Int. J. Production Economics 124 (2010) 252–264

Contents lists available at ScienceDirect

Int. J. Production Economics

journal homepage: www.elsevier.com/locate/ijpe

Integrating sustainability into supplier selection with grey system and rough set methodologies

Chunguang Bai [a], Joseph Sarkis [b,*]

[a] School of Management, Dalian University of Technology, Linggong Street, Dalian, 116024, PR China
[b] Graduate School of Management, Clark University, 950 Main Street, Worcester, MA 01610-1477, USA

ARTICLE INFO

Article history:
Received 4 June 2009
Accepted 12 November 2009
Available online 26 November 2009

Keywords:
Environment
Sustainability
Supply chain
Rough set
Grey system

ABSTRACT

Supplier selection plays an important role in the management of a supply chain. Recent emphasis on sustainability has made this selection more complex. Decision support tools and methodologies can help organizations and supply chain managers make more effective decisions. Many tools have been developed with a variety of formal modeling techniques. These techniques may be limited for a variety of reasons. To help advance this area of research and to help further integrate sustainability discussion into the supplier selection modeling area, we expand on a novel approach first introduced by (Li et al., 2008). This approach utilizes grey system and rough set theory. Our expansion and contribution includes introduction of additional levels of analysis and application of this methodology, the explicit consideration of sustainability attributes, and insights into the technique with some sensitivity analysis. Implications of the methodology and future research directions, further expanding the methodology and its applications, conclude the paper.

1. Introduction

Organizations with complex decisions typically have numerous factors to consider and evaluate in the management of suppliers and supply chains. Eventually managing these suppliers requires a careful balance when seeking to procure supplier services or products. Supplier selection and management can be applied to a variety of suppliers throughout a product's life cycle from initial raw material acquisition to end-of-life service providers. Thus, the breadth and diversity of suppliers makes the process even more cumbersome. As has also been evidenced in the research literature the evaluation of suppliers requires consideration of both tangible and intangible factors (Sarkis and Talluri, 2002). Many times these factors, whether tangible or intangible, are not always very clearly defined. A significant amount of judgment and 'grey' area is involved in the evaluation scheme.

Within supply chain management the supplier selection decision is one of the critical issues faced by operations and purchasing managers to help organizations maintain a strategically competitive position (Chen et al., 2006). Globalization, outsourcing and offshoring have added to this competitive burden where selection of suppliers has become an even more critical partnering issue. Suppliers are needed to furnish organizations with the necessary products, components, and materials in a timely and effective manner to help maintain a competitive advantage. Commodity and price-based supplier relationships are no longer acceptable for suppliers of critical materials or for organizations that seek to introduce innovative supply chain management issues, especially those that focus on social and environmental concerns (sustainability). These strategic and sustainability factors play a vital role for the long-term resiliency of a supply chain (Seuring and Müller, 2008; Ciliberti et al., 2008; Zhu et al., 2008). Given this rise in managerial and organizational importance, strategic management of suppliers becomes important and a strategic decision model that allows inputs from a variety of managerial functional areas and multiple factor dimensions proves beneficial to management. Also, historical performance of the suppliers and the previous decisions related to these suppliers are critical information that has not been effectively integrated into decision models. The sustainability factors utilized within our model will integrate the 'triple-bottom-line' selection factors that include economic/business, environmental and social factors (Robins, 2006). We also provide insights into the evaluation to identify and compare which selections are made when only economic factors versus a complete set of sustainability factors are used for evaluation purposes.

Given that strategic decisions in organizations need to incorporate tangible and intangible factors into any analysis that seeks to identify and select critical supply chain partners, more

* Corresponding author. Tel.: +1 508 793 7659; fax: +1 508 793 8822.
E-mail addresses: chunguang.bai@gmail.com (C. Bai).
jsarkis@clarku.edu (J. Sarkis).

0925-5273/$ - see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.ijpe.2009.11.023

advanced techniques can provide insights (Sarkis and Talluri, 2002). One such toolset integrates grey system theory and rough set theory methodologies (Li et al., 2007; Li et al., 2008). Grey system theory is a generalized form of fuzzy approaches and mathematics. Rough set methodology and theory utilizes set theory to help filter and focus the set of acceptable suppliers and factors in their evaluation. Together these two techniques provide complementary avenues to rank or select preferred organizational suppliers, based concurrently on management/expert opinion and previous supplier performance and decisions. We seek to further develop and apply this tool to help organizations arrive at sustainability focused decisions with respect to supplier selection.

