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Quantifying the complexity of transportation projects using the fuzzy analytic hierarchy process

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Abstract

Transportation projects are increasingly complex. A systematic approach for measuring and evaluating complexity in transportation projects is imperative. Thirty six project complexity factors were identified specifically for transportation construction. Using factor analysis, this study deduced the six components of project complexity, namely *sociopolitical*, *environmental*, *organizational*, *infrastructural*, *technological*, and *scope* complexity. The Fuzzy Analytic Hierarchy Process (Fuzzy AHP) method was employed to determine the weights of the components and parameters of project complexity. Sociopolitical complexity was the most defining component of complexity in transportation construction. A complexity level (CL) was proposed to measure the overall project complexity. The application of the proposed approach was demonstrated in a case study of three transportation projects performed by a heavy construction company. As a quantitative measure CL enables managers to better anticipate potential difficulties in complex transportation projects. As a result, scarce resources will be allocated efficiently among transportation projects in a company's portfolio.

Keywords: Complexity; Project complexity; Transportation projects; Transportation construction; Fuzzy AHP

1. Introduction

Projects are increasingly complex in today's fast changing environment. A complex project involves a multitude of activities contingent each other in various ways to achieve the project's overall outcome (Browning, 2014). Project Management Institute (PMI, 2014) stated that the causes of complexity in programs and projects could be grouped into three broad categories: human behavior, system behavior, and ambiguity. Project management has therefore encountered many difficulties due to the rapidly increasing complexity of most projects (Baccarini, 1996; Bosch-Rekveldt et al., 2011; Thomas and Mengel, 2008; Vidal and Marle, 2008; Williams, 1999). The increasing complexity could even cause a failure for projects if underestimated this complexity (Bosch-Rekveldt et al., 2011). Thus, an understanding of how to manage project complexity was crucial (Baccarini, 1996).

Without exception transportation projects have become progressively complex. The fact that many factors contribute to complexity in transportation construction, managing this complexity is not an easy task. The challenge of how to construct complex transportation projects successfully becomes more difficult. Thus, there is a need to systematically measure and evaluate complexity in transportation projects. This will help parties involved properly allocate their scarce resources in the portfolio of their transportation projects with different levels of complexity. Although many studies attempted to measure project complexity, most measures showed limitations such as: lack of reliability, non-intuitive for end-users, and/or difficult to calculate (Vidal et al., 2011a).

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This research aims at developing: (1) a hierarchical structure of complexity in transportation projects, consisting of complexity components and parameters; and (2) a Fuzzy Analytic Hierarchy Process (Fuzzy AHP) – based model to measure project complexity. Any transportation agency or heavy construction contractor usually has multiple transportation projects at any time period. Our premise is that the top management of these entities should pay more attention and prioritize resources to more complex projects. However, transportation projects may have different levels of complexity that cannot easily determined. A quantitative evaluation of project complexity within a project portfolio was promising because this evaluation resulted in not only which projects were most complex but also how complex these projects are (Vidal et al., 2011a). Project managers agreed that failure to understand the complexity of the project oft-times caused project failure (Hass, 2009). This study helps transportation agencies and heavy construction contractors quantify the complexity levels of transportation projects. When the complexity of each project can be measured, all transportation projects in a portfolio can be ranked based on their complexity levels. Consequently, top management will have more informed decisions in prioritizing projects and allocating resources for different projects. This study focused on transportation projects in the construction phase in Vietnam.

