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Use of structural equation modeling in operations management research: Looking back and forward☆

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Abstract

This paper reviews applications of structural equation modeling (SEM) in four major Operations Management journals (*Management Science*, *Journal of Operations Management*, *Decision Sciences*, and *Journal of Production and Operations Management Society*) and provides guidelines for improving the use of SEM in operations management (OM) research. We review 93 articles from the earliest application of SEM in these journals in 1984 through August 2003. We document and assess these published applications and identify methodological issues gleaned from the SEM literature. The implications of overlooking fundamental assumptions of SEM and ignoring serious methodological issues are presented along with guidelines for improving future applications of SEM in OM research. We find that while SEM is a valuable tool for testing and advancing OM theory, OM researchers need to pay greater attention to these highlighted issues to take full advantage of its potential.

Keywords: Empirical research methods; Structural equation modeling; Operations management

1. Introduction

Structural equation modeling as a method for measuring relationships among latent variables has been around since early in the 20th century originating in Sewall Wright's 1916 work (Bollen, 1989). Despite a slow but steady increase in its use, it was not until the monograph by Bagozzi in 1980 that the technique was brought to the attention of a much wider audience of marketing and consumer behavior researchers. While Operations Management (OM) researchers were slow to use this new statistical approach, structural equation modeling (SEM) has more recently become one of the preferred data analysis methods among empirical OM researchers, and articles that employ SEM as the primary data analytic tool now routinely appear in major OM journals.

Despite its regular and frequent application in the OM literature, there are few guidelines for the application of SEM and even fewer standards that researchers adhere to in conducting analyses and presenting and interpreting results, resulting in a large

☆ *Note*: List of reviewed articles is available upon request from the authors.

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variance across articles that use SEM. To the best of our knowledge, there are no reviews of the applications of SEM in the OM literature, while there are regular reviews in other research areas that use this technique. For instance, focused reviews have appeared periodically in psychology (Hershberger, 2003), marketing (Baumgartner and Homburg, 1996), MIS (Chin and Todd, 1995; Gefen et al., 2000), strategic management (Shook et al., 2004), logistics (Garver and Mentzer, 1999), and organizational research (Medsker et al., 1994). These reviews have revealed vast discrepancies and serious flaws in the use of SEM. Steiger (2001) notes that even SEM textbooks ignore many important issues, suggesting that researchers may not have sufficient guidance to use SEM appropriately.

Due to the complexities involved in using SEM and problems uncovered in its use in other fields, a review specific to OM literature seems timely and warranted. Our objectives in conducting this review are three-fold. First, we characterize published OM research in terms of relevant criteria such as software used, sample size, parameters estimated, purpose for using SEM (e.g. measurement model development, structural model evaluation), and fit measures used. In using SEM, researchers have to make subjective choices on complex elements that are highly interdependent in order to align research objectives with analytical requirements. Therefore, our second objective is to highlight these interdependencies, identify problem areas, and discuss their implications. Third, we provide guidelines to improve analysis and reporting of SEM applications. Our goal is to promote improved usage of SEM, standardize terminology, and help prevent some common pitfalls in future OM research.

2. Overview of structural equation modeling

To provide a basis for subsequent discussion, we present a brief overview of structural equation modeling along with two special cases frequently used in the OM literature. The overview is intended to be a brief synopsis rather than a comprehensive detailing of mathematical model specification. There are a number of books (Maruyama, 1998; Bollen, 1989) and articles dealing with mathematical specification (Anderson and Gerbing, 1988), key assumptions underlying model specification (Bagozzi and Yi, 1988; Fornell, 1983), and other methodological issues of evaluation and fit (MacCallum, 1986; MacCallum et al., 1992).

At the outset, we point to a distinction in the use of two terms that are often used interchangeably in OM: covariance structure modeling (CSM) and structural equation modeling (SEM). CSM represents a general class of models that include ARMA (autoregressive and moving average) time series models, multiplicative models for multi-faceted data, circumplex models, as well as all SEM models (Long, 1983). Thus, SEM models are a subset of CSM models. We restrict the current review to SEM models because other types of CSM models are rarely used in OM research.

Structural equation modeling is a technique to specify, estimate, and evaluate models of linear relationships among a set of observed variables in terms of a generally smaller number of unobserved variables (see Appendix A for detail). SEM models consist of observed variables (also called manifest or measured, MV for short) and unobserved variables (also called underlying or latent, LV for short) that can be independent (exogenous) or dependent (endogenous) in nature. LVs are hypothetical constructs that cannot be directly measured, and in SEM are typically represented by multiple MVs that serve as indicators of the underlying constructs. The SEM model is an a priori hypothesis about a pattern of linear relationships among a set of observed and unobserved variables. The objective in using SEM is to determine whether the a priori model is valid, rather than to 'find' a suitable model (Gefen et al., 2000).

Path analysis and confirmatory factor analysis are two special cases of SEM that are regularly used in OM. Path analysis (PA) models specify patterns of directional and non-directional relationships among MVs. The only LVs in such models are error terms (Hair et al., 1998). Thus, PA provides for the testing of structural relationships among MVs when the MVs are of primary interest or when multiple indicators for LVs are not available. Confirmatory factor analysis (CFA) requires that LVs and their associated MVs be specified before analyzing the data. This is accomplished by restricting the MVs to load on specific LVs and by designating which LVs are allowed to correlate.