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Beyond theory: Towards a probabilistic causation model to support project governance in infrastructure projects

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Abstract

A new project governance model for infrastructure projects is described in this paper. This model contains causal mechanisms that relate a number of project governance variables to project performance. Our proposed model includes relevant variables for measuring project governance in construction projects in uncertain environments. The variables incorporated in the model consider project governance aspects of the relationships between the contracting party and contractors. These aspects cover the early involvement of the contractor in the design and estimation of costs, procurement procedures, integration of design and construction, the incentives and disincentives regime, risk allocation, contract flexibility, and actions that allow the contracting party to maintain bargaining power during possible renegotiations. The proposed model has prediction and diagnosis capabilities enabling decisions to be made on a project-by-project basis and is based on existing theoretical constructs. In developing the model, we used a database consisting of mutually independent records from 58 European infrastructure projects. The records originate from a review of the pre- and post-contract transactions made in these projects. We illustrate the use of the proposed model with examples. After a set of exhaustive analyses, we provide a ranking of the most robust governance actions and factors associated with the occurrence of cost and time underruns. In this way, we show that the proposed model can guide prioritizing project governance actions in specific settings.

Keywords: Project governance; Construction projects; Causal modeling; Uncertainty in construction projects

1. Introduction

Recently, important theoretical developments have been reported in infrastructure governance. For instance, Li et al. (2012) and Chen and Manley (2014) have developed and extensively tested conceptual models in which relevant project governance instruments and factors are identified and related to both project performance and the reduction of transaction costs in construction projects. Chen and Manley's (2014) research focused on collaborative infrastructure projects, while Li et al. (2012) researched the influence of complexity and uncertainty factors on the occurrence of transaction costs in projects. In so doing, the latter authors identified specific methods to cope with the uncertainty of a project so as to, ultimately, reduce transaction costs.

Although the abovementioned research provides elegant theoretical perspectives and important scientific insights, it offers little guidance when it comes to making decisions in a particular construction project. Theories yield generic relationships between variables whereas projects are usually both case- and context-dependent. The one-off nature of projects usually results in specific factors leading to particular outcomes. As such, there is a different set of relevant factors to address in each project situation. This problematic issue is further exasperated by the uncertain nature of construction. A construction project, its environment, and therefore its risks and uncertainties are continuously evolving. New risks and uncertainties are regularly identified and have to be

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analyzed. A project should thus be continuously assessed and re-steered. Hence, decision-support tools capable of coping with these situations are highly desirable to bring real influence on decision-making in particular settings. Although the governance of construction projects has been a hot research topic in recent years (see, for example, Eriksson and Westerberg, 2011; Chen et al., 2012; Zhang et al., 2016), there appear to be no theory-based models that can support decision-making when dealing with project governance in infrastructure projects with the characteristics discussed above. Evidence supporting this point comes from a review of literature of the field of infrastructure projects. Recent papers have reported attempts to provide models supporting decision making related to some aspects of project governance. We found important limitations to the reported models. For instance, Xie and Thomas Ng (2013) developed a multi-objective Bayesian network model for Public-Private Partnership, PPP, decision support. However, the variables incorporated into the developed model as 'decision items' did not undergo comprehensive evaluations, for instance through, Exploratory Factor Analysis to further demonstrate their relevance to decisions in PPP. Moreover, assessments of the causality between the hypothesized factors 'decision items' and the 'objective variables' as outputs of the models were, at least, not reported. These checks are important to provide more optimal inferences informing decision making, as discussed by i.e. Cox (2013). Furthermore, evidence on the flexibility of the models to be used on a case-by-case basis and their ability to cope with changes in a given scrutinized project was not provided. More importantly, however, is that contextual variables were not factored into the analysis. Similar limitations can be observed in the Ozdoganm and Talat Birgonul (2000), Jin and Zhang (2011), Alsalman (2012), Khazaeni et al. (2012), Nasirzadeh et al. (2014), Rudžianskaitė-Kvaraciejienė et al. (2015) research works. In this paper, we aim to develop a model to support project governance in infrastructure projects to address these abovementioned issues. To this end, we use the recent comprehensive theoretical developments by Li et al. (2012) and by Chen and Manley (2014) as a basis for developing a probabilistic causation model. We additionally illustrate a number of possibilities about how a practitioner could become informed and so able to make sound governance decisions within a project. These include the identification of robust actions leading to satisfactory outcomes in a project. Next, we show how contextual factors could be introduced into the model. A further example illustrates how a specific project can be analyzed using the proposed model.

The remainder of this paper is divided into four sections. In the next section, the advocated modeling approach is justified and described. In Section 3, we provide some details about the development and the use of the proposed probabilistic causation model. A discussion of the results and conclusions are reported in the final section.

2. Probabilistic causal modeling overview

Tools that aid decision-making and provide causal knowledge are highly desirable. Here, one needs to be confident about the impact of management actions derived from a given decision tool. When developing models, one needs to avoid being misguided by random statistical associations that lack a causal basis. This aspect has been thoroughly discussed in the literature (Cox, 2013). Fortunately, Bayesian Belief Networks (BBNs), the approach advocated here, include tools that enable causal relationships to be established with degree of confidence and these are illustrated in the following section. While there are alternative approaches that can potentially model causal relationships, BBNs and Structural Equation Modeling (SEM) are the most developed tools and offer the best prescriptions in relation to causal representations (see, for example, Druzdzel and Simon, 1993; Pearl, 2004; Anderson and Vastag, 2004; Cox, 2013).

Anderson and Vastag (2004) showed that, by using BBNs, some of the shortcomings of the traditional SEM approach to causal analysis could be addressed, and this encouraged us to use BBNs to develop the proposed probabilistic causation model. For instance, BBNs do not struggle with non-linear relationships, which is a constraining limitation of SEM. Further, SEM methods are parametric in function and distribution, thereby assuming normality and linearity, which is not the case with BBNs. Furthermore, when information is very limited about an interaction, it can be specified in a probabilistic manner in BBNs whereas this is difficult with the SEM approach. Finally, SEM has limitations when it comes to supporting managerial decisions (Anderson et al., 2004) whereas BBNs are specifically designed to support decision-making.

The publications by Anderson et al. (2004), Anderson and Vastag (2004), Lauría and Duchessi (2006), Gupta and Kim (2008), and Lee et al. (2011) are among the few in which theories are extended to decision support tools. These authors deployed standard methods such as exploratory, confirmatory factor analysis and SEM to capture causal mechanisms and to evaluate theoretical models. In addition, they used BBNs to add prediction and diagnosis capabilities to the theories developed.

A key feature of probabilistic causation involves switching from the occurrence of a cause leading to the absolute determination of an effect, to the occurrence of a cause increasing the probability of an effect. Another characteristic underlying this perspective is that incomplete knowledge concerning causes results in uncertain cause–effect relationships. Accordingly, one does not assume that specified causes alone determine an effect, but rather that they do so in conjunction with unspecified unobserved causes. Thus, one assumes that sets of independent specified causes and unspecified causes are the direct causes of an effect. This was specified by Anderson and Vastag (2004) using the following notation: causes → effect ← unspecified causes.

The BBNs are used for modeling the relationships between variables, and for capturing the uncertainty in the dependencies between these variables using conditional probabilities (van der Gaag, 1996). The probability of a factor having a certain value in the BBN is determined by the occurrence of change in other interrelated factors (Oniśko et al., 2001). In this way, unknown probabilities of a factor in a BBN can be calculated or revised from existing information on interrelated factors. The inference mechanism used in a BBN is the Bayes theorem, which makes it possible to compute the probability of an effect

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