A Network Approach to Investigate Coordination in Construction Projects: A Literature Review and Research Directions

Mohamed A. El-Gafy, Lingci Meng
Michigan State University, East Lansing, Michigan, USA
elgafy@msu.edu;

Amine Ghanem
Roger Williams University, Bristol, Rhode Island, USA
aghanem@rwu.edu

Kasim A. Korkmaz
Eastern Michigan University, Ypsilanti, Michigan, USA
kkorkmaz@emich.edu

Abstract
Construction industry suffers from several problems that cause schedule delays and cost overrun. The traditional engineering project management approach focused extensively on optimizing the project process with the ability to plan and manage the technical resources effectively. By developing an optimum plan and allocating time, money, and labor resources efficiently, management has the ability to ensure that a project stays on schedule and within budget. Although this engineering approach has been proven effective in many aspects, there is a lack of recognition of the importance of participants to the overall success of a project. In this paper, social network analysis (SNA) is discussed as a possible resolution for project management, especially for coordination among the participants of a project. By summarizing previous coordination studies in health care, information technology, and also in construction, this paper points out the possibility and necessity of pursuing SNA in construction. Future directions and recommendations in this area are also discussed at the end of this paper.

Keywords
Coordination, Construction Projects, Project Management, Social Network Analysis

1. Introduction

The construction industry is considered highly fragmented compared to other manufacturing industries due to its unique nature (Jannadi and Bu- Khamisn, 2002). Low productivity, cost and time overruns, frequent change orders, and disputes have been considered the main components of different kinds of performance-related problems (Egan, 1998). Studies to improve these issues have been undertaken from several perspectives, including economic studies (O'Brien et al, 1995), supply chain management (Xue et al., 2007), and project delivery methods (Chang et al, 2010). However, a more widely accepted explanation is that the actors involved in the different activities are unable to coordinate efficiently (Son and Rojas, 2011). The organizational aspects of projects have not been reflected properly in current construction management practice (Shelbourn et al. 2007). Most studies have focused on examining the influence of coordination on project performance (Eriksson and Westerberg, 2011), instead of building a systematic protocol rather than one that is just "piecemeal and anecdotal".

Traditional methods of project management value each participant's success individually, instead of defining their performance by the whole project (Cornick and Mather, 1999). Previous researchers (Latham, 1994; Egan, 2002) have criticized this fragmented approach and suggested that the construction industry should move toward more collaborative approaches. Although different forms of integrated approaches that bring design and construction phases together, such as design and build, have been attempted, none of them fully achieved the expected success (Baiden et al., 2006). Baiden et al. (2006) found that the "fragmented" atmosphere among project teams caused team members to minimize their exposure to poor performance, rather than working together; this is called a "blame culture." Thus, coordination between participating actors in construction projects remains a pending issue to be studied deeply.

Coordination has been considered one of the most important factors of the management process (Pilcher, 1992). In construction, studies have focused on improving coordination, in recognition of its importance; these have included integrated project delivery (Akintan and Morledge, 2013), supply chain management (Xue et al, 2007), information technology (Shin, 1999), and building information modeling (Staub-French and Khanzode, 2007). However, none of these approaches could provide a particular concern with the structure of the relationships among the actors over time, nor have they sought to identify both their causes and consequences as social network analysis (Scott, 1991).

The general objective of this paper is to review the literature and propose potential research directions in applying a network approach to investigate coordination in construction research.

2. Current State of the Knowledge

Coordination is one of the seven processes of management, the others being forecasting, planning, organizing, motivating, controlling, and communicating (Pilcher, 1992). Effective organizational coordination results in streamlined work processes, increased performance and effectiveness, higher productivity, and effective resource management (Litwak and Hylton 1966). Organizational coordination is defined in different ways. The core concept of coordination from these definitions is the alignment of work that is required of organizational units in order to achieve success with a specific duty.

