i p_{ij}}{n-1}$$

Where, p_{ij} represents the number of links between node i and node j ; $\sum_i p_{ij}$ represents the degree centrality of node i; and n represents the total number of nodes in a network.

For H2, K-core is used to measure the degree of collaboration among organizations in the network. K-core is a cohesive subgroup on the basis of degree which represents each node in this subgroup has at least K direct links with other nodes in this subgroup (Seidman, 1983). For instance, 0-core represents the network itself, and 3-core represents the subgroup that the degree centrality of each node is at least 3. The higher the K-core is, the more cohesive this subgroup is. That is to say, the organizations in a 5-core subgroup have closer collaboration relationship among one another than those in a 3-core. It's worth mentioning that in a K-core subgroup (say, a 3-core), an organization may have 3 or more links. In this study, only organizations with exactly 3 links were selected for the analysis.

Case Selection and data processing

This study selected a typical case of large-scale land development zone in Wuxi, China. Wuxi is a city located in the southern part of Jiangsu province, China, with a population of 6.4 million. Wuxi national hi-tech development zone (WNHTDZ) was founded in 1992, and listed as one of the nation's high and new technology zones. From 2008 to 2013, a total of 1,897 new construction projects were approved in WNHTDZ, including 946 civil engineering projects (50%), 189 municipal engineering projects (10%) and 762 industrial projects (40%). In this study, we regarded this 6-years long-term construction development of 1,897 projects as a megaproject. To complete these projects, more than 1000 relevant companies were involved in the construction activities. These companies and their relations form a complex collaboration network.

One of the authors worked closely with WNHTDZ and collected second-hand data since 2008. The data were extracted from the information system hosted by WNHTDZ administration. A total of 1,897 new construction projects that happened from 2008 to 2013 were selected as data input in SNA model. There are 1450 contractors, including 680 owners (investors), 174 designers, 541 contractors, and 55 supervision units.

The study will consider six-years (2008-2013) of collaboration network evolution. In each year, the collaboration network was computed based on the "2-year" rule, meaning that average construction duration in WNHTDZ will last for 2 years. To align with this norm, the network in each year constituted all relevant participants in that particular year and also in the previous year. For instance, when calculating the network for 2012, all companies involved in 2012 and in 2011 were considered in the network. This 2-year rule ensures the continuity and coherence of the SNA model with the construction practice.

