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A compensatory fuzzy approach to multi-objective linear supplier selection problem with multiple-item

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ABSTRACT

Supplier selection problem is a multi-criteria decision making problem which includes both qualitative and quantitative factors. In the selection process many criteria may conflict with each other, therefore decision-making process becomes complicated. In this paper, we propose a compensatory fuzzy approach to solve multi-objective linear supplier selection problem with multiple-item (MLSSP-MI) by using Werners' "fuzzy and" (μ_{and}) operator. The compromise solutions obtained by using "fuzzy and" (μ_{and}) operator are both compensatory and strongly efficient for our MLSSP-MI. To our knowledge, combining compensatory (μ_{and}) operator with MLSSP-MI has not been published up to now. Our compensatory fuzzy approach was explained on a case study.

1. Introduction

In the context of supply chain management, the supplier selection decision plays a key role. In today's globally competitive environment; firms give great attention for selecting right suppliers because it helps reduce purchasing costs, improve quality of final products and services, etc.

Supplier selection problem is a multi-criteria decision making problem which includes both qualitative and quantitative factors like unit cost, delivery on-time, service quality, etc. In this problem many criteria may conflict with each other, so the selection process becomes complicated and it contains two major problems: (i) which supplier(s) should be chosen? and (ii) how much should be purchased from each selected supplier? These problems encountered in purchasing departments of firms and solving them are very significant.

In the last several years, supplier (or vendor) selection problem has gained great importance and is handled by academic researchers and also practitioners in business environment. The literature on this problem exist some researches (i) focused on supplier selection problem criteria, and (ii) proposed methods for supplier selection process.

Many researchers identified several criteria for selection process for example Dickson (1966) identified 23 criteria and Dempsey (1978) described 18 criteria. Weber, Current, and Benton (1991) reviewed, annotated and classified 74 related articles which have appeared since 1966 and specific attention is given to the criteria and analytical methods.

Weber and Current (1993) presented a multi-objective approach to systematically analyze the inherent tradeoffs involved in multi-criteria supplier selection problems. Barbarosoglu and Yazgac (1997) applied the Analytic Hierarchy Process (AHP) to the supplier selection problem. Ghodsypour and O'Brien (1998) proposed an integration of AHP and linear programming (LP). Karpak, Kumcu, and Kasuganti (1999) used a visual interactive goal programming for supplier selection problem. Ghodsypour and O'Brien (2001) developed a mixed-integer non-linear programming approach to solve the multiple sourcing problem. Erol and ve Ferrell (2003) presented a methodology to assist decision makers in selecting from a finite numbers of alternatives for the problems with multiple conflicting objectives and both qualitative and quantitative criteria. Kumar, Vrat, and Shankar (2006) proposed a fuzzy programming model for vendor selection problem in a supply chain as a "fuzzy multi-objective integer programming vendor selection problem" formulation. Amid, Ghodsypour, and O'Brien (2006) developed a fuzzy multi-objective linear model to overcome the vagueness of the information for supplier selection in a supply chain. Demirtas and Üstün (2008) proposed an integrated approach of Analytic Network Process (ANP) and multi-objective mixed integer linear programming for choosing the best suppliers. Wang, Cheng, and Huang (2009) proposed a fuzzy hierarchical TOPSIS method for supplier selection which simplifies Chen and Cheng (2005)'s metric distance method and proposes an algorithm to modify Chen (2000)'s fuzzy TOPSIS.

In this paper, we propose a compensatory fuzzy approach to solve MLSSP-MI by using Werners' "fuzzy and" (μ_{and}) operator. The compromise solutions set obtained by using "fuzzy and" (μ_{and}) operator is both compensatory and strongly efficient (Pareto-optimal) for our MLSSP-MI.

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The paper is organized as follows: Section 2 summarizes the compensatory fuzzy aggregation operators, Section 3 presents the multiple-objective linear supplier selection model, Section 4 explains our methodology using Werners' compensatory "fuzzy and" operator to multi-objective linear supplier selection with multiple-item. Furthermore, giving a theorem and proof, we show that the solutions generated by Werners' compensatory "fuzzy and" operator do guarantee Pareto-optimality for our problem. Section 5 gives an illustrative numerical example in order to demonstrate the feasibility and efficiency of the proposed method using "fuzzy and" operator. Finally Section 6 draws some general conclusions.

2. Compensatory fuzzy aggregation operators

There are several fuzzy aggregation operators. The detailed information about them exists in Zimmermann (1993) and Tiryaki (2006). The most important aspect in the fuzzy approach is the compensatory or non-compensatory nature of the aggregate operator. Several investigators (Lai & Hwang, 1996; Luhandjula, 1982; Shih & Lee, 2000; Zimmermann, 1993) have discussed this aspect.

