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A multi-objective supplier selection model under stochastic demand conditions

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Abstract

Supplier selection is a typical multi-criteria decision problem attracting great attention recently. Cost, quality, delivery and flexibility are generally involved in the supplier selection decision making. In this paper, a measurement of supplier flexibility is extended to consider demand quantity and timing uncertainties comprehensively. A multi-objective supplier selection model is developed under stochastic demand conditions. Stochastic supplier selection is determined with simultaneous consideration of the total cost, the quality rejection rate, the late delivery rate and the flexibility rate, involving constraints of demand satisfaction and capacity. Using a problem specific genetic algorithm, computational results are presented.

Keywords: Supplier selection; Multi-objective; Stochastic demand conditions; Supplier flexibility measurement

1. Introduction

In the last several decades, the supplier (or vendor) selection problem has gained great attention in business literature and practices. It may be the most important decision made in the purchasing process (e.g. Weber et al., 1991; Nydick and Hill, 1992; Mobolurin, 1995). The supplier selection problem was defined as which supplier(s) should be selected and how much order quantity should be assigned to each supplier selected (Weber and Current, 1993).

Supplier selection is a typical multi-criteria decision problem. Twenty three selection criteria were identified in the vendor selection process (Dickson, 1966). The coverage of these 23 criteria was investigated in the literature published from 1966 to 1990, and it was found that price, delivery and quality were the most discussed factors (Weber et al., 1991). The importance of selection criteria was studied and the ranking was found to be quality, service, price and delivery (Wilson, 1994). The gap between the perception and the actual practice of selection criteria was investigated, in which price, quality, delivery and flexibility were the criteria studied (Verma and Pullman, 1998). The investigation revealed that flexibility attracted considerable attention in recent studies.

While earlier studies on flexibility focused on manufacturing flexibility, recent attention turned to that of supply chain (e.g. Vickery et al., 1999; Das

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and Abdel-Malek, 2003; Lummus et al., 2003; Wadhwa and Rao, 2004; Pujawan, 2004). Pujawan presented a framework for assessing the flexibility of a supply chain including the flexibility of product delivery system, production system, product development and supply system (Pujawan, 2004). It was put forward that the flexibility of the entire supply chain was a result of the flexibility of the supply chain components and their interrelationships (Lummus et al., 2003). Therefore, suppliers are supposed to provide enough flexibility to appropriately adjust their supply processes as demand conditions change, and thus to contribute to the flexibility of supply chains. A key problem is how to measure the flexibility of a supplier. A measurement was developed for supply chain flexibility between a supplier–buyer pair with consideration of demand quantity and timing reduction uncertainties (Das and Abdel-Malek, 2003). In this work, the measurement of supplier flexibility is extended to consider the uncertainty when the demand quantity is randomly raised.

A multi-objective supplier selection model was built under deterministic demand conditions assuming known and fixed demand quantity and timing, optimizing cost, quality and delivery (Weber and Current, 1993). Another extension in this paper is the development of a multi-objective supplier selection model under stochastic demand conditions with constraints of demand satisfaction and capacity, optimizing cost, quality, delivery and in addition flexibility.

The rest of the paper is organized as follows. Stochastic demand conditions and supplier flexibility are illustrated in Section 2. Model development is performed in Section 3. Genetic algorithm application is introduced in Section 4. A numerical example and computational results are reported in Section 5. Conclusions are finally drawn in Section 6.

2. Stochastic demand conditions and supplier flexibility

It was found that demand quantity and timing uncertainties were the two most common changes which occurred in supply chains and were often the causes of buyer–supplier grievance (Das and Abdel-Malek, 2003). Stochastic demand conditions are assumed to be modelled based on the available statistical data as follows:

D represents a stochastic demand quantity satisfying a normal distribution, μ_D, σ_D and $\Phi(D)$ are the mean, the standard deviation and the probability density function of D; T represents a stochastic demand timing satisfying a normal distribution, μ_T, σ_T and $\Phi(T)$ are the mean, the standard deviation and the probability density function of T; D and T are assumed to be independent of each other.

Demand uncertainty raises the issue of supplier flexibility. One central question is how to measure the flexibility of a supplier so as to find flexible solutions. Six supplier flexibility parameters ($Q_i^{\min}, \beta_i$, $Q_i^{\max}, \gamma_i, L_i^{\min}, \alpha_i$) are introduced in Table 1. And the stochastic demand conditions and the flexibility parameters are further illustrated in Fig. 1.

Das and Abdel-Malek (2003) developed a measurement of supply chain flexibility considering demand quantity and timing reduction uncertainties. Their measurement includes the factors $Q_i^{\min}, \beta_i, L_i^{\min}$ and γ_i, which can be regarded as

Table 1
Supplier flexibility parameters

Parameters	Description
$Q_i^{\min}$	Minimum order quantity. When the order quantity is reduced below $Q_i^{\min}$, the buyer has to pay the supplier a penalty, indicated as demand quantity reduction penalty (DQRP).
β_i	Maximum DQRP value. When the order quantity is dropped to $0.6Q_i^{\min}$, $(1-0.6)\beta_i = 0.4\beta_i$ is charged for DQRP.
$Q_i^{\max}$	Maximum order quantity. When the order quantity is raised above $Q_i^{\max}$, the buyer has to pay the supplier a penalty, indicated as demand quantity increase penalty (DQIP). However, the order quantity cannot exceed one's capacity C_i.
γ_i	Maximum DQIP value. When the raised order quantity above $Q_i^{\max}$ is $0.1(C_i - Q_i^{\max})$, $0.1\gamma_i$ is charged for DQIP.
$L_i^{\min}$	Minimum supply lead time. When the demand timing schedule is brought forward ahead of $L_i^{\min}$, the demand timing reduction penalty (DTRP) is incurred.
α_i	A proportional raise in the unit price due to unit time reduction ahead of $L_i^{\min}$, e.g. $L_i^{\min}$ is 3 weeks and T is shortened to 2.5 weeks, thus a price premium of $(3-2.5)\alpha_i p_i = 0.5\alpha_i p_i$ is charged for DTRP.