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Mathematical modelling of sustainable procurement strategies: three case studies

Tülin Aktin*, Zeynep Gergin

Istanbul Kültür University, Department of Industrial Engineering, Ataköy Campus, 34156 Bakırköy, Istanbul, Turkey

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ABSTRACT

Sustainable procurement is the process of meeting the needs of an organisation with the most beneficial monetary value, while mitigating the diverse effects of its operations on society and environment. There are studies which adopt environmental criteria to procurement decisions, whereas, works integrating the three dimensions and discussing the trade-offs between them are scarce. In this paper, the three dimensions of corporate sustainability; environmental–economical–social, are integrated into supplier selection and demand allocation decisions. With their integrated approach, the proposed mathematical models aim to contribute to the relevant literature by analysing different sustainable procurement strategies. Initially a questionnaire is introduced for measuring the sustainability scores of a company's potential suppliers, and these scores are then used as an input to the models. The developed mixed-integer linear programming models distribute demand to the most sustainable firms in the supplier pool of the company, while ensuring minimum procurement cost for the identified strategy. The questionnaire and models are implemented in three companies to interpret the outcomes of different sustainability strategies on the procurement decisions. Selection of the most appropriate strategy is a managerial decision influenced by the varying dynamics of the company and the market conditions. These models demonstrate an easy and practical approach in assisting sustainable procurement. Results are promising in displaying the trade-offs between the sustainability dimensions of different strategies with alternating procurement costs, and can aid the managers to integrate environmental, economical, and social aspects into their supply chain operations.

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1. Introduction

Companies operating in today's challenging market conditions require an effective procurement process to gain competitive advantage. While classical purchasing decisions consider cost as the primary component, the emerging management approaches integrate many other factors besides cost. In this context, "sustainability" concept is one of the factors recently associated with the buying decision processes.

Corporate sustainability involves the integration of environmental, economical, and social dimensions, which are also called the triple-bottom-line (3BL), into the company processes. A recent literature review by Hassini et al. (2012) shows that there is an increasing interest in sustainable supply chains. On the other hand, there is a need to have a greater focus on the linkages and trade-offs between the 3BL elements, together with measuring the different aspects of sustainability (Walker et al., 2012).

Singh et al. (2009) perform a study on the various sustainability indices and assessment methodologies. They claim that, although there are numerous efforts on measuring sustainability, most of them do not have an integrated approach in considering the environmental, economical and social dimensions simultaneously. In most cases, the focus is on one of the three pillars. Among the 191 papers reviewed by Seuring and Müller (2008) on green and sustainable supply chain management for the period between 1994 and 2007, only 31 of them integrate the environmental and social dimensions. Lozano (2012) highlights the drawbacks of partial consideration of these dimensions, and proposes a new framework to adopt sustainability into a company's system with a thorough approach.

Seuring (2013) has advanced the research by Seuring and Müller (2008) to include more than 300 papers, and reviewed studies on sustainable supply chain management which apply modelling techniques. Since only 36 of these studies build or use quantitative

* Corresponding author. Tel.: +90 212 498 4237; fax: +90 212 465 8308.
E-mail address: t.aktin@iku.edu.tr (T. Aktin).

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models, he concludes that the environmental dimension clearly dominates, while the social aspects are widely ignored. Tang and Zhou (2012) who have studied the research advances in environmentally and socially sustainable operations also agree with the shortage of quantitative procurement models concentrating on environmental and social responsibility. Moreover, company implementations on assessing their suppliers to meet certain environmental and social standards are common in practice, nevertheless the work by Kermani et al. (2011) states the void of comprehensive mathematical models which are capable of explaining environmental issues, price, and other decisive factors in selecting a supplier. After examining more than 25 papers published between 2002 and 2013 on green/sustainable supplier selection, Azadnia et al. (2014) claim that most of the studies consider only economical and environmental factors. What's more, with respect to the solution methodologies, little attention is paid on practical mathematical models, and only five of the reviewed studies consider order allocation. They also refer to the works of Genovese et al. (2013) and Govindan et al. (2013) to emphasise the lack of real-world applications in the sustainable procurement literature.

