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Modeling synergies in multi-criteria supplier selection and order allocation: An application to commodity trading

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ABSTRACT

We propose a novel meta-approach to support collaborative multi-objective supplier selection and order allocation (SSOA) decisions by integrating multi-criteria decision analysis and linear programming (LP). The proposed model accounts for suppliers' performance synergy effects within a hierarchical decision structure. It incorporates both heterogeneous objective data and subjective judgments of the decision makers (DMs) representing various groups with different voting powers (VPs). We maximize the total value of purchasing (TVP) by optimizing order quantity assignment to suppliers and taking into consideration their synergies encountered in different time horizons. We apply the proposed model to a contractor selection and order quantity assignment problem in an agricultural commodity trading (ACT) company. We maximize the strategic effectiveness of both the customers and the suppliers, minimize risks, increase the degree of cooperation between trading partners on all levels of supply chain integration, enhance transparent knowledge sharing and aggregation, and support collaborative decision making.

1. Introduction

Rapid globalization, economic growth and substantial scientific and technological progress have resulted in enormous competition in international trading (Engau, 2010). The gap between product quality and performance is narrowing with intensifying competition in the global market (Chang, Chang, & Wu, 2011). As business is becoming more and more competitive, purchasing and supply chain management have been increasingly recognized by top managers as key business drivers (Gunasekaran & Ngai, 2012; Van Weele, 2009). For companies who spend a high percentage of their sales revenue on supplies, savings from suppliers are of particular importance (Karpak, Kumcu, & Kasuganti, 2001). Thus, a great deal of the research has been aiming at defining supplier evaluation and selection methodologies that, despite being simple to use and easy to understand, are able to produce reasonably accurate results (Ha & Krishnan, 2008). In particular, the need for a systematic approach to purchasing decisions related to the supplier selection and order allocation has been amply declared through the last decades (Aissaoui, Haouari, & Hassini, 2007; Tempelmeier, 2002; Vonderembse & Tracey, 1999; Weber, Current, & Benton, 1991).

The use of supplier selection and order allocation (SSOA) by trading companies is complicated for several reasons: (1) suppliers may be interdependent in terms of resource sharing or synergistic performance; (2) decisions must take into account multiple objectives and opinions of different supply chain participants; (3) the objectives are often conflicting; (4) supplier assessment criteria can result from decision makers' (DMs') value-focused thinking (VFT), or be based upon a simple comparison of suppliers using alternative-focused thinking (AFT); (5) decision criteria can be quantitative and qualitative; (6) criteria may characterize suppliers indirectly, via intermediate objects, such as external facilities or third-party service providers; (7) decisions are made on a regular base and rely upon suppliers' performance history, measure of their strategic value, and operational characteristics; (8) in the case of multiple sourcing the set of suppliers needs to be balanced in terms of criteria weights; (9) the number of feasible solutions is often very large; and (10) uncertainties can affect the decision outcome.

More in general, the goal is to choose the most effective set of suppliers at the minimum costs subject to demand restrictions and

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additional requirements imposed by the single suppliers on the buyers or vice versa. At the same time, an order allocation problem must be solved, that is, the demanded quantity must be distributed among the selected suppliers so as to maximize the overall value of the purchase. This goal can be achieved using integrated multi-criteria decision analysis and optimization approaches. Suppliers' individual priorities can be calculated using multi-criteria analysis tools, and an optimization procedure can be utilized to find optimal order quantities for all feasible sets of suppliers from which the final choice can be made.

Constraints can be dictated by buyers' or customers' needs, as well as by suppliers' offers. For example, suppliers' interdependency based on resource sharing must be considered when several bidders offer a commodity from the same stock of limited capacity and the sum of the maximum offered quantities of the individual suppliers exceeds the quantity available in stock. However, the suppliers' interaction cannot always be expressed by a constraint. Positive or negative synergies of the suppliers must be explicitly considered when the joint performance of several suppliers according to a certain criterion differs from their individual performances with respect to the same criterion.

Thus, while, supplier selection and order quantity assignment decisions are fairly structured when the decision criteria concern only independent characteristics of the different suppliers, accounting for the interdependencies among criteria and alternatives make the problem much more complex and requires a much more involved use of multi-criteria decision making tools.