The success of work in organizations is achieved by a division among staff members specializing in different aspects of work (Durkheim, 1984). Problems could be caused by both the specialization and decomposition of activities, (Heath and Staudenmayer, 2000) or the presence of interdependencies among activities that need to integrate the interdependencies (Malone and Crowston, 1994) . Eastman et al. (1998) described the coordination practices of design process for a 92 story tower in Shanghai. They addressed the main problems stemming from contractual relationships and working familiarity between team members. They examined the factors of shared visibility of certain work and responsibilities, privacy issues, coordination using shared artifacts, tentativeness of commitments, process knowledge as a basic aspect of professional expertise, technological and procedural heterogeneity, adaptive process and meta-level discussions, professional trust, and face-face interactions.

Coordination is an important function in the building process but recent research has shown that poor or inadequate coordination has been consistent on construction sites (Saram and Ahmed, 2001). The ability to coordinate is an influential factor in customer satisfaction (Kraut and Streeter, 1995) and it improves the capability to produce quality work (Faraj and Sproull, 2000). A study from Nagappan et al. (2008) argued that elements of organizational structure could be effective predictors of failure-proneness in a large product. Similarly, in a study of data collected and analyzed from IBM's developer teams, communication patterns have also been used to predict building quality, suggesting communication structures have an influence on building outcomes (Wolf et al., 2009).

In construction, Jha and Iyer (2006) discussed the findings of a questionnaire on the factors affecting cost performance of Indian construction projects. Among the 55 success and failure attributes identified, "coordination among project participants" turns out to be the most important factor obtained from the results of regression analysis. Sweis et al. (2008) pointed out that "insufficient coordination among the parties by the Owner/Contractors/Consultant engineer" is a main cause of project delay.

3. Coordination Models, Strategies, and Mechanisms

Researchers have described numerous models of coordination in various domains, including computer science, distributed artificial intelligence, biology and sociology (Gillette and McCollom, 1995, Bonabeau et al., 1999). These models were developed mainly to provide a framework when designing tools and technologies to support coordination (Tolksdorf, 2000).

Malone and Crowston's (1990) theory explains how people work together in the aspect of coordination. Four components of coordination were highlighted; Goals, Activities, Actors, and Interdependencies. The fourth component, interdependencies, is unique to coordination, while the other three also exist as types of working processes. The fundamental types of interdependencies are prerequisite, shared resource, and simultaneity.

Mintzberg (1983) formulated a coordination model containing five basic parts. The operating core, as the foundation, includes all those employees who produce the basic products and services of the organization. The middle line comprises those managers who link the top managers to employees. The strategic apex stands at the peak of the organization, and consists of the top general managers and their assistants. Technostructure and the support staff, acting as complementary departments in the organization, provide analytic techniques and the other indirect support. The model also explains five different coordination components, including mutual adjustment, direct supervision, standardization of work processes, standardization of work outputs, and standardization of work skills.

Some organizational coordination problems can be resolved by employing coordination strategies and mechanisms (Malone and Crowston, 1994). A coordination strategy is defined as a logic through which coordination is exercised, while a coordination mechanism is a technique used to achieve coordinated action within organizations (Dietrich and Kujala, 2007). Mechanistic coordination is characterized by formal, non-cooperative and centralized strategies (Galbraith, 1993). The main types of this category are explicit coordination structures (Serfaty et al., 1998), coordination by standardization (Mintzberg, 1983), coordination using plans (Thompson, 1967) and scripts (Brown and Sambamurthy, 1998). Organic coordination is characterized by informal, cooperative and decentralized strategies (Bardram, 1998). For example, coordination by mutual adjustment (Thompson, 1967, Mintzberg, 1983) is a widely used mechanism of coordination under this category. Other coordination mechanisms in this category are implicit coordination processes (Rico et al., 2008), instrumental coordination (Bardram, 1998), relational coordination (Gittell, 2006), and coordination achieved using shared knowledge (Espinosa, et al., 2005).

4. Coordination Studies in Construction

In recognition of the importance of coordination in construction, researchers have undertaken various studies in an effort to improve it, such as integrated project delivery (Akintan and Morledge, 2013), supply chain management (Xue et al, 2007), information technology (Shin, 1999), and building information modeling (Staub-French and Khanzode, 2007). However, none of these approaches are particularly concerned with the structure of relationships among the actors over time, nor do they seek to identify causes and consequences as social network analysis (Scott, 1991).

