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Quantitative models for supply chain performance evaluation: A literature review

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ABSTRACT

This paper presents a review of 84 studies published in the literature from 1995 onwards that propose quantitative models to support supply chain performance evaluation. A conceptual framework is proposed to characterize the studies according to several factors such as the purpose and scope of the model, supply chain strategy, choice of metrics, modeling uncertainty, type of model, techniques, learning capacity, type of application, data source for performance evaluation and validation approach. The reviewed papers were selected from Science Direct, Scopus, Emerald Insight and IEEE Xplore® databases, as well as the Google Scholar search tool. The results show that most of the studies evaluate more than one performance dimension and are based on multicriteria decision making techniques. AHP and DEA are the most used techniques. Pairwise comparisons and the fuzzy set theory are the dominant approaches to deal with uncertainty. Most studies have reported real case applications and do not include a validation procedure. The paper also discusses some research opportunities and suggestions of further studies brought about by reviewing the current body of knowledge on quantitative models for supply chain performance evaluation.

1. Introduction

Supply chains include different organizations, such as suppliers, manufacturers, transporters, warehouses and retailers. Supply chain management is the integration of planning, implementing and controlling all business processes associated with material and information flow and the transformation of goods from the raw material stage to the end user (Handfield & Nichols, 1999; Lambert, Cooper, & Pagh, 1998; Melo, Nickel, & Saldanha-da-Gama, 2009). The main objective of supply chain management is to minimize overall costs while delivering value to customers and other stakeholders, by producing and distributing goods in the right quantity, to the right place, at the right time and in a sustainable way (Ko, Tiwari, & Mehnen, 2010; Seuring, 2013).

Performance measurement can be defined as the process of evaluating quantitatively and/or qualitatively the effectiveness and the efficiency of an activity or a business processes (Neely, Gregory, & Platts, 1995). General benefits of evaluating performance include assessing and controlling progress, highlighting accomplishments, improving understanding of key processes, identifying potential problems and providing insight about possible future improvement actions, among others (Ahi and Searcy, 2015b). Evaluating the effectiveness and efficiency of a supply chain involves using metrics related to various performance objectives such as cost, agility, responsiveness, flexibility, sustainability, among others (Webster, 2002). Evaluating supply chain performance is a complex undertaking mainly because this is a transversal process, involving several players, which contributes to various barriers such as decentralizing historical data, a lack of cohesion between metrics and poor communication between reporters and users (Lohman, Fortuin, & Wouters, 2004; Naini, Aliahmadi, & Jafari-Eskandari, 2011).

The literature on supply chain performance evaluation includes a wide range of studies, including conceptual frameworks of metrics (Gunasekaran, Patel, & Tirtiroglu, 2001), surveys to identify the metrics mostly used (Gunasekaran, Patel, & Mcgaughey, 2004), case studies (Cuthbertson & Piotrowicz, 2011) and quantitative models to support the performance evaluation process (Chithambaranathan, Subramanian, Gunasekaran, & Palaniappan, 2015). Over the last decade, quantitative models have been increasingly investigated as a way to support the supply chain evaluation and management. Various types of techniques have been studied for such an application, including multicriteria decision making (Chithambaranathan, Subramanian, Gunasekaran et al., 2015), statistical (Ahi & Searcy, 2015a, 2015b), mathematical programming (Gong, 2008), artificial intelligence (Ganga & Carpinetti, 2011) and simulation techniques (Bhaskar & Lallement, 2008). Due to the variety of

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studies, literature reviews are needed to classify different types of research, examine the general trends of this research area and help identify research gaps. Fahimnia, Tang, Davarzani, and Sarkis (2015) presented a bibliometric analysis of 489 papers on quantitative models to support supply chain risk management. Brandenburg, Govindan, Sarkis, and Seuring (2014) conducted a review of 134 papers on quantitative models that address sustainability aspects in supply chains. Seuring (2013) reviewed 36 papers on quantitative models that also address sustainability in supply chains. Ko et al. (2010) carried out a review of papers on quantitative models that address various aspects of supply chain management, including manufacturing flow management, order fulfilment, demand management, supplier relationship management, product development and returns management. Melo et al. (2009) reviewed papers on quantitative models to support supply chain facility location decisions.

Although there are some review papers on quantitative models to support supply chain management, none of them focus on the analysis of quantitative models for supply chain performance evaluation. Therefore, the objective of this paper is to present a review of papers that propose quantitative models to support supply chain performance evaluation so as to answer some research questions such as what are the most used techniques, how the performance metrics are chosen, what are the data sources to evaluate performance, among others.

To guide the analysis of the reviewed papers and to answer the research questions, a conceptual framework is proposed to characterize the studies according to several factors such as the purpose and scope of the model, supply chain strategy, choice of metrics, modeling uncertainty, type of model, techniques, learning capacity, type of application, data source for performance evaluation and validation approach. The study analyzed 84 papers searched for on the Science Direct, Scopus, Emerald Insight and IEEE Xplore® databases, as well as the Google Scholar search tool. The time span considered for this study was the past two decades, from 1995 onwards. The papers were also classified according to the year of publication, journal and geographic location of the author's filiation.

