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Evolutionary analysis of the collaboration networks within National Quality Award Projects of China

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Abstract

Construction organizations are increasingly cooperating in what are often referred to as "collaboration network" that enabled them to share risks, pool resources and explore opportunities to jointly participate in managing large-scale projects. In this study, we construct the so-called inter-contractors' collaboration networks by mapping the electronic database of NQAPC for an 8-year period (2003–2010). In these networks, nodes represent contractors; two contractors are connected by an edge if they have cooperated at least one project. By using a variety of network measures, i.e., giant component, degree distribution, average path length, and clustering coefficient, we aim to descriptively investigate the structural evolution of the collaborations between contractors in the construction industry of China. As network size increases, we find a structural transition in the collaboration community size, the degree follows power-law distribution with an exponential cutoff, the average path length tends to decrease, and the clustering coefficient slightly decreases. Some explanations and a series of construction insights are discussed. The results and methodologies not only would help governors understand the social mechanisms underlie processes of construction industry, but could help contractors choose competent partners by identifying network properties.

Keywords: Collaboration network; National Quality Award Project of China (NQAPC); Contractors; Project management; Construction industry

1. Introduction

The last few years have witnessed a tremendous activities devoted to the understanding of complex networks, such as the World Wide Web (Albert et al., 1999), metabolic networks (Stelling et al., 2002), food webs (Williams et al., 2002), and last but not least, social networks (Liljeros et al., 2001; Wasserman and Faust, 1994). A social network is considered a social structure composed of actors that are connected by one or more specific types of relationships, e.g., friendships, firm alliances, and international trades (Liljeros et al., 2001; Newman, 2001a; Wasserman and Faust, 1994). As an important research subject, social network analysis (SNA) has so far centered on intra- and inter-organizational relationships, i.e. within and between organizations. The former assess the level and performance of partnerships between individuals within an organization, while the latter assess the level and performance of partnerships between organizations.

In construction field, all organizations are social networks and can be addressed in terms of a set of nodes linked by social relationships, i.e., intra-organizational relationships (e.g., Pryke, 2004). Further, the environment in which an organization operates might be viewed as a network of other organizations, i.e., inter-organizational relationships (Pryke, 2004). Focusing on intra-organizational relationships, Chinowsky et al. (2008, 2010) introduced social network model into project organization development, and developed high-performance organizations through an analysis of both leadership and team actions within a

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project team framework. Di Vincenzo and Mascia (2012) defined social capital in project-based organization as the way individuals are linked, and provided evidence that levels of project performance are significantly associated with the particular structure of projects' social capital. Using centrality measures of SNA, Hossain and Wu (2009), and Hossain (2009) explored the association between communications network centrality and coordination score from a real-world dataset of complex projects with hundreds of people working together. Chowdhury et al. (2011) applied network theory to identify and distinguish potential stakeholders in Public Private Partnership (PPP) affiliation.

In the inter-organizational networks, actors (nodes) are identified as construction firms, rather than individuals. In this respect, Pryke (2004, 2005) proposed that the project coalition be conceptualized as a network of relationships. The methodology was applied to investigate the managerial attributes of UK construction projects with regard to procurement modes. Using a social network analysis approach, Park et al. (2011) produced a collaboration network model to investigate a variety of collaboration patterns and their impacts on the level of profit performance. Recently, Son and Rojas (2011) introduce an agent-based simulation of the evolution of collaboration within inter-organizational networks of construction project teams. In each of the cases, quantitative indicators of SNA offer potentials for guiding researchers and practitioners in monitoring the organization characteristics (e.g., Hossain, 2009; Hossain and Wu, 2009; Pryke, 2004). However, there are limitations in previously mentioned social network studies in construction field. Firstly, most of the networks constructed in SNA studies were identified through interviewing participants and distributing questionnaires (e.g., Pryke, 2005). Secondly, most of the SNA analyses focused on the ego-network properties, e.g., core-peripheral stakeholders, influential intermediary participants and their interdependence (e.g., Chinowsky et al., 2010; Chowdhury et al., 2011; Di Vincenzo and Mascia, 2012). Although these studies have revealed details about the cognitive, psychological, and sociological features of the networks, they suffer from several problems (e.g., subjectiveness, sampling issues, and statistical accuracy) and limit themselves to small-size networks—typically to tens of stakeholders or people (e.g., Chinowsky et al., 2008; Pryke, 2004). Last and foremost, most of the studies focused on the frozen network in a given year (e.g., Chowdhury et al., 2011). However, the social network constantly expands by the addition of new actors and acts.