A list of 64 activities related to achieving coordination in a construction project were part of a questionnaire Saram and Ahmed developed (Saram and Ahmed, 2001). Construction project managers and coordinators identified these activities as being of "high, mid or low" importance to help achieve a formal understanding of day-to-day coordination and to find out the most important and time-consuming activities from the project manager's perspective. Alarcón and Pavez (2006) collected data from a detailed real time monitoring of the activities of seven project managers from four different companies to identify the main activities they carried out and the communication means they used. The outcomes of this kind of method show pragmatic conclusions by collecting data from people working on site. Nevertheless, the limited number of participants sharing personal opinions could lead to contestable conclusions. They also failed to apply knowledge from other research domains.

Ngacho and Das (2014) developed a questionnaire for 175 respondents, clients, consultants and contractors involved in Constituency Development Fund projects constructed between 2003 and 2011 in Kenya to demonstrate a multidimensional performance evaluation framework. Similar studies about Key Performance Indicators (KPI) in construction have been implemented by others (Chan and Chan, 2004, Bassioni et al., 2005). In addition to the traditional performance evaluation criteria of time, cost and quality, these studies also included safety of the project site (Billy et al., 2006), site disputes (Tabish and Jha, 2011), environmental impact (Eriksson and Westerberg, 2011), and community/client/customer satisfaction (Chan and Chan, 2004). However, these empirical investigations have failed to show details and direct correlations between coordination and project performance due to the data being collected from subjective individuals and from a lack of quantitative analysis.

5. Current Research Gaps related to Construction project Coordination

Although a lot of researches have focused on coordination in construction and determined it as a key component for project success, there are still research gaps in these studies. First, despite being widely accepted that coordination is a relevantly efficient starting point to deal with uncertainties, interdependences, and operational inefficiency (Dubois and Gadde, 2002), traditional methods, such as meetings, plans, and contract documents, used by project participants to coordinate their work usually fail to reach effectiveness (Carlson and Davis, 1998). A study by Pocock et al. (1996) has shown that, although there is a strong relationship between project performance indicators and degree of interaction (DOI), project performance does not improve significantly when the DOI increases. Similarly, Patrashkova-Volzdoska et al. (2003) argued that high levels of team communication can impede team performance rather than result in better performance. Thus, as emphasized by Chang and Shen (2013), increased coordination does not necessarily increased effectiveness. There is a lack of effort by construction academics and industry to investigate coordination and how it could be enhanced to improve its effectiveness.

Second, various studies have been implemented to pursue better project performance by managing coordination effectiveness from different perspectives, such as trust (Sheppard and Sherman, 1998), communication (Hossain, 2009), people (Mohamed and Stewart, 2003), team work (Rico et al., 2008), and organization alliances (Gulati and Singh, 1998). Iyer and Jha (2006) developed a questionnaire to identify key coordination activities in order to enhance the coordination rating of project. However, most of these prior studies merely focused on one influential factor of coordination effectiveness, while there are multiple key components to formalize coordination networks, including agents, knowledge, tasks and organizations (Carley, 2002). To characterize three domain elements in a network -individuals, tasks and resources, Krackhardt and Carley (1998) developed a model based on five prime relations among these domain elements. The relations include precedence, commitment of resources, assignment of individuals to taks, networks and skills linking individuals to resources (PCANS). As an extension of their work, Graham (2005) defined a set of ten inter-linked networks under the concept of the meta-matrix, wherein changes in one network cascade into changes in others, as do the relationships. This highlights the importance of looking into the multiple examples of coordination in construction projects in order to improve coordination effectiveness in the construction industry.

Third, although many research studies have adopted a network perspective, few have dealt with the dynamic nature of construction (West, 2014; Wambeke et al., 2011; Park et al., 2011), as in general project control studies (Navon, 2005). While static features and impacts of projects have been extensively researched and applied to project management practice, more effective understanding or utilization of dynamic features should be explored (Ford, 1995). Building on the concept of systems and contingency theory, Stoner et al. (1995) used the term "dynamic engagement" to describe the modern construction project management system. Involving multiple feedback processes and nonlinear relationships, construction projects are inherently complex and dynamic (Sterman, 1992). It is expected that insight into coordination issues in construction projects will be advanced through the use of dynamic network analysis.

