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Possibilistic linear-programming approach for supply chain networking decisions

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ABSTRACT

Supply chain networking decisions are very important for the medium- and long-term planning success of manufacturing companies. The inputs to supply chain planning models are subject to environmental and system uncertainties. In this paper, a fuzzy set theory-based model is proposed to deal with those uncertainties. For this purpose, a possibilistic linear programming (PLP) model is used to make strategic resource-planning decisions using fuzzy demand forecasts and fuzzy yield rates as well as other inputs such as costs and capacities. The objective of the proposed PLP is to maximize the total profit of the enterprise. The model is applied to Mercedes–Benz Türk, one of the largest bus-manufacturing companies in the world, and conclusions and suggestions for further research are provided.

1. Introduction

Supply chain management (SCM) has been considered as the most popular operations strategy for improving organizational competitiveness in the 21st century. One of the most important processes within the SCM concept is supply chain planning (SCP), which is concerned with the coordination and integration of the key business activities undertaken by the enterprises beginning from procurement until the final consumption. When effective SCP creates more value for customers, the result will provide competitive advantage (Gunasekaran et al., 2008; Guillén et al., 2005; Koutsoukis et al., 2000; Lakhal, 2006; Peidro et al., 2009).

According to the time horizon taken into consideration SCP can be classified as strategic, tactical and operational. The strategic planning model, which is the focus of this paper, has a relatively long-term impact: somewhere between 5 and 10 years. Strategic SCP is the long-term part of SCP, where the product programme and supply chain (SC) network are determined (Fandel and Stammen, 2004).

In the view of Shapiro (2004), strategic planning exercises in many companies are traditionally based on qualitative managerial judgements about the future directions of the firm and the markets in which it competes. Despite managerial interest in expanding the scope of strategic analysis, current SC network optimization studies are still limited. In too many companies, purchasing, manufacturing and distribution planning activities are not well integrated. This partitioning of decision-making in the firm is reflected in the goals of strategic SC studies and the optimization models developed to support them. In order to contribute to the expansion of the scope of strategic SCP models, this study proposes a network-based SCP model.

On the other hand, as is also pointed out by Sabri and Beamon (2000), uncertainty is one of the most challenging and important problems in an SC. The SCP problems are due to uncertainties like other real-life problems. The SC is a dynamic network of several business entities that involve a high degree of imprecision. The complex nature and dynamics of the relationships among the different actors in an SC imply an important degree of uncertainty in SCP decisions. The sources of the uncertainties in the SC may be environmental or originated from the system itself. In all circumstances, neglected uncertainties in the models may result in inaccurate solutions. In this context the fuzzy set theory could provide an effective approach to model the uncertainties in SCP (Peidro et al., 2009; Petrovic et al., 1999; Torabi and Hassini, 2008; Roghanian et al., 2007; Wang and Shu, 2005, 2007).

In SCP problems, demand has been the most important and extensively studied source of uncertainty (e.g., Das and Abdel-Malek, 2003; Guillén et al., 2005; Hsu and Wang, 2001; Leung et al., 2006; Liang, 2006; Petrovic, 2001; Wang and Fang, 2001). Given the fact that effectively meeting customer demand is what mainly drives most SCP initiatives, it is appropriate to emphasize incorporating demand uncertainty into planning decisions. Furthermore, because demand fluctuations affect the production system and suppliers over time, demand is the main source of uncertainties.

However, other types of uncertainty are also possible in the system and in the supply. For instance, system uncertainty may result

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from the unreliability of the production process because of machine breakdowns and supply uncertainty can be related to the variability of the suppliers' performance due to late deliveries. Besides, system and supply uncertainties affect each other. In such an uncertain environment, an effort to make crisp decisions may result in irrelevant or irreversible long-term decisions that will require major revisions in the medium or short term. Therefore, fuzzy decisions are recommended for strategic SCP planning in the proposed model. Fig. 1 shows the logic behind the proposed model.

The main idea of the proposed model is to allow uncertain and therefore flexible decisions to cope with the uncertainties revealed in strategic SCP. For this purpose, decisions are made in a fuzzy manner to let the long-term strategies remain in an uncertain framework. By this approach the long-term fuzzy decisions might be defuzzified in the medium and short term with more reliable inputs. Therefore, the fuzzy decisions at the strategic level provide more flexibility for the tactical and operational decision levels (Kabak, 2008).

In this paper, an attempt has been made to develop a framework for an enterprise, considering it as a network of collaborative products and resources in the strategic planning context. The main idea is to allow uncertain decisions to cope with the uncertainties revealed in strategic SCP. In the proposed model, a possibilistic linear programming (PLP) based model is developed to let the long-term strategies remain in an uncertain framework.