A major class of social networks is the collaboration network, defined as a network of actors (e.g., movie stars or paper authors) involved in collaboration acts (e.g., movies or scientific papers). Collaboration networks are considered as an important research subject in both social network studies (Wasserman and Faust, 1994) and complex network investigations (Barabási and Albert, 1999; Watts and Strogatz, 1998), such investigations including movie actor collaboration networks (Zhang et al., 2006; Chang et al., 2007), scientific collaboration networks (Newman, 2001a, 2001b, 2001c), and so on. Newman (2001a,b, 2004) has taken an important step towards applying complex network measures to reveal the global structural properties of scientific collaboration networks for biomedicine, physics, and mathematics. In these networks, nodes are scientists, two scientists are connected by an edge if they have wrote a paper. The collaboration network research provides a powerful paradigm for the representation and analysis of collaboration relationships between organizations. More specifically, the collaboration network research mainly focused on the global structure of the network, and the network constructed is large—containing over a million individuals—and for which a reliable statistical description of the topological properties is possible (Newman, 2001a, 2001b).

As construction projects are getting larger and more complex, no single contractor with a limited capacity and partial information can handle all matters (Son and Rojas, 2011). The importance of collaboration, coordination and communication for effective project execution has been emphasized in the construction industry (de Saram and Ahmed, 2001; Morton et al., 2006; Shohet and Frydman, 2003). A number of collaborative forms including partnerships, strategic alliances and joint ventures (Alvarez and Barney, 2001; Anvuur and Kumaraswamy, 2007; Badger and Mulligan, 1995; Ozorhon et al., 2008; Walker and Johannes, 2003; Wong and Cheung, 2005; Xu et al., 2005) suggest that collaboration among heterogeneous construction contractors is increasing in a wide range of construction fields. One of the most important motivations for forming collaboration among contractors is that collaboration can provide sufficient financing strength to participate in capital-hungry projects. Other motivations include bridging knowledge and expertise gaps, sharing of the burdens of risk exposure, and exploring local market opportunities (Walker and Johannes, 2003).

A comprehensive investigation of how contractors gathered and evolved from a global network view can not only illuminate the development trend of organizations' collaborations in the industry level, but also provide evidence of better performance for collaborative entities and thus prove beneficial when firms develop their strategies to improve project performance at the firm level (Pryke, 2004). To our knowledge, few studies have attempted to assess inter-organization collaboration relationships in construction field from an industry perspective. Focusing the contractors' collaborations in the National Quality Award Projects of China (NQAPC), we aim to construct and present analysis of the global structural properties of realistic inter-organizational collaboration networks (containing hundreds of heterogeneous contractor companies, corporations and groups). The relatively larger collaboration networks within NQAPC permit to obtain solid statistic conclusions concerning the global structure. More specifically, our purpose is to empirically investigate the structure of collaboration patterns in the construction field in China and explore the evolutionary characteristics by analyzing real cases of collaboration at first time. Our goal is to extract main properties and mechanisms that are crucial to the understanding of collaboration progress within NQAPC from a global network view. This study goes one step further than previously mentioned SNA studies by providing a comprehensive and systematical picture of the principle of how inter-organizational network evolved from an industry perspective.

The outline of the paper is as follows. In Section 2 we present the main idea for constructing the NQAPC contractors'