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Measuring the complexity of mega construction projects in China—A fuzzy analytic network process analysis

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Abstract

Mega construction projects in China are usually very complicated in nature, thus evaluating and understanding these complexities are critical to the success of these megaprojects. However, empirical studies related to the measurement of the complexity of megaprojects remain lacking. This paper aims to fill this gap by developing a complexity measurement model based on the Shanghai Expo construction project in China using fuzzy analytic network process (FANP). Firstly, a complexity measurement model consisting of 28 factors, which are grouped under six categories, namely, technological, organizational, goal, environmental, cultural and information complexities, is formulated through literature review using the content analysis technique. The model is then refined by a two-round Delphi survey conducted in the case megaproject. Finally, the refined model and suggestions for its application are provided based on the survey results. The model is believed to be beneficial for scholars and serve as reference for professionals in managing megaprojects.

Keywords: Mega construction projects; Complexity measurement; Fuzzy analytic network process; Shanghai Expo construction project

1. Introduction

In recent years, rapid urbanization has increased the number of mega construction projects in China, with each megaproject costing over RMB 5 billion or about 700 million USD (Hu et al., 2012; World Bank, 2010). These projects are usually very complicated in nature (Chan et al., 2004; Flyvbjerg et al., 2003). Examples of these projects include the national high-speed rail network, the Shanghai Yangshan deepwater port, and the Beijing Capital International Airport Terminal 3 project. However, understanding the complexity of a specific megaproject in today's complex and dynamic environment is very difficult (Sinha et al., 2006). Because of lacking relevant knowledge, these projects are usually beset with low performance, such as cost overruns and schedule delays (Kennedy et al., 2011; Thomas and Mengel, 2008).

Complexity measurement is therefore a critical issue in managing construction megaprojects. Although practitioners usually use a generic term 'complex' to describe mega projects, but the academics prefer to use complicated more sophisticated term to define the nature characteristics of these projects (Baccarini, 1996; Geraldi et al., 2011; Remington and Pollack, 2007). This study goes along with this idea and used the term 'complex' to describe project environment. Complexity is the state of being involved and intricate as a result of including many varied interrelated parts within a subject (Baccarini, 1996). Therefore, project complexity is defined as complicated characteristics of a project as a result of composing many interconnected parts within a project (Xia and Chan, 2012). Evaluating the complexity of a

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specific project can provide reference for decision makers and managers involved in the project. However, previous studies on project complexity are very limited, with most studies focusing only on the conceptual framework of project complexity (Maylor et al., 2008; Sinha et al., 2006). Moreover, seldom do these studies provide a practical model for assessing the complexity of a construction project quantitatively, particularly the mega construction projects in China. Mihm et al. (2003) stated that project complexity is measured by a function of several interrelated factors. Correspondingly, measuring project complexity should adopt a systematic approach. Therefore, this study aims to develop a systematic model for measuring the complexity of mega construction projects in China using the fuzzy analytic network process (FANP) approach and illustrate the use of this model based on a case study of the Shanghai Expo construction.

The analytic network process (ANP), an extension of analytic hierarchy process (AHP), is a main method used in this study. This method can allow for the analysis of complex systems and determine the complexity of project systems (Saaty, 1996). Difficulties or limitations are expected when measuring the complexity levels of the factors of a construction system. Therefore, measuring qualitative factors by using fuzzy numbers helps in speeding up decision making processes and in obtaining highly realistic results (Chan et al., 2009). Thus, the FANP is appropriate to be used in this study to determine the weights of factors/sub-factors in computing project complexity.

The paper is organized as follows. Section 2 first reviews recent works on complexity measurement in construction projects. Section 3 then introduces the FANP. Section 4 develops a refined measuring model using the FANP, followed by a case study on the 2010 Shanghai Expo construction project in China to examine the practicality of the proposed model and discuss the results in Section 5 and 6, respectively. The final section makes conclusions and suggestions for the application of the proposed model.

2. Measuring the complexity of construction projects

Project complexity is an emerging but critical topic in the construction project management field. Many researchers have increasingly recognized the importance of complexity measurement in project diagnosis, particularly in mega construction projects (Baccarini, 1996; Chryssolouris et al., 1994; Frizelle and Gregory, 2000; Little, 1997; Wiendahl and Scholtissek, 1994). With the recognition that project complexity is difficult to be quantified precisely, many scholars have still carried out a great number of research studies to identify the measurement factors and categorize these factors. For instances, Baccarini (1996) and Williams (1999) defined project complexity in terms of differentiation and interdependency. Tatikonda and Rosenthal (2000) believed that project complexity is closely related to interactions among organizational elements and sub-tasks. Remington and Pollack (2007) divided the influencing factors into four dimensions, namely, experience and ability of organization members, project organizational structure and its exchange and coordination with other key participants, project culture, and project business process. Vidal and Marle (2008) identified influencing factors as project size, project variety, project interdependence, and elements of context. Maylor et al. (2008) identified the elements of project complexity as mission, organization, delivery, stakeholders, and team. Geraldi et al. (2011) summarized the project complexity framework including structural, uncertainty, dynamics, pace and socio-political complexity. Xia and Chan (2012) identified six key measures of project complexity, namely, building structure and function, construction method, the urgency of the project schedule, project size/scale, geological condition, and neighboring environment. In addition, several scholars have summarized the categories of project complexity, such as project complexity model ALOE (Vidal and Marle, 2008), two-stage model (Wood and Ashton, 2010), five-dimensional model (Owens et al., 2012), TOE framework in large engineering projects (Bosch-Rekveldt et al., 2011), and house of project complexity in large infrastructure projects (Lessard et al., 2013). Based on these reviews, a six-category framework of project complexity consisting of technological, organizational, goal, environmental, cultural and information complexities is proposed in this study to measure the complexity of construction megaprojects in China.

(1) Technological complexity
Mega construction projects are usually characterized with high technological complexity, such as building type, overlapping of design and construction works, and dependency on project operation. The trend that has innovative and green technologies increasingly in construction, such as three-dimensional technology, energy conservation technologies, and new construction materials, also increases technical complexities in managing mega construction projects (Harty et al., 2007; Hu et al., 2014). Many scholars have reported various kinds of technological complexity in managing projects, such as diversity of technology in project, dependence of technological processes, interaction between the technology system and the external environment, and risk of highly difficult technology (Baccarini, 1996; Bosch-Rekveldt et al., 2011; Maylor, 2003).

(2) Organizational complexity
The execution of a project is conducted by a project organization, which involves project staff, organizational structure and various teams. Consequently, project complexity is also manifested by organizational complexity. As the most central part of project complexity, organizational complexity had received increasing attention in the past two decades such as members' experience, number of hierarchies, and departments of organizational structure influence project complexity (Baccarini, 1996; Bosch-Rekveldt et al., 2011; Xia and Lee, 2004).

(3) Goal complexity
Goal complexity is usually caused by several factors, such as various project participants' requirements, project task complexity, and limited resources. Williams (1999) stated that goal complexity is a kind of structural complexity, because almost all projects have multiple objectives. On the other hand, Remington and Pollack (2007) stated that this complexity might stem from ambiguity that existed in