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Review

A critical review of structural equation modeling applications in construction research

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ABSTRACT

Structural equation modeling (SEM) is a versatile multivariate statistical technique, and applications have been increasing since its introduction in the 1980s. This paper provides a critical review of 84 articles involving the use of SEM to address construction related problems over the period 1998–2012 including, but not limited to, seven top construction research journals. After conducting a yearly publication trend analysis, it is found that SEM applications have been accelerating over time. However, there are inconsistencies in the various recorded applications and several recurring problems exist. The important issues that need to be considered are examined in research design, model development and model evaluation and are discussed in detail with reference to current applications. A particularly important issue concerns the construct validity. Relevant topics for efficient research design also include longitudinal or cross-sectional studies, mediation and moderation effects, sample size issues and software selection. A guideline framework is provided to help future researchers in construction SEM applications.

Contents

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1. Introduction

Since Bentler's appeal to apply the technique to handle latent variables (i.e. unobserved variables) in psychological science [8], structural equation modeling (SEM) has become a quasi-routine and even indispensable statistical analysis approach in the social sciences. Computer programs designed for conducting SEM analyses have emerged and enabled the technique to be used in even wider applications [6]. Newly developed graphical user interfaces have also made much easier for researchers and practitioners to use [36].

On one hand, the utility of SEM in approximating reasonable results in measurement and structural analyses has been widely acknowledged [4,8,12,25,34]. On the other hand, SEM has been criticized for generating implausible conclusions due to its indiscriminate use [6]. Some results obtained through SEM are of doubtful authenticity, especially when both researchers and reviewers have little experience with the method. The overall quality of SEM applications in construction research is similarly affected. Many mistakes exist in current publications and basic principles are often violated or ignored.

Despite the special care needed in SEM applications, no explicit body of knowledge has been developed for their use in construction research to assess the proposed models, and errors continue to be made over assumptions and interpretations. The purpose of this paper, therefore, is to provide a comprehensive and critical review of SEM applications in construction research to date, through the evaluation of previous applications of SEM to solving related research problems including, but not limited to, papers published in leading construction journals. The review focuses on the practical use of the SEM technique and analyses the applications in terms of model design, model development and model evaluation issues for the benefit of future research.

2. Methodology

2.1. Introduction to SEM

The emergence and development of SEM was regarded as an important statistical development in social sciences in recent decades and this "second generation" multivariate analysis method has been widely applied in theoretical explorations and empirical validations in many disciplines [21,35]. Compared with other statistical tools such as factor analysis and multivariate regression, SEM carries out factor analysis *and* path analysis simultaneously [61], since it can (1) measure and accommodate errors of manifest variables (i.e. observed variables); (2) represent ambiguous constructs in the form of latent variables (i.e. unobserved variables) by using several manifest variables; and (3) simultaneously estimate both causal relationships among latent variables and manifest variables [35,61]. In addition, SEM can also provide group comparisons with a holistic model, resulting in much more vivid impressions than traditional ANOVA. SEM can also handle longitudinal designs when time lag variables are involved [23,40].

As introduced above, SEM describes and tests relationships between two kinds of variables — latent variables (LVs) and manifest variables (MVs). Latent variables cannot be observed directly due to their abstract character. In contrast, observed variables contain objective facts and easier to measure. Several observed variables can reflect one latent variable [12]. As presented in Fig. 1, a structural equation model usually consists of two main components, a structural model and several measurement models. A simple measurement model includes a latent variable, a few associated observed variables and their corresponding measurement errors. The structural model consists of all LVs and their interrelationships. For model development purposes, some researches aim to validate their assumptions of a dimensional framework of one or several discriminant LVs (e.g. [19]), while others aim to elicit the causal relationship between the LVs. Confirmatory factor analysis (CFA) with correlating latent variables satisfies the former purpose, while these correlations need to be replaced by directional relationships for the latter [35,61].

Fig. 1 provides a simple example of a structural equation model investigating the effect of LV Y1 on LV Y2, and where several MVs are used to represent the LVs. The MVs are shown in rectangles, the LVs in ellipses, measurement errors in circles and with arrows indicating the direction of the effects. If directional arrow between Y1 and Y2 is replaced by a correlation two-way arrow, the model is a CFA and its purpose is to test whether MVs can represent LVs well (i.e. convergent validity) and whether Y1 and Y2 are different (i.e. discriminant validity). The basic concepts and principles of SEM are now well established with the help of early explorations by researchers in the 1980s (e.g. [3,5,8,9,21,48]), structured textbooks (e.g. Byrne [12]; Keline [35]), well developed soft programs (e.g. LISREL by Jöreskog [33], EQS by Bentler [7] and AMOS by Arbuckle [2]), and *Structural Equation Modeling*, the first ranked journal for mathematical methods, in publication since 1994[24]. These are rich sources for beginners to acquire the basic knowledge needed before applying SEM.

The use of SEM in construction research is relatively new, with the early work by Sarkar et al, published in the *Journal of International Management* [56], in their examination of the mediation effects of relational bonding between variables such as role clarity and the collaborative behavioral processes of global construction firms. Another early work is Molenaar et al.'s examination of the effects of a range of factors on contract disputes between owners and contractors [46], published in the *Journal of Construction Engineering and Management*. In both cases, SEM helped to deepen the understanding of traditional research topics. SEM has also proved to be a helpful tool in some emerging research areas. Lee and Yu, for example use SEM to examine the effects of three antecedent variables on the intention to use the Project Management Information System and user satisfaction, and the effect on construction management efficiency [37], while Yang et al. apply SEM to assess the impact of information technology on project success, finding that project performance is not affected directly but through the mediation role of knowledge management [63]. Son et al. applied SEM to measure the acceptance and usage of mobile computing devices among construction professionals in South Korea [58] and Park et al. investigated the effects of selected antecedent variables such as organizational support for construction professionals' acceptance of web-based training [50].

2.2. Article selection

Many previous review papers (e.g. [6,40,56]) focus on analyzing publications in leading journals in their specific research fields, such as marketing. However, research in construction can be seen as a combination of multiple disciplines covering both technical and managerial topics. Therefore, this review provides a comprehensive search of quality SEM applications for solving problems in construction. Although it is an obvious option to use academic databases, none of these is fully inclusive. Elsevier's Scopus, for example, while they publish AUTCON, IJPM and B&E, JCEM and JME are from the ASCE library, CME from Taylor & Francis, and ECAM from Emerald.

To achieve a comprehensive search, the Google Scholar was used as the first stage. According to a recently published analysis in Science, Nicolás Robinson-Garcia, a bibliographer at the University of Granada in Spain said that "Google Scholar's compendium of articles is at least as comprehensive as the leading commercial academic search databases Thomson Reuters' Web of Science and Elsevier's Scopus — and for many disciplines in the social sciences and humanities, even better." [10]. Additionally, Harzing conducted a longitudinal study of Google Scholar coverage between 2012 and 2013 of four disciplines in Chemistry and Physics concluded that Google Scholar has become suitable for bibliometric research [28]. The oversell impression is that all leading construction journals are included in a Google Scholar search.