The motivation of the mathematical modelling approach in this paper has been triggered by the limited number of quantitative studies that consider the 3BL dimensions simultaneously. The current study is cultivated on two previous researches. The first one introduces a mathematical model for the integration of sustainability factors into procurement decisions for a printing company (Gergin and Aktin, 2011). Subsequently, in the works by Coşkun et al. (2012) and Ersoy et al. (2012), the models and scenarios are further enhanced, and the approach is implemented in different industries.

The objectives of this study can be summarized as follows:

- to introduce a generic tool for measuring the sustainability scores of suppliers,
- to propose mathematical models that will aid in procuring from the most sustainable suppliers in the potential candidates pool,
- to implement the models on three different cases,
- to analyse the procurement decisions of the companies by applying alternative sustainability scenarios via the models.

The paper is organized as follows: Section 2 gives a literature review on corporate sustainability, 3BL dimensions, and sustainable procurement. The methods employed are presented in Section 3, and the implementation and evaluation of the proposed mathematical models on three real world cases are provided in Section 4. Section 5 is dedicated to the discussions of the numerical results and scenario analysis. Finally, the study concludes in Section 6.

2. Literature review

This section presents relevant literature on corporate sustainability and sustainable procurement studies.

2.1. Corporate sustainability

Corporate sustainability for a business is to consider the expectations of stakeholders on economic prosperity, protection of the natural environment and social justice, with sensitivity and in balance, in all business processes and decision-making mechanisms. This strategy is later called the “Triple Bottom Line” by Elkington (1997), and the dimensions of sustainability are also labelled as the three pillars; profit, planet, and people. Elkington states that, these three dimensions of sustainability are closely related, whereas are partly in conflict with each other.

“Environmental dimension” of corporate sustainability is often achieved by green supply chain management through administering the consumption of energy and non-renewable resources, reducing manufacturing waste, and disposing it in a safe and legal manner. However, enhancing the environmental pillar usually conflicts with the economical factors. Some researches conclude that strategic decisions with ambitious environmental goals can come with high costs, offering trade-offs between environmental and economical results (Wu and Pagell, 2011).

In common with environmental sustainability, “social dimension” of corporate sustainability is the idea of maintaining/improving the current social welfare for the future generations. In terms of corporate sustainability, this relates to fair practices such as; maintaining a safe work environment with tolerable working hours, paying fair salaries, developing professional skills, avoiding child labour and gender discrimination. Furthermore, the company is expected to give back to the community by contributing to various initiatives such as supporting social responsibility projects, and special community services (Chaabane et al., 2011). Quantifying this bottom line is relatively new, problematic and often subjective.

“Economical dimension” is concerned with reducing economic scarcity, and companies have paid significant attention to this bottom line for many years to persist their market share. The economic component of the triple bottom line is often assumed to be synonymous with financial performance. However, finance is only about the provision of money required for consumption or for investment in commerce, whereas economics as a dimension of corporate sustainability is the company's economic prosperity in its contribution to the satisfaction of shareholders, customers, employees and the company itself. Consequently, it depends on the sustainability of other dimensions.

2.2. Sustainable procurement

Managing the supply chains in a sustainable manner has become an increasing concern for companies of all sizes across a wide range of industries. According to Seuring (2013), “Sustainable supply chain management is the management of material, information and capital flows, as well as, cooperation among companies along the supply chain, while integrating goals from all three dimensions of sustainable development, which are derived from customer and stakeholder requirements”. Many studies suggest that sustainable supply chain practices require the integration of important decisions at different levels of strategic, tactical and operational planning while considering the trade-offs between conflicting performance indicators (Ferretti et al., 2007; Grossmann and Guillen-Gosalbez, 2010; Kleindorfer et al., 2005). For the sustainable development of supply chains, various strategies are developed either from a macro-level or from a micro-level. Macro-level strategies apply methods that adopt regional, national, or international strategies, whereas, micro-level strategies encompass the sustainability issues into company operations.

Many companies have recently started to respond to the need for sustainability in their procurement decisions. For example, as Hollos et al. (2011) describe in their paper, E.ON UK has developed joint social and environmental standards in co-operation with its suppliers, and implements a ‘responsible procurement’ policy which focuses on social rights, minimization of environmental impacts, and maintenance of ethics. BASF, which is another

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