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Supplier selection using fuzzy quality data and their applications to touch screen

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ABSTRACT

The purchasing function directly affects the competitive ability of a firm. Since the determination of suitable suppliers from a set of suppliers has become a key strategic consideration, managers need to periodically evaluate suppliers on the basis of their products quality to select suppliers whose quality characteristics of products meet the standards. The quantification of the process capability is effective to understand the quality of the units shipped from a supplier. While fuzzy data commonly exist in our real world, the quality-based supplier selection with fuzzy quality data is proposed in this paper. We apply the resolution identity result, a well-known method used in fuzzy sets theory, in terms of solving the nonlinear programming problems with bounded variables to construct the membership function of a fuzzy capability-index estimate for each supplier. The preferred suppliers are selected by using a ranking method of fuzzy preference relations of suppliers. Finally, a case study of touch screens is provided to describe the applicability that incorporates the fuzzy data into the problem of quality-based supplier selection and evaluation.

1. Introduction

It is well recognized that suppliers play a crucial role in the production chain and hence in the long term viability of a company. Close working relationships with high performing suppliers are essential in modern production environments. Just-in-time, total quality management, and flexible manufacturing systems have become part of the standard vocabulary in management theory. Supplier selection decisions are an important component of production and logistics management for many firms. Such decisions entail the selection of individual suppliers to employ, and the determination of order quantities to be placed with the selected suppliers. Selecting right suppliers significantly reduces the material purchasing cost and improves corporate competitiveness, which is why many experts believe that the supplier selection is the most important activity of a purchasing department (2005).

Supplier selection is one of the most critical activities of purchasing management in a supply chain, because of the key role of supplier's performance on cost, quality, delivery and service in achieving the objectives of a supply chain. With increasingly competitive global world markets, companies are under intense pressure to find ways to cut production and material costs to survive and sustain their competitive position in their respective markets. Therefore, an efficient supplier selection process and evaluation of supplier performance are becoming major challenges faced by the manufacturing and purchasing, it needs to be in place and of significant importance for successful supply chain management.

Usually, quality is a critical concern for most manufacturers while purchasing materials. The need of high-quality suppliers has always been an important issue for many manufacturing organizations (1991). With reference to Dickson (1966), quality and delivery are two of the most demanded items by component suppliers. Similarly, Weber, Current, and Benton (1991) considered quality to be of "extreme importance" and delivery to be of "considerable importance". In additions, Weber's research on the Just-In-Time (JIT) model, the importance of quality and delivery remains the same. In another study, Pearson and Ellram (1995) surveyed 210 members of the National Association of purchasing management (NAPM), they were randomly selected from the listings of electronic firms, and they indicated that quality is the most important criterion in the selection and evaluation of suppliers for both the small and large electronic firms that were surveyed. Additionally, there are many researchers studied about the supplier selection topic in the past period. Table 1 summarizes the results from various papers. Obviously, quality can be regarded as a fundamental factor for supplier evaluation among various criteria.

Much evidence suggest that high quality has a positive impact upon significantly increasing profitability, through lowing operating costs and improving market share (Chen & Chen, 2009; Garvin, 1988; Maani, 1989; Phillips, Chang, & Buzzell, 1983; Voehl, Jackson, & Ashton, 1994). Kane (1986) stated that the quantification of the process mean (μ) and variation (σ^2) is essential to understand the quality of the units produced from a manufacturing process. Tagu-

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chi emphasized the loss occurred in a product's worth when its key quality characteristic deviates from the customers' target $\tau = (USL + LSL)/2$, where *USL* and *LSL* stand for the upper and lower specification limits, respectively, and the values of *USL* and *LSL* are determined by decision-makers. In order to take into account these basic parameters that have been widely used to measure the manufacturing processes performance or supplier potentials, Hsiang and Taguchi (1985) introduced C_{pm} index defined as

$$C_{pm} = \frac{USL - LSL}{6\sqrt{\sigma^2 + (\mu - \tau)^2}}, \quad (1)$$

sometimes called the Taguchi index or loss-based capability. Table 1 lists the various values of C_{pm} and its corresponding maximum possible nonconformities in parts per million (PPM). The value of C_{pm} is varied from the lower value of 1.00 to the upper value of 2.00 with increments of 0.05 at each step. For example, if a process has capability with $C_{pm} \geqslant 1.2$, then the production yield would be at least 99.968%. In other words, the number of the nonconformities is less than 318.2 PPM.

C_{pm}	PPM	C_{pm}	PPM	C_{pm}	PPM	C_{pm}	PPM
0.95	4371.923	1.30	96.193	1.55	3.319	1.80	0.067
1.00	2699.796	1.35	51.218	1.60	1.587	1.85	0.029
1.10	966.848	1.40	26.691	1.65	0.742	1.90	0.012
1.20	318.217	1.45	13.614	1.70	0.340	1.95	0.005
1.25	176.835	1.50	6.795	1.75	0.152	2.00	0.002

It is natural to investigate the problem of supplier selection and evaluation for the cases with q ($q \geqslant 2$) candidate suppliers based on the C_{pm} index. Let P_i be the population of supplier i with the mean μ_i and variance σ_i^2 for $i = 1, 2, \ldots, q$. The capability index C_{pmi} of supplier i can be defined as follows:

$$C_{pmi} = \frac{USL - LSL}{6\sqrt{\sigma_i^2 + (\mu_i - \tau_i)^2}} \quad (2)$$

for $i = 1, 2, \ldots, q$.