2. Previous studies

2.1. Project complexity

Literature proposed various definitions of project complexity. However, project complexity was still vaguely defined because it was not easy to describe project complexity adequately (Klir, 1985; Sinha et al., 2001). Baccarini (1996) defined project complexity as "'*consisting of many varied interrelated parts' and can be operationalized in terms of differentiation and interdependency*." This author further elaborated his proposed definition in two types of project complexity, namely organizational complexity and technological complexity. Williams (1999) specified that overall project complexity could be characterized by structural complexity (i.e. number of elements and interdependence of elements) and uncertainty (i.e. uncertainty in goals and uncertainty in methods). Geraldi and Adlbrecht (2007) divided project complexity into three groups: faith, fact, and interaction. Bosch-Rekveldt et al. (2011) developed a framework of technical, organizational, and environmental elements for the complexity of large engineering projects. Although it was difficult to understand, foresee, and control project complexity (Vidal et al., 2011a), project managers were well-prepared if project complexity could be measured. In other words, "*how organizations anticipate, comprehend and navigate complexity determines their successes and failures*" (PMI, 2013).

2.2. Project complexity factors

A review of previous studies revealed that project complexity could be characterized by a number of complexity factors. However, classifications of these factors were not consistent. Vidal et al. (2011a,b) divided project complexity factors into organizational and technological complexity factors. Bosch-Rekveldt et al. (2011) characterized project complexity in three aspects, namely technical, organizational, and environmental.

The technical aspect was an important aspect to project complexity (Bosch-Rekveldt et al., 2011). The technical aspect includes many factors contributing to project complexity such as: experience with technology (Baccarini, 1996; PMI, 2013), technological newness of the project (Dewar and Hage, 1978; Geraldi and Adlbrecht, 2007; Tatikonda, 1999; Vidal and Marle, 2008), technical risks, quality requirements (Bosch-Rekveldt et al., 2011), variety of project management methods and tools applied (Vidal and Marle, 2008), and variety of tasks (Williams, 1999). As a result, identifying technical complexity factors could help project participants to navigate project complexity.

The organizational aspect appeared to be the greatest source of project complexity (Qureshi and Kang, 2015; Vidal et al., 2011a). The organizational aspect includes many factors contributing to project complexity such as: project duration (Vidal and Marle, 2008; Xia and Lee, 2005), size of site area, interfaces between different disciplines (Bosch-Rekveldt et al., 2011), trust in project team (Bosch-Rekveldt et al., 2011; Geraldi and Adlbrecht, 2007; Vidal and Marle, 2008), trust in contractor (Bosch-Rekveldt et al., 2011; Geraldi and Adlbrecht, 2007), experience with parties involved, number of different languages (Bosch-Rekveldt et al., 2011; Geraldi and Adlbrecht, 2007), contract types, organizational risks (Bosch-Rekveldt et al., 2011), and ambiguity of project features, resources, and phases (PMI, 2013).

The environmental aspect was the other important characteristic of project complexity (Bosch-Rekveldt et al., 2011). The environmental aspect includes many factors contributing to project complexity such as: weather conditions (Bosch-Rekveldt et al., 2011; Vidal and Marle, 2008), stability of project environment, political/authority influences (Geraldi and Adlbrecht, 2007; PMI, 2013), remoteness of location (Bosch-Rekveldt et al., 2011), number of stakeholders (Baccarini, 1996; Geraldi and Adlbrecht, 2007; Vidal and Marle, 2008; Williams, 1999), variety of stakeholders' perspectives (Geraldi and Adlbrecht, 2007; PMI, 2013; Vidal and Marle, 2008), interference with existing site, risks from environment (Bosch-Rekveldt et al., 2011), and level of competition (Vidal and Marle, 2008).

2.3. Measurement of project complexity

Previous studies proposed a few models for measuring project complexity. Davies (1973), Davis (1975) and Kaimann (1974) used a coefficient of network complexity (CNC) to calculate the degree of complexity of a critical path network. Temperley (1982) suggested a measure of project complexity based on chart and relationship of activities. Nassar and Hegab (2006) developed a measure of assessing project schedules' complexity based on connectivity of activities. However, these studies focused on measuring schedule network complexity and not project complexity. Cicmil and Marshall (2005) proposed a conceptual framework for understanding the complexity of construction projects. This framework consisted of three