Sanathanam and Kyparisis (1996) classified interdependencies among information system projects into resource, benefit and technical interdependencies. Later, Lee and Kim (2001) advocated the necessity to consider interdependencies among criteria and alternatives in information system project selection. Jointly selected suppliers can offer additional benefits or opportunities for the trading firm and its customers, or conversely, cause larger losses or sharper risks. For example, cost savings can be achieved by coordinating the transportation of commodities purchased from several suppliers in a given period. On the contrary, bigger risks may be associated with selecting contractors who purchase from the same source, particularly in the cases of stock-out or delivery difficulties. In complex supply chains, multiple positive and negative synergies of suppliers' performance can emerge simultaneously.

The existing multi-objective SSOA methods fail to take into consideration positive or negative performance synergies. New models and trade-off mechanisms are needed to synthesize all suppliers' individual non-synergistic and group *synergistic* performance characteristics.

We propose a new process that facilitates a simultaneous trade-off between the synergistic and non-synergistic supplier characteristics. First, all the relevant combinations of suppliers have been identified. Then, each combination is assessed with respect to synergistic criteria and each single supplier is assessed with respect to non-synergistic criteria. Finally, the assessed suppliers are aggregated within each combination to compute their total value of purchasing (TVP) and achieve a final ranking of all feasible alternatives.

We pursue two main objectives: (1) to develop a structural collaborative approach for the support of complex multi-objective SSOA decisions involving suppliers' synergism; (2) to demonstrate the application of this methodology to SSOA in ACT companies.

More specifically, the first objective in this study is to present an integrated empirical and technical framework for multi-objective SSOA decision support in complex collaborative environments with the following five key characteristics: (a) a flexible structure of decision criteria based on the compound value system of different decision making and interest groups utilizing both the AFT and VFT approaches for criteria identification; (b) a comprehensive framework where all relevant objective data and subjective judgments regarding the weight of decision factors and performance values of the discrete alternatives on intangible strategic and operational criteria must be incorporated; (c) a framework allowing for decision options constructed by taking into consideration possible effects of suppliers' synergism in case of multiple sourcing; (d) an optimal order quantity allocation process aiming at maximizing the TVP of feasible discrete sets of potential suppliers; and (e) a clearly delineated decision committee providing proper feedbacks.

The second objective of this study is fourfold: (a) to reveal the variables necessary to measure the performance of agricultural commodity suppliers taking into account possible suppliers' synergisms; (b) to generate feasible combinations of commodity suppliers and evaluate them; (c) to optimize order quotes to be assigned to suppliers within each feasible combination; and (d) to select the best set of suppliers with optimally distributed order quantities.

The proposed method was implemented to solve a SSOA problem in one of the largest agricultural corporations in Germany. The results obtained in the case study show the applicability of the proposed method and the efficacy of the designed procedures.

The remainder of this paper is organized as follows. The next section presents the motivation and background for the proposed collaborative decision support framework and its application to SSOA in the commodity trading industry. Section 3 illustrates the formal framework of the proposed multi-objective SSOA model. Section 4 discusses some axiomatic issues and practical implications of the model. Section 5 presents the case study. Section 6 concludes outlining some future research directions.

2. Motivation and background

This section outlines the main trends in purchasing management, the key features and drawbacks of collaborative decision making and the most used SSOA methods in the contemporary literature.

2.1. Trends in purchasing management

Traditionally, companies focus on short-term transactional purchases primarily based on cost considerations where supplier assessment is used to eliminate the unwanted suppliers rather than developing reliable and acceptable suppliers (Karpak et al., 2001; Lamming, 1996). However, recognizing the need for developing sustainable long-term relations with suppliers and focusing on customer needs, two concepts belonging to supplier relationship management (SRM) and customer relationship management (CRM), have recently become the crucial indicators for successful purchasing activities. In particular, Sheth et al. (2009) argued that the integration between purchasing and marketing should be taken into consideration when choosing suppliers. The use of market intelligence creates superior value for the customers and promotes both superior company performances and sustainable competitive advantages in several sectors (Day, 1994; Gatignon & Xuereb, 1997; Hätönen & Ruokonen, 2010; Li et al., 2010; Narver & Slater, 1990).

The degree of market-oriented activities may vary within different value chains and depend on the managerial decision making activities undertaken by an organization (Grunert, Trondsen, Campos, & Young, 2010). Market orientation predetermines supply chain integration (SCI) strategies (Li, Chau, & Lai, 2010; Zhao, 2011). External SCI focuses on a customer-oriented supplier selection decisions optimizing the trade-off between the total costs of a supplier for the buying firm and the revenues generated by the supplier (Wouters, Anderson, & Wynstra, 2005). Internal SCI includes all the internal activities needed to align purchasing strategies with the development of synchronized processes aiming at