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Integrated analytical hierarch process and mathematical programming to supplier selection problem with quantity discount

Ali Kokangul [a,*], Zeynep Susuz [b]

[a] *Department of Industrial Engineering, Cukurova University, 01330 Adana, Turkey*
[b] *Alize Design and Graphics, Adana, Turkey*

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Abstract

In this article an integration of analytical hierarchy process and non-linear integer and multi-objective programming under some constraints such as quantity discounts, capacity, and budget is applied to determine the best suppliers and to place the optimal order quantities among them. This integration-based multi-criteria decision making methodology takes into account both qualitative and quantitative factors in supplier selection. While the analytical hierarchy process matches item characteristics with supplier characteristics, non-linear integer programming model analytically determines the best suppliers and the optimal order quantities among the determined suppliers. The objectives of the mathematical models constructed are maximizing the total value of purchase (TVP), minimizing the total cost of purchase (TCP) or maximizing TVP and minimizing TCP simultaneously. In addition, several "what if" scenarios are facilitated and the quality of the resulting models is evaluated on real-life data.

Keywords: Supplier selection; Discounted cost; AHP; Non-linear integer programming

1. Introduction

The selection of suppliers plays a key role in an organization because the cost of raw material constitutes the main cost of the final product. A typical manufacturer spends 60% of its total sales on purchased items such as raw materials, parts, subassemblies and components [1]. In automotive industries, these costs may be more than 50% of the total revenues. That can go up to 80% of the total product costs for high technology firms [2]. Many experts believe that the supplier selection is the most important activity of a purchasing department [3]. Therefore, the supplier link in the supply chain appears to have significant cost-cutting opportunities. Determining selection criteria and selection techniques are the most important sides of supplier selection.

* Corresponding author.
E-mail address: kokangul@cu.edu.tr (A. Kokangul).

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1.1. Selection criteria

Supplier selection is complicated by the need to consider various criteria. It can be seen that the supplier selection process should not only consider price, but also a wide range of factors such as quality, and capacity. Dickson [4] examined the importance of supplier evaluation criteria and presented 23 supplier attributes that managers consider in such an evaluation. Quality, cost, and delivery performance history are identified as the three most important criteria in supplier selection. In their survey Weber et al. [2] classified all published papers (since 1966) according to the studied criteria and they identified quality, cost and on-time delivery as the most important supplier selection criteria in the evaluation of supplier performance. Production facilities and capacity, technical capability and geographical location were also identified as important criteria. Chrysler, the car manufacturer, evaluates suppliers based on four factors: quality, cost management, delivery and technology. Moreover, Chrysler weights each of these factors, with quality being weighted as 40% and the remaining three factors as 20% each [5]. Thomas and Janet [6] surveyed purchasing managers of US automotive companies and concluded that quality and delivery remained the most important criteria across all levels. Choi and Hartley [7] presented 26 supplier selection attributes from a survey of US automotive companies.

Most of the articles referenced above suggest that managers perceive quality, cost, and delivery performance to be the most important supplier selection criteria.

1.2. Techniques in supplier selection

There are various mathematical techniques for selecting suppliers, such as linear and non-linear programming.

Weber et al. [2,8,9] discussed linear weighting models, mathematical programming models and statistical models as quantitative approaches to supplier selection. Lamberson et al. [10] and Monzcka and Trecha [11] proposed linear weighting techniques for assessing supplier performance. These methods frequently considered many supplier performance attributes simultaneously, and weighted those attributes based on the opinions of purchasing managers or staff.

Kaslingam and Lee [12] developed an integer programming model to select suppliers with minimum total supplying costs including purchasing and transportation costs. Weber et al. [9] suggested models to negotiate with suppliers selected by the multi-objective programming model under non-cooperative negotiation strategy. Talluri and Baker [13] developed and applied a multi-phase mathematical programming approach for effective supply chain design. Ghodsypour and O'Brien [14] developed a mixed integer non-linear programming model to solve the multiple sourcing problems, which takes into account the total cost of logistics, including net price, storage, transportation, and ordering costs. Hajidimitriou and Georgiou [15] employed the goal programming (GP) technique for the supply chain partner selection problem that is able to achieve multiple goals for different performances of the corresponding attributes.

Chaudry et al. [16] presented linear and mixed binary integer programming models on supplier selection with price breaks which depend on the sizes of the order quantities. Sadrian and Yoon [17,18] proposed a mixed-integer programming model to optimize the total cost of purchases in the presence of price discount constraints. Xu et al. [19] introduced a dynamic lot sizing model with volume discounts and used mixed integer programming and heuristic procedure. Crama et al., [20] described purchasing decisions faced by a chemical company and formulated cost minimization problem as a non-linear mixed 0-1 programming problem in the presence of total quantity discounts. In these techniques, the cost is considered as a single objective function and other criteria such as quality and demand are taken into account as equally-weighted constraints. In doing this, the qualitative factors which are very important for the supplier selection problem can not be considered. Equally-weighted constraints rarely happen in practice. To assign different weights to various criteria, it is possible to use multiple-objective mathematical programming techniques such as linear goal programming [14,21–23] but these techniques also have problems in involving qualitative factors.

Ghodsypour and O'Brien [24] developed an integrated AHP and linear programming (LP) model to help managers consider both qualitative and quantitative factors in the purchasing activity in a systematic approach. Yahya and Kingsman [25] use Saaty's analytic hierarchy process (AHP) method to determine priority in selecting suppliers. Sarkis and Talluri [26] developed a decision framework on selecting electronic