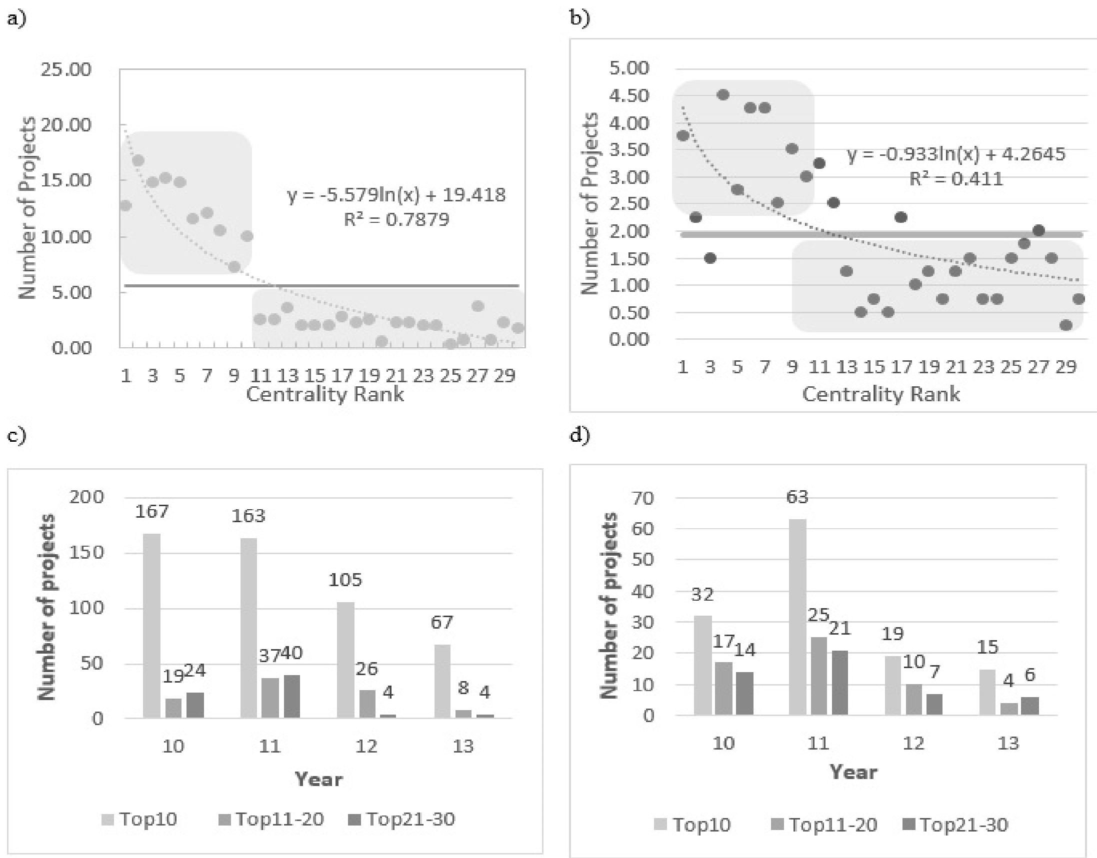

Figure 2 the Relationship between centrality rank and the number of projects that designers and contractors participated.

Fig. 2a) Relationship between centrality rank (in current year) and the number of projects that designers participated (in the following year); Fig. 2b) Relationship between centrality rank (in current year) and the number of projects that designers participated (in the following year); Fig. 2c) The number of projects that designers with different centrality participated in the years; Fig. 2d) The number of projects that contractors with different centrality participated in the years.

**Note: the nodes marked in darker grey in Figure 2a and 2b represent the average new projects in which those who rank the same place in each year network participate next year.*

RESULT AND DISCUSSION

Organizational competitiveness based on degree centrality

PIPs network will be mainly discussed in this part. During the evolution of megaprojects, with the centrality rank declining, the average number of new projects that designers and contractors participate in next year show a gradual descending trend (see Figure 2a and 2b). And the designer has higher R2 than that of contractor through fitting analysis (0.78 > 0.41). That means the trend for designers is more obvious. Furthermore, in terms of degree centrality, the top 10 designers and contractors are more competitive when facing a new project because of the dominant network position.

Figure 2c and 2d respectively show the number of new projects that top ranked designers and contractors participate in next year. During the evolution of megaprojects, whether designers or contractors, the total number of new projects that top 10 organizations participate in are larger than that of latter 20 organizations. And in each year network, the organizations with higher degree centrality are more competitive when facing a new project and can win more project. Compared to contractors, designers show a more obvious advantage. For designers and contractors, the relationship between degree centrality and the number of new projects that they participate in next year is non-linear.

Base on above analysis, during the evolution of megaproject, the organizations with higher degree centrality are more competitive to win more projects. However, compared to contractors, designers show a more obvious advantage. Thus, H1 could be validated.

Organizational competitiveness based on K-core

Figure 3a and 3b show the average number of new projects that designers and contractors in respective K-core participate in next year.

