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A dynamic feasibility analysis of public investment projects: An integrated approach using system dynamics and agent-based modeling

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Abstract

Increasingly, public sector investment projects face a dynamic environment that incorporates both macroscopic system and microscopic individuals. Prior attempts to analyze the feasibility of those projects, however, have been subject to limitations in accommodating such environmental changes. As a remedial measure, the combination of system dynamics (SD) and agent-based modeling (ABM) is proposed due to their complementary strengths. Consequently, this paper suggests a new approach to dynamic feasibility analysis for public investment projects through an integrated simulation model using SD and ABM. The former SD part elucidates the relationships among system elements that constitute project's benefits and costs, while the latter ABM part depicts users' emergent behavior with their heterogeneity. A bridge construction case study demonstrates the applicability of the proposed approach. The findings show that the proposed approach can provide a valuable and flexible framework for analyzing project feasibility in a dynamic environment.

Keywords: Public investment projects; Dynamic feasibility; System dynamics; Agent-based modeling; Integrated approach

1. Introduction

A feasibility study has played an important role as the first thing to be done before implementing and investing in projects. A feasibility study is important in that it enables decision makers to obtain comprehensive information and results for the viability of an investment project (Jónsson, 2012). Thus, a feasibility study provides a basis for the decision on whether a project is to be implemented or not. Therefore, a feasibility study has been used to support a decision making regarding implementation and prioritization of projects. Especially, a feasibility study has been commonly applied to public investment projects, such as transportation, energy, power, water and sewage, and telecommunication infrastructure investments (Yun and Caldas, 2009; Ziara et al., 2002). For successful implementation of projects, a feasibility study usually considers various types of feasibility, including legal, marketing, technical and engineering, financial and economic, and social feasibility (Abou-Zeid et al., 2007).

Therefore, an expert-based analytic hierarchy process (AHP) is applied in a few feasibility studies to evaluate a project's feasibility and determine a project's priority by considering multiple criteria of evaluation (Alidi, 1996; Dey, 2001; Dey and Gupta, 2001; Lee and Park, 2011). However, the AHP-based feasibility study may results in a bias and inconsistency because of the nature of the AHP method (Yun and Caldas, 2009).

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On the other hand, a feasibility study can be simply understood as an examination to determine the feasibility of investment alternatives by predicting costs and benefits for every alternative (Abou-Zeid et al., 2007). Traditionally, a cost-benefit analysis, which is a quantitative analysis, has been conducted for a feasibility analysis (Hutcheson, 1984; Shen et al., 2010; Yun and Caldas, 2009) because the two core elements that constitute a feasibility analysis are costs and benefits (Young, 1970).

In this context, recent public sector investment projects have had intense exposure to dynamic environments. The growth of the dynamic aspects of such investment projects can be explained in two parts: the dynamics of (1) a macro level (system level) and (2) a micro level (individual level). First, the dynamics of a macro level results from the fact that public investment projects have a range of potential effects. Because the ripple effects of public investment projects span not only the investment area but also external areas such as economic, social, and environmental (El-Sayegh, 2008; Katrin and Stefan, 2011), the macro elements that construct the benefits and costs, drawn from the investment projects, are diverse and react sensitively to environmental changes. Moreover, the elements of benefits and costs are interrelated in the macroscopic system, where the benefits and costs incurred by the project are formed. Second, the dynamics of a micro level results from the agents that participate in an investment project. The agents have a substantial impact on an investment project because they create a demand that significantly affects the feasibility of the project. Further, these agents interact with one another, following their decision rules over time. This microscopic dynamics that the agents create influences the macroscopic system of project feasibility. Thus, it is difficult to predict the feasibility of a project regarding its macro and micro dynamics with an AHP-based analysis or a traditional cost-benefit analysis that are usually static.

To overcome this limitation, there have been attempts to apply a single simulation method to deal with the dynamic complexity of feasibility analysis (Aldrete Sanchez et al., 2005; Cirillo et al., 2008; Conzelmann et al., 2005; Rode et al., 2001; Turek, 1995). However, such a method lacks the scope to cover the recent characteristics of public investment projects. For instance, Monte Carlo simulation does not reflect a change of system such as the feedback effect, system dynamics (SD) does not consider behavior at user level by focusing only on the dynamics of a system level, and an agent-based modeling (ABM) does not offer a systematic view and a causal relationship by focusing only on the dynamics of an individual level.

Nonetheless, a review of the literature on the simulation field reveals that various attempts to combine SD and ABM have been made to complement each simulation method (Figueredo and Aickelin, 2010; Größler et al., 2003; Kieckhäfer et al., 2009; Kim and Juhn, 1997; Schieritz and Größler, 2003; Vincenot et al., 2011). However, there has been no attempt to apply a combined SD and ABM method to feasibility analysis despite the complementary strengths that enable such an analysis to incorporate a dynamics of macroscopic system and microscopic individuals.

Therefore, this paper suggests a new approach for dynamic feasibility analysis that uses a combined SD model and agent-based (AB) model for public investment projects. The combination of a SD model and an AB model is proposed because of the dynamic aspects of the system and individual levels of public investment projects. The proposed model has the potential to analyze dynamic changes in the future and provide comprehensive information for project judges or policy makers in advance. Further, the proposed model is illustrated with a bridge construction case study as an example of the model's practical use.

2. Feasibility studies

2.1. Feasibility studies for public investment projects

The pre-investment phase of a project comprises several stages: the identification of investment opportunities; the analysis of project alternatives and preliminary project selection as well as project preparation (pre-feasibility and feasibility studies); and project appraisal and investment decisions (Abou-Zeid et al., 2007; Behrens and Hawranek, 1991). A feasibility study is the first and most important factor before undertaking project design and construction because the study's effectiveness directly affects the project's success. A feasibility study aims to objectively and rationally uncover the strengths and weaknesses of a proposed project, the opportunities and threats present in the environment, the resources required to complete the project, and ultimately the prospects for success (Justis and Kreigsmann, 1979).

A feasibility study for public investment typically considers the following types of feasibility: legal, marketing, technical and engineering, financial and economic, and social (Abou-Zeid et al., 2007). For instance, the Asian Bond Markets Initiative (ABMI) Group of Experts (2010) evaluated the feasibility of regional settlement intermediary (RSI) options for the Association of Southeast Asian Nations (ASEAN + 3), especially for the following: pre-feasibility to select RSI options, operational feasibility to identify the scope of services of RSI options including interface functional blocks and service flows, legal feasibility to assess the extent of problem regulations or laws as "barriers" for each RSI option, and business feasibility to examine whether RSI options would be viable as commercial entities.

To incorporate the multiple components of feasibility, an expert-based AHP, a multi-attribute decision-making technique, is generally used as an analytical tool for a feasibility study (Alidi, 1996; Yun and Caldas, 2009). For example, Alidi (1996) proposed a methodology based on the AHP to measure the initial viability of projects and rank the priorities of projects..Dey (2001) used the AHP to suggest an integrated framework, which is incorporating technical, environmental, and social assessment, for project feasibility analysis. Dey and Gupta (2001) applied the AHP to select pipeline routes in a cross-country petroleum pipeline project. Lee and Park (2011) applied the AHP to assess the feasibility of Korea National R&D program.