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Evolutionary optimization of model specification searches between project management knowledge and construction engineering performance

Jui-Sheng Chou *, Jung-Ghun Yang

National Taiwan University of Science and Technology, Taiwan

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ABSTRACT

Many studies have attempted to specify alternative model configurations as fitting empirical data with the aid of structural equation modeling (SEM) method. However, significant path searching between constructs has increased in difficulty and complexity. One way to enhance modeling efficiency is evolutionary optimization by genetic algorithm (GA). This study applies the project management (PM) knowledge possessed by construction personnel and uses techniques, tools, and skills (TTS) to explore the causal relationship between TTS usage and construction engineering project performance (PP). A questionnaire survey is used to empirically measure the effectiveness of PM TTS on PP. The research framework is first defined by hypotheses supported by the literature. The GA is then applied to the model fitting process to optimize the structural paths. Analytical results show that evolutionary optimization for singular and multiple goodness of fit effectively searches the SEM specifications. By using GA in SEM procedure, researchers can perform automated specification searches to find the best empirical model fit to the data.

1. Introduction

In the behavioral social science domain, numerous hypothetical constructs cannot be measured or known by observation alone. For instance, quality, communication, risk, satisfaction, and success are intangible characteristics or abstract constructs. These constructs can only be observed indirectly by measuring indicators that reflect the characteristics of the constructs. Thus, structural equation modeling (SEM) was created to evaluate and analyze causal relationships between latent constructs and measurable indicators.

The SEM technique, which originates from confirmatory factor analysis and structural path analysis, was initially proposed by Joreskog (1973) and is now a widely used research tool in psychology (Anderson, Babin, Black, & Hair, 2010), social sciences (Fitch, 2007), health sciences (Gonzalez-de la Parra, Namur, & Rodriguez-Loaiza, 2006), and management (Chinda & Mohamed, 2008; Hsu & Sabherwal, 2011). However, the use of SEM to analyze the path between different constructs must consider both direct and indirect effects. Thus, the difficulty of the search for specific structures increases as the number of path alternatives in the hypothetical research model increases. Traditionally, model specifications are searched manually, which is time-consuming and inefficient. Automating the search process facilitates management of this chaotic procedure.

For the above reasons, this study applied genetic algorithm (GA), an adaptive heuristic search procedure for processing large-scale optimization problems. Model specifications are optimized in a case study of causal linkages between project management (PM), techniques/tools/skills (TTS), PM knowledge and construction engineering project performance (PP). Additionally, although the PM approach includes the fundamental practices needed for success in the construction industry, it does not consider the effectiveness of PM TTS that are considered useful to practitioners in terms of project performance.

This study fills this gap in the literature. The four research stages were research assumptions, questionnaire design and analysis, structure optimization, model modification and discussion. Detailed descriptions are as follows: Step 1 – Research assumptions: set research objectives and explore the relationship between PM TTS, PM knowledge, and PP through a literature review followed by construction of the research structure model. Step 2 – Questionnaire design and analysis: distribute design questionnaires to interviewees. After retrieving questionnaires, perform statistical analyses, including descriptive statistical analysis, reliability analysis, validity analysis, confirmatory analysis, path analysis and normality testing. Step 3 – Optimize the overall structural model: use GA-SEM to determine the optimal structure specifications. This study applies GA to improve the initially assumed structural path by executing evolutionary procedures. Step 4 – Model modification and discussion: after completing verification in the

* Corresponding author. Address: National Taiwan University of Science and Technology, 43, Sec. 4, Keelung Rd., Taipei 106, Taiwan. Tel.: +886 2 2737 6321; fax: +886 2 2737 6606.

E-mail address: jschou@mail.ntust.edu.tw (J.-S. Chou).

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previous step, modify the optimized structure model to fit the empirical data. Finally, the effects of PM TTS on project performance are analyzed and discussed.

2. Literature review

Because the construction industry is project-oriented, effective PM is essential (Arditi, Birgonul, Dikmen, & Isik, in press; Belout & Gauvreau, 2004). Particularly, project performance assessment is a primary metric in measuring project success (Ahadzie, Olomolaiye, & Proverbs, 2008). In general, project output results can be improved by using the Project Management Body of Knowledge (PMBOK), a collection of standard practices, knowledge, processes, skills, tools, and techniques; it includes essential methods for business operations performed by any organization (PMI, 2008). Applying these skills, tools, and techniques can help project managers and project teams increase the chances of project success.

However, although PMBOK is an essential resource, the knowledge areas and management techniques included in PMBOK may not be all applicable in every industry. For example, the effectiveness of PMBOK has not been fully investigated in engineering practices in the construction industry. The following sections briefly review the content of PMBOK and the management techniques related to possible engineering project performance improvement.