In Section 2, the motivation for this study is provided and the need for the current study is highlighted. In Section 3, the proposed model is presented. Section 4 includes the application of the proposed model to Mercedes–Benz Türk Inc. (MBT), one of the largest bus-production plants in the world. Finally, conclusions and areas for further research are presented.

2. Motivation for the study

2.1. Current state of the art

A detailed literature survey has been conducted for the 2004–2008 period to reveal the current state of the art in SCM literature. For this purpose, SC-related papers are classified (Kabak, 2008; Kabak and Ülengin, 2009) according to the type of study, the model type, and the SC environment (see Table 1 for the classification scheme used).

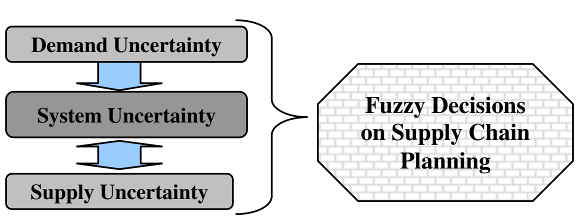

Fig. 1. Logic of the proposed model.

The classification of the articles according to the type of study indicates that theoretical papers (61%) are much greater in number than application-based (17%) and mixed (17%) papers. Theoretical papers do not generally supply hypothetical examples. Applied papers, on the other hand, usually include real-world cases. Real-life application-based papers and papers integrating theory and application are fewer in number than pure theoretical papers.

In terms of the type of modelling, the deterministic single-objective models dominate the others (with 53%). One of the least preferred modelling devices is fuzzy set theory (4.1%). Hybrid (0.7%) and IT-driven (5.5%) models are not frequently used, either.

The results related to the SC structure show that the majority of the papers (69%) deal with 2-stage SCs. The one vendor, one buyer structure is encountered at the highest level (52% of 2-stages). Serial and network SCs are modelled at nearly the same level (15%).

Literature classifications show that applied and mixed (applied and theoretical) papers are less frequent than theoretical ones. Therefore, real case studies in applications should be one of the further research directions in this area. Additionally, the SC problems are mostly solved through single-objective deterministic models. Especially fuzzy logic-based models are not frequently encountered. However, in SCM models there are several uncertainties that should be taken into account. Especially in specific problems that necessitate future projections such as new product SC design or strategic planning, there will be parameters that cannot be estimated deterministically. Fuzzy logic is an important tool to model those types of uncertainties. Thus, another future research area may be the application of fuzzy logic to SC problems. Finally, although an SC is defined as the chain starting from the procurement of the raw material to the customer delivery, most of the papers take only two stages of the SC into consideration. Serial and network SCs are not frequently studied. However, the use of network structures simplifies the representation of SC units and/or functions as well as the interrelationships among them. Consequently, the network structures could be easily transformed to mathematical models. This property is important for the improvement of an SC system as well as for taking the operational and strategic decisions. Therefore, network SC models may be another good research area.

The analyses of the state of the art in SC models highlight the insufficiency in terms of network-based SC models taking into account the uncertainties.

2.2. Network-structured supply chain models

Table 2 gives a summary of network-structured models. Network-structured models are used to model an integrated SC as a whole (e.g., Lakhal, 2006; Lakhal et al., 2001; Roghanian et al., 2007; Ryu et al., 2004; Sabri and Beamon, 2000) or as part of a network such as a product-distribution network (e.g., Altiparmak et al., 2006; Shen, 2006), or else they are specifically related to a particular company problem (e.g., Lakhal et al., 2001; Wang and Shu,

Table 1
Definitions of the classification scheme.

1. Type of study	2. Type of modelling	3. SC environment
1.1. Theoretic	2.1. Deterministic single objective	3.1. Two-stage SC
1.1.1 No example	2.2. Deterministic multiple objective	3.1.1. One vendor, one buyer
1.1.2. Hypothetical examples	2.3. Stochastic	3.1.2. One vendor, multiple buyers
1.2. Applied	2.4. Hybrid (deterministic and stochastic)	3.1.3. Multiple vendors, multiple buyers
1.2.1. Real-world case-data based	2.5. Information technology (IT) driven	3.1.4. Multiple vendors, one buyer
1.2.2. Benchmarking	2.6. Fuzzy set theory	3.2. Serial SC (in stages (more than two); one member at each stage)
1.3. Mixed theoretic and applied		3.3. Network SC (multiple stages (more than two); at least one of the stages has more than one member)
1.4. Literature reviews		