6. The Potential for Social Network Analsysis to Adress Current Resaerch Gaps

Social network analysis (SNA) was applied in construction as far back as 1998 (Loosemore, 1998). Loosemore introduced basic ideas of SNA and emphasized the dangers of using qualitative or quantitative methods in isolation. Pryke (2004) used SNA to identify and quantify changes in actors' roles and positions. Chinowsky et al. (2008) developed a social network model in construction by collecting data from one project team in an international design and construction competition for energy- efficient housing. Ling and Li (2011) implemented a study focusing on the relevance of social network strategy and the important network practices when managing construction projects in China for both foreign and local firms. These studies prove that social network analysis is adaptable for construction. As a feasible alternative, SNA provides a quantitative method to analyze coordination in construction. Previous studies without SNA lacked distinguishing coordination quantity and coordination effectiveness. The data collected in traditional social network analysis is normally collected over a period of time and then analyzed using techniques that remove all dynamic attributes (Chung, 2006). Thus, applying dynamic network analysis (DNA), which can handle large, dynamic, multi-mode, multi-link networks in construction, is essential for making further progress in coordination management (Carley, 2003).

Some researchers have focused on the network prespective of the construction projects (Pryke 2004; Chinowsky et al. 2008; Hossain 2009; Wambeke et al 2011; Ling and Li 2011; Park et al. 2011; Ning 2013; Sanaei et al. 2013; and West, 2014). However, multiple key corporate construction entities have not been analyzed correspondingly, but have been considered as interdependent factors and isolated from each other. Organizational Risk Analyzer (ORA), based on previous work in social networks, takes relations among personnel, knowledge, resources and tasks into account (Reminga and Carley, 2003) and is used as a network analysis tool that detects risks or vulnerabilities in an organization's design structure.

Taking the meta-matrix as input, the metrics of ORA include social network, task management, and dynamic network metrics. These measurements provide three classifications based on risk and vulnerability, input requirements, and type of output produced. As a valuable approach for understanding human socio-cultural behavior, ORA and Dynamic Network Analysis can support overall deductions about individuals, groups, and their activities, as well as improve situation awareness (Carley and Pfeffer, 2012).

Different from the static network approach used in previous studies, Effken et al. (2013) used ORA as a dynamic network analysis tool to study communication networks on nursing units and how they affect the quality and outcomes of patient care. ORA has been widely used in different domains including health care (Effken et al., 2013) and the military (Graham, 2005). Gelernter et al. (2015) also used map visualizations made by ORA to show relationships among people at a particular time and location.

Thus, using dynamic network analysis software such as ORA could fill current research gaps including the need to: 1) build up the connection between coordination and project performance over coordination effectiveness; 2) consider influential factors of coordination solely, rather than correspondingly; and 3) analyze only static and stable perspectives of construction.

7. Conclusions and Future Directions

The social network approach for construction provides an innovative and transformative approach to improving overall project performance. Compared with the historic engineering project management approach, which emphasizes on a continuous refinement of tasks as a basis for achieving high performance, SNA identifies the key roles of individuals within project networks. Coordination between participants is the basis for achieving high performance in construction projects. Previous studies have proven the necessity of applying SNA in construction, and a basic social network model has been established by Chinowsky (Chinowsky and Galotti, 2008).

However, significant challenges still exist in the construction industry, which will affect the implementation of a social network model. Both instability and the dynamic nature of construction create difficulties for using the traditional network approach through the overall project process. ORA and other new updated softwares provide functions to follow and analyze particular projects point by point, which allows researchers to dynamically identify issues and possible improvements.

Although it is beyond the scope of this paper to further explore the application of dynamic network analysis approach in construction, it is recognized that this new method could affect the future application of a network approach to construction project management.

Based on a lack of studies focusing on a dynamic network approach, the future research direction is clearly expected to implement practical analysis in real-life projects. Questionnaires, or interviews of on-going project participants, could be used during the data collection process. Using a dynamic network analysis approach to analyze these data and comparisons between the historic and dynamic approaches should be made to address the advantages and disadvantages of this new method. It is anticipated that due to the uniqueness of the construction industry, the project network must be managed based on a dynamic method to achieve the next level of performance improvement.

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