According to the PMBOK Guide, project management is the application of the knowledge, skills, tasks, and techniques needed to plan activities to meet project needs. Project management is a series of processes ranging from project planning to implementation, and it also includes measurements of project progress and performance. Essential PM activities are identifying project requirements, establishing project objectives, balancing different limitations, and considering stakeholder needs and expectations.

Project management includes five major processes and nine knowledge areas (PMI, 2008). Specifically, the nine knowledge areas are integration management, scope management (PSM), time management (PTM), cost management (PCM), quality management (PQM), human resource management (PHrM), risk management (PRM), communications management (PCoM), and procurement management (PPM). Briefly, these fields of knowledge in PM can be categorized as: core management and facilitating management. Current research issues are the importance of PM knowledge and techniques and the relationship between PM knowledge and project performance. Studies show that PM has had a major impact on the performance (Egbelakin, Ling, Low, & Wang, 2008) and success (Dvir & Lechler, 2010) of construction projects in mainland China.

A study of PM by Kim, Han, Kim, and Park (2009) used SEM to examine the key factors in project performance and project success; they found that these factors included communications management, cost management, and scope management (Kim et al., 2009). Cho, Hong, and Hyun (2009) reported that cost, progress, and quality management significantly affect project performance (Cho et al., 2009). Subsequent studies by Kang et al. (2008) and by O'Connor and Yang (2004) also confirmed that the growing use of information technologies have significantly improved performance (Chapman, Kang, O'Brien, & Thomas, 2008; O'Connor & Yang, 2004). Additionally, exceptional product and service quality can also improve project performance (Hoo, Ibbs, & Ling, 2006).

A study by Dvir (2003) suggested that defining objectives and functional requirements and applying technological specifications are essential for successful national security defense-related projects (Dvir, Raz, & Shenhar, 2003). Yang (2006) further found that information technology and automated technologies significantly affect the success of small and medium-sized projects (O'Connor, Wang, & Yang, 2006); Yang also suggested that automated technologies are critical for successful task execution (Yang, 2007). Qureshi, Warraich, and Hijazi (2009) studied the business models developed by the European Foundation for Quality Management (EFQM) and found that project scope management and human resource management positively affect project performance (Qureshi et al., 2009).

Yeung, Chan, and Chan (2009) suggested that cost, quality, time, and safety performance are reliable indicators of project performance (Yeung et al., 2009). Studies by the Construction Industry Institute (CII) and Kang, O'Brien, Thomas, and Chapman (2008) showed that project performance can be measured in terms of cost, time, safety, design change ratio, and rework ratio (Construction Industry Institute, 2009; Kang et al., 2008). Ling et al. (2006) found that understanding customer requirements is the key variable in architectural, engineering, and construction projects; meeting customer needs is essential for good project performance and high customer satisfaction (Ling et al., 2006). Cho et al. (2009) analyzed the overall relationship between project performance and project characteristics; they identified causal relationships between seventeen project characteristics and five project performance indicators. The five project performance indicators were: "reward ratio," "unit cost," "progress growth," "cost increases," and "speed of completion" (Cho et al., 2009). In Ling et al. (2008), the nine knowledge bodies specified in PMBOK were used to examine international project practices and revealed significant effects on construction site performance (Ling et al., 2008).

However, although specific management knowledge is assumed to have an important effect on project outcomes, no empirical studies have demonstrated the empirical relationship between applications of PM techniques/tools/skills (TTS) and construction project performance (PP). This study tries to fill the gap by applying GA-based SEM for empirical study of the causal linkages between PM TTS, PMBOK and PP using real-world data.

3. Research assumptions

The PMBOK Guide notes that PM processes typically use clearly defined interfaces to indicate individual processes. In practice, however, they may mutually overlap. The need for integrated project management results from the interaction among different processes. Therefore, this study hypothesizes that PM TTS improve management of project scope (PSM), time (PTM), cost (PCM), quality (PQM), human resource (PHrM), communications (PCoM), risk (PRM), and procurement (PPM).

Based on the literature and research assumptions, the study framework contains up to 64 paths as described below between PM knowledge and PP constructs for identification. Thus, the causal relationships become complex and difficult.

H_{01}: PSM significantly affects PTM.
H_{02}: PSM significantly affects PCM.
H_{03}: PSM significantly affects PQM.
. . .. . .
H_{32}: PQM significantly affects PSM.
H_{33}: PQM significantly affects PTM.
H_{34}: PQM significantly affects PCM.
. . .. . .
H_{61}: PPM significantly affects PHRM.
H_{62}: PPM significantly affects PCoM.
H_{63}: PPM significantly affects PRM.
H_{64}: PPM significantly affects PP.

According to the literature (Cho et al., 2009; Construction Industry Institute, 2009; Hughes, Tippett, & Thomas, 2004; Kang et al., 2008; Kim et al., 2009; Chan, Chong, Ee, & Ling, 2004; Ling et al., 2006; Jiang, Klein, Sobol, & Tesch, 2009; PMI, 2008; Yeung et al., 2009),