This paper advances the use of Grey system and Rough set theory as an effective and realistic modeling approach for supplier selection. To help accomplish this objective the paper begins with a brief discussion on the issues facing organizations in strategic supplier selection. To help set the foundation of this model we summarize a number of sustainability factors that have been considered in the literature. These factors may then be integrated into a "Triple-Bottom-Line" model. Even though we do not present this model in all its detail it provides some starting point for organizations on factors they can consider in evaluating suppliers. The next section of the paper demonstrates an illustrative case application of the proposed model. The results provide interesting managerial insights, implications, and possible avenues for future research and development of the model. These issues will be summarized and presented in the final section.

Our contributions from this study include: (1) modeling the decision problem within the context of a sustainable supply chain management decision; (2) incorporating additional layers and levels of variable and decision maker weighting schemes; and (3) providing additional rough set decision environments that help evaluate the sensitivity of the technique, allowing users and researchers to identify advantages and limitations in the approach.

2. Sustainability supplier selection, factors, and models

Sustainable supplier selection processes require consideration of a number of attributes beyond those used in operational decisions. With increased emphasis on environmental and social issues within organizations and the maturing concept of corporate social responsibility, the need for considering supplier relationships from a sustainable and strategic perspective has become even more apparent (Ciliberti et al., 2008; Presley et al., 2007; Seuring and Muller, 2008).

The supplier selection decision is one of the most fundamental and important decisions made by buyers and organizations. Difficulties do arise from the increased levels of complexity involved in considering various supplier performance and relationship factors. In order to perform a comprehensive sustainability evaluation of suppliers, a number of criteria may be utilized. Managers must be able to analyze and document the importance of several factors, converting instinctive and perceptual qualitative indicators to concise empirical measures. We review some of the major factors from a sustainability perspective in the next section.

2.1. Expanding supplier selection approaches

While much of the initial research in supplier management and evaluation primarily emphasized cost factors, more recently studies have utilized multiple factors in the evaluation process.

Several evaluation models for supplier selection have been proposed over the past three to four decades (de Boer et al., 2001). Methodologies typically found in reviews of supplier selection (choice) approaches include: weighted linear model approaches, mixed integer programming, the analytical hierarchy process, linear and goal programming models, matrix methods, clustering methods, total cost of ownership, human judgment models, principal component analysis, interpretive structural modeling, statistical analysis, discrete choice analysis experiments, and neural networks/case-based reasoning approaches. A majority of the above methodologies are based on multiple supplier attributes. Although these approaches and proposed methodologies have their own relative advantages, many disadvantages also exist. We cannot go into each but issues related to types of factors included, data requirements, transparency of process, integration of managerial perceptions and intangibility, and integration of previous knowledge and decisions into decision analysis are limitations that exist in each of these techniques and that our framework intends to address. One of the missing aspects of many of these techniques is the post-hoc consideration of previous performance into the latest decision. Thus, learning the effectiveness of previous decisions may be useful in determining the applicability of factors for future decision purposes. The data-mining characteristics of rough set theory help to advance this development along with the capability of effectively considering the tangible and intangible factors and perceptions from multiple decision makers that arise from grey-based rough set methodologies. These are some advantages of using a joint grey-based rough set methodology.

Limitations to the grey-based rough set methodology also exist. These limitations include the reliance on perceptual data and input from managers, the amount of data that needs to be collected, and some difficulties with assumptions of necessary decision parameters. Additional difficulties and limitations with this technique and its application are discussed in the concluding section and provide ample opportunity for further development and possible integration with other approaches that may help to fill in the gaps of this methodology.

2.2. Sustainability and supplier selection

Among the conventional supplier selection research neither environmental nor social sustainability factors have been emphasized. Although scarce, the environmental consideration in supplier selection research is emerging while more general sustainability issues, incorporating other social sustainability dimensions are quite scarce (Hutchins and Sutherland, 2008). Managing the supplier qualification and selection process is a necessary step for companies seeking to manage their corporate legitimacy and reputations. Increasingly more authors are addressing supplier selection issues in the light of environmental aspects (Handfield et al., 2002; Humphreys et al., 2003; Lee et al., 2009; Sarkis, 2006). There still exists a necessity to incorporate other, social, sustainability factors such as social equity and employee health.

Sustainable development and sustainability is frequently interpreted as a synthesis of economic, environmental and social development, a triple-bottom-line approach (Gauthier, 2005). Even though environmental considerations in supplier selection decisions have existed, a more systematic inclusion of other sustainability factors is needed. The previous dual concerns of economic and environmental aspects in supplier selection need to be expanded into a triad that involves social factors, e.g., human rights abuses, child labor, and irresponsible investment. Globally, companies are increasingly acknowledging the importance of