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Measurement model of project complexity for large-scale projects from task and organization perspective

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Abstract

Large-scale projects have grown in size, quantity, and complexity; thus, measuring project complexity has become an integral part of project management. This study used the task and organization (TO) perspective to propose a measurement model of project complexity through hidden work that reflected the dynamic "emerging" effect of influencing factors on project complexity. TO measures were identified and mapped with attribute settings of ProjectSim software. The proposed TO measurement method was then expressed as hidden workload divided by direct workload. Overall, 12 hypotheses on the relationship between TO measures and hidden workload were put forth. The Shanghai World Expo construction project was chosen to test the synchronous relationship between hidden workload and project complexity as well as to validate the proposed method. The measurement method could truly reflect the project complexity and therefore can be used to manage the complexity of large-scale projects.

Keywords: Large-scale projects; Project complexity; Measurement model; Hidden workload

1. Introduction

The rapid rate of urbanization in recent years has resulted in an increase in the number of large-scale projects in China with large amounts of dollars invested in infrastructure construction (Hu et al., 2012; World Bank, 2010). Large-scale projects are usually highly complicated (Chan et al., 2004). Lack of relevant knowledge on the part of project managers often results in these projects being beset with issues such as low performance, cost overruns, and schedule delays (Kennedy et al., 2011; Thomas and Mengel, 2008). Therefore, understanding and measuring project complexity are significant for large-scale projects because it can serve as a reference for decision makers and managers involved in the projects (He et al., 2014).

Project complexity is defined as the inherent characteristics of a project that result from its various interconnected parts (Xia and Chan, 2012). Project complexity involves dynamism and uncertainty (Baccarini, 1996; Geraldi and Adlbrecht, 2007), which are mainly manifested in task and organizational complexities (Baccarini, 1996; Li et al., 2009). Various authors have attempted to measure project complexity through case studies and surveys. However, previous studies on project complexity are limited, as most studies have focused only on the conceptual framework of project complexity (Maylor et al., 2008; Sinha et al., 2006). Existing methods of measuring project complexity are based mainly on the macro-perspective, and ignore emergency features rooted in micro-influencing factors. To address this drawback, the present study aims to develop a complexity measurement model for large-scale projects that considers emerging characteristics of project complexity, which are also distinct from others.

Computational organization science, a growing interdisciplinary area centered on the development of organization theory through the use of computational techniques (Carley, 1994), is a neo-information processing approach to the study of social, organizational, and policy systems that combines social

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science, computer science, and network analysis (Carley, 2002a, 2002b). Computational organization modeling is called the thought experiment, and relative to the induction, deductive, computational organization modeling expresses people's ideas in a more intuitive way (Prietula et al., 1998). The hypothesis may be simple, but the conclusion may not be obvious. Relative to the theory of mathematics, physics and engineering, the lack of comparable referents makes it difficult for researchers to assess the effectiveness of modeling (Axtell, 2001). Computational organization theory is based on simulation and organization science, but for the model validation, it is difficult to directly copy the validation method of the natural engineering system, and also transcend the traditional empirical methods, on which scholars have reached consensus (Axtell, 2001; Carley, 2002a, 2002b; Sargent, 1992). Virtual Design Team (VDT), based on the extended information-processing view of organizations, attempts to develop a computational model of project organizations to analyze how activity interdependencies raise coordination needs and how organization design and communication tools change team coordination capacity and project performance (Yan and Levitt, 1996).

Numerous "hidden works" exist in large-scale projects; these hidden works are caused by influencing factors of project complexity and are ultimately reflected on rework, coordination, and waiting work. Hidden work provides a direct reflection of the extent of project complexity. Therefore, project complexity can be measured indirectly by hidden workload. VDT can reflect the dynamic emergence of micro-elements and predict accurately the actual project schedule, quality, cost, hidden work, and all types of risks caused by work backlog, thereby compensating for the shortage of predicting hidden workload quantitatively. Thus, with the help of ProjectSim and from the task and organization (TO) perspective, a measurement model of project complexity is proposed in this study. The model uses hidden workload that reflects the dynamic "emerging" effect of influencing factors on project complexity.

The paper is organized as follows. Section 2 reviews recent studies on project complexity and measurement in construction projects. Section 3 analyzes the factors of task and organizational complexities. Section 4 develops a measuring model from hidden workload, followed by a case study of the 2010 Shanghai Expo construction project in China to demonstrate the relationship between hidden workload and project complexity in Section 5. The final section presents the conclusions for the proposed model.

2. Literature review on project complexity and measurement

2.1. Project complexity definition

Complexity is a term that is difficult to define and even more difficult to quantify precisely. Thus, most scholars define complexity from the perspectives of their own fields, and a consensus on its definition has not been reached (Corning, 1998). The dictionary simply defines complexity as the characteristic of having a large number of interacting parts; essentially, the science of complexity is the study of these interactions.

Complexity has been recognized as one of the most relevant topics in project management research (Cicmil et al., 2006). Interest in the complex dimension of projects is new and significant efforts began to be reported only in the late 1990s (Baccarini, 1996). During this period, the explicit study of complexity in projects began. Baccarini (1996) defined project complexity as "consisting of many varied interrelated parts" and can be operationalized in terms of differentiation and interdependency. In the definition, differentiation refers to the number of varied components of the project (tasks, specialists, subsystems, and parts), and interdependency refers to the degree of interlinkages among these components. Williams (1999) highlighted project complexity as structural complexity, the number and interdependence of elements (following a paper by Baccarini (1996)), and uncertainty in goals and means (following a paper by Turner and Cochrane (1993)). In addition, Vidal et al. (2010) classified complexity into four categories: project scale, differentiation of project elements, interaction of project elements, and interaction with external environment; and further stressed that these factors constitute the necessary and insufficient conditions for project complexity. Geraldi et al. (2011) summarized that project complexity includes structural, uncertainty, dynamics, pace, and sociopolitical complexity.

Most authors emphasized the influence of interdependencies and interactions of various elements on project complexity (Ivory and Alderman, 2005). Other authors regarded project complexity as having non-linear, highly dynamic, and emerging features. Vidal et al. (2011), for example, proposed the definition of project complexity as "the property of a project which makes it difficult to understand, foresee, and keep under control its overall behavior, even when given reasonably complete information about the project system."

In conclusion, studies on the concept of project complexity have been conducted for years; the lack of consensus on the definition of project complexity has resulted in difficulty in understanding this concept. Thus, the present study proposes that project complexity can be defined as "consisting of many varied interrelated parts, and has dynamic and emerging features" (Baccarini, 1996; Geraldi and Adlbrecht, 2007).

2.2. Measurement methods of project complexity

Project complexity is an emerging but critical topic in construction project management. Researchers have increasingly recognized the importance of complexity, particularly in large-scale projects (Baccarini, 1996; Chryssolouris et al., 1994; Frizelle and Woodcock, 1995; Little, 1997; Wiendahl and Scholtissek, 1994). Thus, several attempts have been made to measure the project complexity (Table 1).

Given the fact that project complexity is difficult to quantify precisely, a number of studies have focused on identifying factors or aspects relating to project complexity (Xia and Chan, 2012) and attempted to measure complexity factors to build a framework that describes project complexity qualitatively, such as project complexity model (Vidal and Marle, 2008), five-dimensional model (Owens et al., 2012), framework in large engineering projects (Bosch-Rekveldt et al., 2011), and