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Fuzzy multi-objective programming for supplier selection and risk modeling: A possibility approach

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ABSTRACT

Selection of supply chain partners is an important decision involving multiple criteria and risk factors. This paper proposes a fuzzy multi-objective programming model to decide on supplier selection taking risk factors into consideration. We model a supply chain consisting of three levels and use simulated historical quantitative and qualitative data. We propose a possibility approach to solve the fuzzy multi-objective programming model. Possibility multi-objective programming models are obtained by applying possibility measures of fuzzy events into fuzzy multi-objective programming models. Results indicate when qualitative criteria are considered in supplier selection, the probability of a certain supplier being selected is affected.

1. Introduction

Supply relationship management in supply chains seeks the participation of good suppliers providing low cost and high quality. A recent trend in 21st Century business is outsourcing product manufacturing. With an increase in outsourcing, offshore-sourcing, and electronic business, supply management decisions are becoming ever more complex in a global market. Supply management strategies such as offshore-sourcing can emphasize manufacturers at low cost locations such as China, India, or Vietnam, assemblers at high-tech operations in Taiwan and Korea, and distributors where customers reside all over the globe. There are increased risks expected from differences in product quality, as well as differences in the probabilities of late delivery. Many other factors have been considered as well [1,2]. One risk-reducing strategy is to rely upon long-term commitments. Swink and Zsidisin [3] found trade-offs in that firms pursuing longer commitments were subject to risks that might offset short-range benefits.

Supplier selection by its nature involves the need to trade-off multiple criteria, as well as the presence of both quantitative and qualitative data. Twenty three distinct criteria are identified in various supplier selection problems in [4,5]. A recent survey study of 12 papers indicates that cost, quality and time response are traditional key criteria that consistently appear for vendor selection [6].

The supplier selection decision in a supply chain does not depend solely on cost or quality measures, but also on various risk and socio-economic factors, usually incorporated as constraints or filters. Many supply chain risks have been identified. Ojala and Hallikas [7] and Li [8] analyzed supplier investment risks, and how each could be managed. Olson and Wu [6] classified a broader set of supply chain risks as internal and external, as well as by the level of controllability. However, crisp or statistically valid data for long-term decision-making and for supplier evaluation in a global market is often difficult to obtain. Various risks can be the major factors that influence the supplier selection. In supplier selection application under risk and uncertainty, these data are non-precise. For example, unit cost is usually assumed to be crisp. However, since there is vagueness in estimating unit cost, the unit cost might be introduced as a fuzzy number. It is also apparent the fuzzy determination of the quality provided by the supplier is reasonable since the quality concept can be very vague. Some studies

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[9,10] have recognized this vagueness and uncertainty through methods accommodating fuzzy data. But these methods fail to consider uncertainty and risk factors in an integrated model.

Various optimization models have been presented to select supply chain partners, taking into consideration of uncertainty and risk. Most of these studies propose to derive the probability distribution from historical data and model supply chain uncertainty (e.g., uncertain demand) using the derived probability distributions in a decision model [11–16]. For example, Talluri et al. [17,36] used data envelopment analysis (DEA) and applied stochastic DEA models to vendor selection problems. However, these decision models may result in sub-optimal solutions since they typically consider one objective function, e.g., the minimization of expected cost or maximization of expected profit. Multiple criteria are quite often present in decisions involving selection of supply chain partners and sourcing arrangements [18]. Thus, multi-objective programming models [19,20] have been presented. Kull and Talluri [35] combined analytic hierarchy process and goal programming for supplier selection in the presence of risk measures and product life cycle considerations. But these models seldom simultaneously consider multiple objective and uncertainty and risk. Simulation-based optimization may provide an alternative approach for dealing with the SC risk and uncertainty [6] if rich data sets are available.

This paper develops a fuzzy multi-objective programming (FMOP) vendor selection model for supply chain outsourcing risk management. We consider both quantitative and qualitative supplier selection risk factors. Quantitative risk factors include cost, quality and logistics, each characterized with historical data although not necessarily with some probability distribution. Vague input data can be specified for these quantitative risk factors using historical data based on historical data quantile described in existing work such as [34,38]. Qualitative risk factors include economic environmental factors and vendor ratings using fuzzy data. We yield possibility multi-objective programming models by applying possibility measures of fuzzy events into fuzzy multi-objective programming models. The proposed approach allows decision makers to perform trade-off analysis among costs, quality acceptance levels, on-time delivery, and risk factors. This also provides alternative tools to evaluate and improve supplier selection decisions in an uncertain global market.

The rest of the paper is organized as follows. Section 2 of the paper presents fuzzy multi-objective programming models. Section 3 discusses our solution approach. Section 4 presents results and analysis, and Section 5 concludes the paper.

2. Fuzzy multi-objective programming models

We have the following notations and definitions in the multi-objective programming.

n_i the number of candidate suppliers desired by the ith customer
x_{ij} decision variables, quantity purchased by the ith customer from supplier j
z_{ij} binary variable, equal to unity if supplier j is selected by customer i; or 0
c_{ij} per unit purchase cost from supplier j by the ith customer
λ_{ij} percentage of items late from supplier j to the ith customer
β_{ij} percentage of rejected units from supplier j
D_i demand for item over planning period from the ith customer
u_{ij}^u maximum amount of business for item to be given to supplier j by the ith customer
u_{ij}^l minimum amount of business given to supplier j by the ith customer
w_{ij}^u maximum order quantity from supplier j by the ith customer
w_{ij}^l minimum order quantity from supplier j by the ith customer
Objective 1 minimize the total purchase cost
Objective 2 minimize the number of or rejected items
Objective 3 minimize the number of late deliveries
Objectives 4 and 5 minimize risk factors of economic environment and vendor service rating
Constraint 1 ensures that the quantity demand is met
Constraint 2 ensures that the vendor's capacity is not exceeded
Constraint 3 ensures that the customer's proposed business to the vendor is not exceeded
Constraint 4 establishes minimum order quantities the vendors supply
Constraint 5 establishes minimum business for selected vendors
Constraint 6 ensures that there are no negative orders
Constraint 7 establishes binary nature of vendor selection decision

First we present a multi-objective programming supplier selection model LMOP (1). This model differs from prior models, e.g., Weber and Ellram [19], Weber and Current [20], and Ghodsypour and O'Brien [21] due to the consideration of various demand risks from many different customers.

LMOP (1)

$$\min \quad f_1(x_{ij}) = \sum_{i=1}^{m}\sum_{j=1}^{n_i} c_{ij}x_{ij} \quad \{\text{total cost}\} \tag{1.1}$$

$$\min \quad f_2(x_{ij}) = \sum_{i=1}^{m}\sum_{j=1}^{n_i} \lambda_{ij}x_{ij} \quad \{\#\text{late}\} \tag{1.2}$$

$$\min \quad f_3(x_{ij}) = \sum_{i=1}^{m}\sum_{j=1}^{n_i} \beta_{ij}x_{ij}\{\#\ \text{rejected}\} \tag{1.3}$$

$$\text{s.t.} \quad \sum_{j=1}^{n} x_{ij} \geqslant D_i, \quad i = 1,\ldots,n_i, \tag{1.4}$$