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Supplier selection for sustainable operations: A triple-bottom-line approach using a Bayesian framework

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ABSTRACT

In evaluating and selecting sustainable suppliers, we take a triple-bottom-line (profit, people and planet) approach and consider business operations as well as environmental impacts and social responsibilities of the suppliers. Different metrics are introduced to measure performance in these three areas. To examine the influences of different organizational and supply chain operating philosophies, the objectives in selection of suppliers are designed so that some of them favor profit or the business operations, others the planet or the environment and the remaining focusing on people or social responsibility. A novel methodological approach based on a Bayesian framework and Monte Carlo Markov Chain (MCMC) simulation is developed to rank and select suppliers using specific selection objectives. This technique is also effective when smaller or missing data sets exist, which is an especially prevalent characteristic for newer and complex measures such as in a sustainability decision environment. Results obtained from the MCMC simulation provide a wealth of information about supplier performance, which form the basis for additional statistical analyses. The model allows the decision maker to execute various scenarios by changing importance weights attached to the triple-bottom-line areas. We present results for some of those scenarios with managerial and research implications and future research directions identified.

1. Introduction

Supplier selection is an important operational and strategic task for sustainable supply chain partnership development. Environmental, social and economic supplier characteristics are necessary considerations for effective sustainable supplier evaluation and selection. Part of supplier selection involves supplier evaluation and ranking across multiple dimensions (Sarkis and Talluri, 2002). These dimensions tend to increase geometrically when sustainability is to be considered (Bai and Sarkis, 2010).

With an emphasis on outsourcing initiatives, organizations have become more dependent on suppliers, thus making it critical to choose and evaluate supplier performance. Supplier evaluation and selection requires consideration of multiple objectives and criteria requiring multi-criteria decision-making approaches and analyses (Ekici, 2013). Research has been robust in this field with studies that include adopting and implementing of approaches from a wide range of mathematical practices and methodologies. Numerous multi-criteria decision support tools have been developed for structuring and supporting such decisions (Govindan et al., forthcoming).

Environmental, economic, and social sustainability in supplier selection have seen recent increased importance both in practice and tool development (Govindan et al., forthcoming). This topic requires screening of suppliers based on organizational environmental and social performance whether the selection is for commodity or strategic material and product procurement.

Recent and established research has utilized supplier selection mechanisms which consider environmental and social concerns (Humphreys et al., 2003; Yeh and Chuang, 2011; Bai and Sarkis, 2010). Arguably, one of the most potentially effective ways of managing a company's sustainability policy is by linking these policies with purchasing function activities, i.e. through supplier selection.

Unfortunately for most organizations, models are heavily dependent on historical or expert data, but information related to sustainability of suppliers is still in the process of general acquisition, with little easily accessible data available. Many models and tools require significant detailed and specific assumptions about a number of factors. In addition, a number of supplier selection techniques (sustainability focused or more traditional) still look at a snapshot or cross-section of information in their evaluation. To help address some of these issues we introduce a statistical approach based on Bayesian analysis for the

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evaluation and ranking of various suppliers on multiple sustainability dimensions.

The methodology introduced in this paper uses a state of the art approach with Markov chain Monte Carlo (MCMC) simulation using a Gibbs sampler can start with a relatively small set of data arrive at a robust analysis of various suppliers. The technique can prove practically valuable with its capability to consider smaller and missing data sets. Theoretically and methodologically this paper helps initiate a new direction of research into utilizing a series of simulation and stochastic tools for more effective supplier selection in a complex and dynamic decision environment. The approach, unlike other techniques, does not rely heavily on subjective inputs from experts and managers; however the user can very easily incorporate this additional information as prior probability distributions into the decision making process. The technique may also utilize both qualitative (categorical probability distributions) and quantitative (mathematical probability distributions) information for analysis.

The next section of this paper sets some foundational background related to pertinent issues in supply chain sustainability and supplier selection. In this background discussion, an overview of sustainability and supplier selection with a focus on analytical modeling is presented. We then introduce some methodological discussion on Bayesian analysis that sets the foundation for the illustrative application of the technique. An illustrative example with a variety of scenarios helps to provide further detail into the methodology with some robustness checks included. An evaluation of the results from the illustrations helps to set the stage for managerial and research insights and directions for future research. The conclusions section summarizes the paper clearly identifying limitations with directions for future research.