The paper is organized as follows: Section 2 provides details of the conceptual framework proposed. Section 3 presents the database search procedures and keyword strings. Section 4 presents and discusses the results of the review. Section 5 summarizes the research gaps and trends. Finally, conclusions are drawn in Section 6.

2. A framework to analyze quantitative models for supply chain performance evaluation

The main objective of this proposed framework is to highlight the factors used to analyze and characterize the quantitative models for supply chain performance evaluation reviewed in the literature. Fig. 1 presents the factors that comprise the model.

The factors proposed in the model were based on reviews about quantitative models on supply chain management (Brandenburg et al., 2014; Fahimnia et al., 2015; Govindan, Soleimani, & Kannan, 2015; Melo et al., 2009) as well as qualitative studies concerning supply chain management (Cuthbertson & Piotrowicz, 2011; Farahani, Rezapour, Drezner, & Fallah, 2014; Gattorna, 2010). They are grouped into factors related to modeling and factors related to application and validation. The connections shown by the arrows mean the interdependence between the factors. The issues implicit in each of the factors are commented on next.

- **Purpose:** although the purpose of all the studies was performance evaluation, some of them aim to support prediction of performance (prediction of lag indicators based on lead indicators or projecting performance stability over time), while others propose to identify performance gaps based on targets or benchmarks.
- **Supply chain strategy:** this considers the competitive strategy adopted by the supply chain. Five main strategies were identified in the studies reviewed: lean, agile, flexible, green and sustainable (Farahani et al., 2014; Gattorna, 2010). Lean supply chains are characterized by high volume, low variety, low cost, predictable demands and lead times, high reliability and low risk. Agile supply chains are designed for responsiveness and for launching new products in the market before competitors. Their main characteristics are rapid response in unpredictable conditions, available capacity, flexible scheduling, fast decision making and delivery. Flexible supply chains are designed to meet unplanned or unplannable solutions, especially finding creative solutions. Their main features are related to flexibility, ability to problem resolution, speed and measures of innovation (Gattorna, 2010). Green supply chains focus on how a firm utilizes its suppliers' processes, technology and capability, and integrates environmental concerns to enhance competitive advantages. It is a facet of the supply chain that promotes reduction, reuse and recycling of resources involved in both upstream and downstream activities (Naini et al., 2011). Sustainable supply chain strategy involves integrating environmental and social aspects with economic considerations, known as the triple-bottom-line (Brandenburg et al., 2014).
- **Scope:** considers whether the model deals with a broad evaluation of performance or if considers only a single dimension of performance, such as agility or flexibility.
- **Choice of metrics:** this considers whether the choice of metrics was based on specialist opinion, on other studies or on a particular performance measurement conceptual framework.
- **Modeling uncertainty:** this refers to the approach used to model uncertainty. In supply chain performance evaluation, uncertainty relates to the lack of precision of the scores of the alternatives, as well as the relative importance of different criteria. This imprecision may be due to: subjective evaluation by multiple decision makers, inexistence of historical data and difficulty of assessing intangible aspects of supply chain performance (Brandenburg et al., 2014; De Boer, Wegen, & Telgen, 1998). Modeling uncertainty can be based, for instance, on pairwise comparisons or stochastic variables (Govindan et al., 2015; Melo et al., 2009).
- **Type of model:** this groups the models according to the nature of the techniques used to aid the evaluation process (Brandenburg et al., 2014; Govindan et al., 2015): multicriteria decision making (MCDM), statistical, mathematical programing, simulation and artificial intelligence (AI) techniques.
- **Techniques:** this refers to the technique(s) used in the decision model (Govindan et al., 2015). They can be used in a combined or single approach. A combined approach proposes the sequential application of two or more techniques.
- **Learning capacity:** this refers to the adaptation capacity of the decision model to the application environment. While some models are trained based on judgments of the decision makers, others are based on supervised learning algorithms.
- **Type of application:** this groups the studies into real or illustrative numerical applications. It also considers the economic sector of real applications (Melo et al., 2009).
- **Data source for performance evaluation:** this groups the studies according to the data source used for quantifying supply chain performance. For instance, some studies are based on historical data, while others are simulated or based on judgments.
- **Validation approach:** this considers whether the study includes a validation approach and the techniques used for validation.

3. Paper selection procedure

The papers were searched for on the following academic databases: Science Direct (www.sciencedirect.com), Scopus (www.scopus.com), Emerald Insight (www.emeraldinsight.com) and IEEE Xplore® (ieeexplore.ieee.org). An additional search was made using the Google Scholar search engine (scholar.google.com). The string "supply chain