Table 1
Attributes for supplier selection.

No.	Researcher	Attributes for supplier selection
1	Gregory (1986)	Quality, production plan and control system, amount of past business, purchasing item, price
2	Wagner, Ettenson, and Parrish (1989)	Quality is the most important, the second one is delivery, the last one is cost
3	Pacheco (1989)	Customer service, product quality, service, delivery, the quality of clerk
4	Houshyar and David (1992)	Price, quality, delivery, transportation cost
5	Chaudhry, Forst, and Zydiak (1993)	Quality, delivery, price, capacity
6	Lau and Lau (1994)	Quality, lead time, price
7	Anderson (1994)	Financial status, product quality, geographical location, inventory, facility layout, administration management, technical capability, delivery
8	Wilson (1994)	Quality, service, delivery, price
9	Benion and Redmond (1994)	Product characteristic is more important then service, supporting, and quality
10	Pearson and Ellram (1995)	Quality and cost are the most important. Then goes for supplier design and technical capability
11	Swift (1995)	To emphasis on price, product quality. Under single source circumstance, it is needed to evaluate technical supporting from supplier and the reliability of product
12	Patton (1996)	Price, quality, delivery, service, equipment & technical, company's financial status
13	Lambert, Ronald, and Margaret (1997)	The most important attributes are including quality, delivery, and service

Conceptually, in evaluating a group of suppliers, the assessment requires knowledge of μ_i and σ_i of each supplier in Eq. (2). However, μ_i and σ_i usually unknown for $i = 1, 2, \ldots, q$. In this case, the sample data must be collected from each supplier which is in order to estimate the value of index C_{pmi} and to assess/select the appropriate suppliers. Let $x_{i1}, x_{i2}, \ldots, x_{ini}$ be the independent random samples from P_i for $i = 1, 2, \ldots, q$. Generally, continuous data obtained from the output responses of supplier's key quality characteristics are always assumed to be real numbers as in the studies by Prasad and Calis (1999), Shiau, Chiang, and Hung (1999), Zimmer, Hubele, and Zimmer (2001), Pearn and Shu (2003), Xekalaki and Perakis (2004) and Hsu and Shu (2008). In this assumption, the statistical point estimate $\hat{c}_{pmi}$ of C_{pmi} is given as

$$\hat{c}_{pmi} = \frac{USL - LSL}{6\sqrt{s_i^2 + (\bar{x}_i - \tau)^2}}, \quad (3)$$

where the process mean μ_i in Eq. (2) is switched by the sample mean $\bar{x}_i$ that is given by

$$\bar{x}_i = \frac{1}{n_i}\sum_{j=1}^{ni} x_{ij}$$

and the process standard deviation σ_i in Eq. (2) is replaced by the sample standard deviation s_i that is given by

$$s_i = \left[\frac{1}{n_i}\sum_{j=1}^{ni}(x_{ij} - \bar{x}_i)^2\right]^{1/2}$$

for $i = 1, 2, \ldots, q$.

In a practical situation, the output continuous quantities collected from key quality characteristics of suppliers' products always appear to be somewhat imprecise manner. For example, the data may be given by color intensity pictures or by the readings on an analogue measurement equipment, as in the studies of Filzmoser and Vertl (2004) and Viertl and Hareter (2004). In addition, the imprecise data may come from the insufficient sample data such as the observations made with coarse scales, linguistic data, or data collected with vague and incomplete knowledge, as described by Sugano (2006), Gulbay and Kahraman (2007), Zhang and Chu (2009), and Lee (2009). In the other study, Hong (2004) and Lee (2001) proposed an estimation of single yield-based index by considering fuzzy numbers when the measurement refers to the decision-making's subjective determination. Since supplier selection problems is usually involved with preferences which are often vague and imprecise. In this paper, we propose a method for the selection and evaluation of supplier using fuzzy data.

The paper is organized as follows. In Section 2, we introduce the basic properties of fuzzy numbers. In Section 3, the fuzzy estimate of C_{pmi} for each supplier is expressed by using fuzzy data. To obtain the membership function of fuzzy estimate of each supplier, the resolution identity theorem is applied and the membership degree can be obtained by solving optimization problems. In Section 4, we provide a ranking method proposed by Yuan (1991) to sort the fuzzy estimates of C_{pmi}, which makes decision-makers being capable of selecting the preferable suppliers. In Section 5, we demonstrate the application of the proposed methodology to supplier selection and evaluation using fuzzy data. In Section 6, the conclusions are presented.

2. Fuzzy numbers

The key idea of fuzzy set theory is that an element has a degree of membership in a fuzzy set. It is defined by a membership function, all the information about a fuzzy set is described by its