2. Background and literature review

We provide a review of the general supply chain modeling and supplier selection literature to properly situate our study in its greater context. This background will help inform the development and evaluation of the analytical technique proposed in this paper. We also survey related works that focus on the sustainability within supplier selection modeling.

2.1. Supply chain management – supplier selection

The supply chain management literature has identified a number of management decision concerns to maintain a competitive supply chain (Talluri and Narasimhan, 2004):

- Which suppliers should be considered for partnering?
- Which suppliers should be part of supplier development initiatives?
- Which suppliers must be removed from the supply base?
- How can weak suppliers improve their performance?
- How can firms effectively allocate resources to supplier development programs?

From these concerns, supplier partnering and selection is the primary focus of this paper, and is closely intertwined with each of the other managerial concerns.

The number of supplier selection models has increased exponentially over the past couple decades (De Boer et al., 2001; Chai et al., 2013). Many modeling approaches and criteria considerations have been utilized. These approaches range from basic vendor selection optimization models with traditional business criteria (e.g. Sarkis and Semple, 1999) to integrated techniques where multiple methods are used to evaluate a variety of tangible and intangible criteria (e.g. Kar, 2014). In many cases supplier selection decision modeling has transcended the traditional boundaries of deciding which supplier(s) to select. For example, the supplier selection decision has been integrated with benchmarking and improvement (Azadi et al., 2013), production planning and transportation decision making (Choudhary and Shankar, 2014), product development considerations (Deng et al., 2014), purchase/procurement quantities (Zhang and Chen, 2013), supplier failure (Ruiz-Torres et al., 2013), and sustainability/environment issues (Genovese et al., 2013; Kumar et al., 2014).

2.2. Sustainable supply chain management and supplier selection

Although a consensus definition for green and sustainable supply chains does not exist, sustainable supply chain management can be defined as incorporating various dimensions of social and environmental sustainability into supply chain management (Ahi and Searcy, 2013). Sustainability can be defined as an intergenerational philosophy (Bruntland, 1987), using resources today without compromising the needs of future generations, and through the triple-bottom-line concept of integrating environmental, social, and economic dimensions into organizational decision making (Norman and MacDonald, 2004).

The cross-functional, inter-organizational, and multiple additional decision dimensions that are characteristic of sustainable supply chain management complicate sustainability-oriented corporate decisions. This complexity is dependent on the defined supply chain boundaries (Sarkis, 2012). Sustainable supply chain decisions are broader in content, process, and influence. In a conventional decision environment the roles of environmental personnel, the third-party auditors, and external stakeholders may not play a role in supplier selection or development, but may do so in sustainability-oriented decisions. The level of criteria, data availability, and outcome intangibility for the broader sustainability issues also varies. Hence, tools that can improve decision making in this involved context, with sporadically available data, can serve to further identify and address important issues.

Supplier selection with environmental and social sustainability metrics has started to see some growth in recent years as a number of reviews have shown (Genovese et al., 2013; Govindan et al., forthcoming; Igarashi et al., 2013). But overall, sustainable supply chain analytical modeling is still the relatively novel technique (Seuring, 2013) with only about 10% of sustainable supply chain studies relying on analytical or decision modeling (Brandenburg et al., 2014). With many of the multiple criteria and quantitative modeling efforts falling into use of the Analytical Hierarchy Process (AHP) or linear programming optimization approaches (Seuring, 2013). Other techniques have been proposed, but are not as well developed or advanced (Seuring, 2013; Govindan et al., forthcoming).

Many types of tools and techniques have been utilized and exist for sustainable supply chain decisions. One of the most underrepresented set of analytical tools that can provide substantial managerial and theoretical insight into sustainable supply chain management are normative stochastic tools, the tool set recommended in this study. Yet, surprisingly these very powerful, flexible, and practical tools have not received the attention of more deterministic tools (Brandenburg et al., 2014). Also, the applications of these tools have been exclusively in non-sustainable supplier selection investigations such as sustainable technology evaluation or broader strategic planning purposes. Having such tools can prove quite valuable without the need for extensive data or managerial input requirements such as required for rough set theory (Bai and Sarkis, 2010) or AHP (Seuring, 2013). Bayesian approaches have had no published studies related to sustainable supply chain management and/or supplier selection.

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