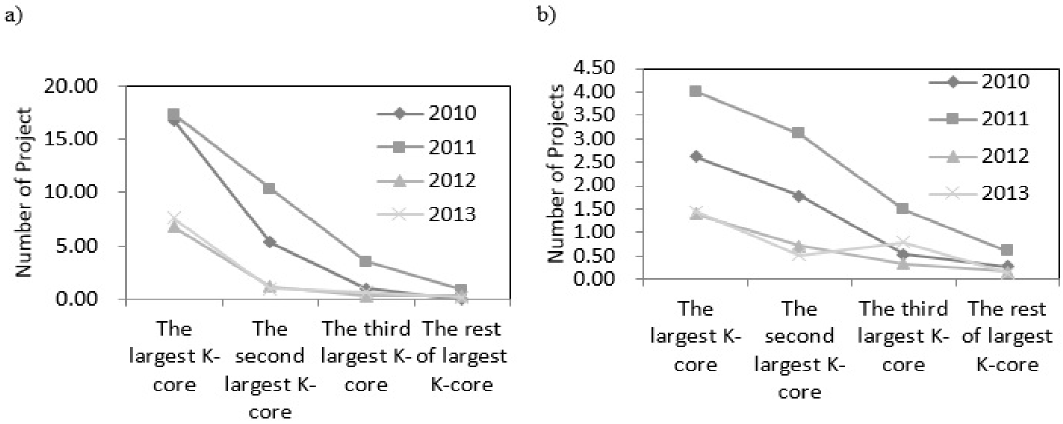

Figure 3 the number of projects that designers and contractors in different K-core participated in different years. a) the number of projects that designers in different K-core participated in different years; b) the number of projects that contractors in different K-core participated in different years.

For both designers and contractors in respective K-core, with the K-core dropping, the average number of new projects that they participate in next year show a non-linear decreasing trend. The larger the K-core is, the more competitive the organizations in that K-core are when facing a new project. Furthermore, when the K-core increases by 1, the organizations in this K-core have multiple opportunities to win a new project, especially for designers.

On the one hand, above finds explain why the organizations make effect to occupy the core position in the network, which means strong competitiveness and can enable these organizations to win more new projects; on the other hand, the larger K-core represents closer collaboration relationship between organizations. Compared to those in lower K-core, the organizations in larger K-core can take advantage of their network position and share more chances to win or participate in more new projects, especially for designers.

Base on above analysis, during the evolution of megaproject, the organizations in larger K-core are more competitive to win more projects. However, compared to contractors, designers show a more obvious advantage. Thus, H2 could be validated.

CONCLUSION

This study investigated organizational competitiveness in a megaproject collaboration network based on SNA and case study. A new framework with two hypotheses was proposed and tested in the PIPs collaboration network. The key conclusions are summarized as follows. Firstly, the organizations with higher degree centrality have larger social capital and are more competitive to win new projects. This finding is more significant for designers than contractors. In the result, top 10 designers had absolute advantages to win new projects than the ones ranked lower. Contractors showed the similar result, yet with large fluctuations. Secondly, the organizations in higher K-core also have closer collaboration and more social capital. Compared to those in lower K-core, the organizations in higher K-core can leverage their network position and secure more chances to win new projects. Similarly, this finding is especially true for designers rather than contractors.

The finding of this study can also provide insightful implications to megaproject governance and administration in several aspects, such as to monitor the longitudinal changes of network position and structure, to identify key organizations and their performance in the collaboration network, and to make differentiated and targeted policies based on organizations' power. In particular, first, the governance of PIPs network needs focus on the design consortium, which show preliminary sign of monopoly of wining new projects. Second, the government may also design precaution policies that prevent the negative behaviours, such as corruption and collusion, due to high degree centrality in the design market. Third, designers and contractors are able to strengthen their social capital and to improve the competitiveness in two ways. One is to improve the satisfactory relationship with existing owners, in expectation of obtaining future project opportunities; another is to increase their network power by extending their relations and reaching out to key stakeholders in the collaboration network.

This study contributes to the existing knowledge in two ways: 1) is to introduce the network analysis (such as positions and collaborative relationship) as an additional dimension to the organizational competitiveness; and 2) to enrich the research on the megaproject management from the dynamic evolutionary perspective and from stakeholders' collaborations. Although this study selected a typical case in Wuxi, the discussion and conclusion from this study could potentially contribute to understanding organizational competitiveness in other construction projects network in other national development zones.

However, several limitations exist in this research. First, the study only analyses organizational competitiveness of PIPs network, but does not investigate organizational competitiveness of GIPs network. The future research can conduct analysis of organizational competitiveness of GIPs network. Second, this study focuses more on the network measures, but hasn't considered the performance of designers and contractors, such as the project quality, cost and schedule. Therefore, further study can establish the linkage between network measure and project performance in order to better understand the organizational competitiveness of megaproject collaboration network.

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