Using the linear membership function, Zimmermann proposed the "min" operator model to the multi-objective linear problem (MOLP) (Zimmermann, 1978). It is usually used due to its easy computation. Although the "min" operator method has been proven to have several nice properties (Luhandjula, 1982), the solution generated by min operator does not guarantee compensatory and Pareto-optimal (Guu & Wu, 1997; Lee & Li, 1993; Wu & Guu, 2001). The biggest disadvantage of the aggregation operator "min" is that it is non-compensatory. In other words, the results obtained by the "min" operator represent the worst situation and cannot be compensated by other members which may be very good. On the other hand, the decision modeled with average operator is called fully compensatory in the sense that it maximizes the arithmetic mean value of all membership functions.

As a result of experiment made by Zimmermann and Zysno (1980), most of the decisions taken in the real world are neither non-compensatory (min operator) nor fully compensatory. So, these operators do not seem to be very suitable for modeling the real world problems in many situations. To overcome this difficulty Zimmermann and Zysno (1980) have suggested a class of hybrid operators called compensatory operator with the help of a suitable parameter of compensation γ.

In this paper, we will use Werners' compensatory "fuzzy and" operator and show that the solutions generated by this operator do guarantee Pareto-optimality for our MLSSP-MI problem. Let us introduce *Werners' compensatory "fuzzy and" operator:*

Based on the γ-operator, Werners (1988) introduced the compensatory "fuzzy and" operator which is the convex combinations of min and arithmetical mean:

$$\mu_{and} = \gamma \min_i(\mu_i) + \frac{(1-\gamma)}{m}\left(\sum_i \mu_i\right),$$

where $0 \leqslant \mu_i \leqslant 1,\ i = 1, \ldots, m$, and the magnitude of $\gamma \in [0, 1]$ represent the grade of compensation.

Although this operator is not inductive and associative, this is commutative, idempotent, strictly monotonic increasing in each component, continuous and compensatory. Obviously, when $\gamma = 1$, this equation reduces to $\mu_{and} = \min$ (non-compensatory).

3. The multi-objective linear supplier selection model with multiple-item

A general multi-objective linear supplier selection model can be stated as follows (Amid, Ghodsypour, & O'Brien, 2006):

$$\min\ Z_1, Z_2, \ldots, Z_k, \tag{1}$$
$$\max\ Z_{k+1}, Z_{k+2}, \ldots, Z_J, \tag{2}$$
s.t.
$$x \in X_d,\ X_d = \{x | g(x) \leqslant b_k,\ k = 1, \ldots, K\}, \tag{3}$$

where $Z_1, Z_2, \ldots, Z_k$ are the negative (minimization) objectives like cost, quantity of rejected items, etc., and $Z_{k+1}, Z_{k+2}, \ldots, Z_J$ are the positive (maximization) objectives such as quality, on time delivery, after sale service, and so on. X_d is the set of feasible solutions which satisfy the constraint such as buyer demand, supplier capacity, etc.

3.1. Model development for MLSSP-MI

Following set of assumptions, index set, decision variable and model parameters are considered to develop the multi-objective linear supplier selection model with multiple-item.

Assumptions:
1. Quantity discounts are not taken into consideration.
2. No shortages of the items are allowed for any of suppliers.
3. Multi-item can be purchased from each supplier.

Index:

i	Index for suppliers, $i = 1, 2, \ldots, n$
s	Index for items, $s = 1, 2, \ldots, S$
j	Index for objectives, $j = 1, 2, \ldots, J$
k	Index for constraints, $k = 1, 2, \ldots, K$

Decision variable:

$x_{i,s}$	Order quantity of item s from supplier i

Model parameters:

D_s	Demanded quantity of item s
$C_{i,s}$	Upper limit of the quantity of item s obtained by supplier i
n	Number of suppliers competing for selection
$p_{i,s}$	Unit price of item s obtained by supplier i
$k_{i,s}$ (%)	Percentage of service quality level of item s from supplier i
$r_{i,s}$ (%)	Percentage of quality level of item s from supplier i
$f_{i,s}$ (%)	Percentage of rejected quantity of item s from supplier i
F_s	Upper limit of rejected quantity for item s
B_s	Budget constraint allocated to item s

Objective functions:
1. *Total purchased cost minimization:* The buyer expects to minimize the total purchase cost, so the objective function can be stated as:

$$\text{Minimize } Z_1 = \sum_{i=1}^{n}\sum_{s=1}^{S} p_{i,s}x_{i,s}. \tag{4}$$

2. *Service quality maximization:* Suppliers' service quality rating is a very important indicator for supplier selection problem. This rating value contains after sale service, items delivery on time, etc. The objective function maximizes the total service quality and can be stated as:

$$\text{Maximize } Z_2 = \sum_{i=1}^{n}\sum_{s=1}^{S} k_{i,s}x_{i,s}. \tag{5}$$

3. *Item quality maximization:* The buyer expects to maximize total quality of items so the objective function can be stated as:

$$\text{Maximize } Z_3 = \sum_{i=1}^{n}\sum_{s=1}^{S} r_{i,s}x_{i,s}. \tag{6}$$

Constraints:

$$\sum_{i=1}^{n} x_{i,s} \geqslant D_s, \quad s = 1, 2, \ldots, S, \tag{7}$$