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A Mathematical Model-Based Supplier Selection

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Abstract—*Supplier selection is an important part of supply chain management (SCM).Processes such as supplier selection, evaluation and development have a critical role, and has important impact on purchasing in supply chain management. Supplier selection is currently a subject of great importance to companies. Supplier is an important element of SCM(supply chain management)in order to different costs, therefore evaluation and selection of the potential suppliers has become an important component of SCM. Therefore the development of effective supplier selection model is desirable. Numerous articles have been published, recommending different methods for evaluation and selection of suppliers. In the present paper the literature has been thoroughly reviewed and critically analyzed to address the issue. This paper seeks to present a nonlinear multi-objective programming approach of selecting suppliers and allocating the optimal order quantity among them, taking into account transportation.*

Keywords: *Supply chain management (SCM), Supplier selection, Transportation.*

1. INTRODUCTION

A supply chain management system consists three key parts such as the supply focuses on obtaining raw materials to manufacturing, the manufacturing focuses on converting raw materials into finished products and the distribution focuses on reaching these finished products to different customers through different distributors. The entire chain connects customers, manufactures and supplier with the creation of raw materials or component parts by suppliers, and ending with consumption of the product by customers. Selection of suppliers plays a critical role in an organisation because it contributes to the overall performance of a supply chain system. Supplier selection is a strategic process as it can be mitigate upstream supply chain risk partially, if not completely. Better supplier- buyer relationship can be enhancing supply chain visibility and capability to cope with high demand volatility. To choose the right supplier deals, with an important evaluation, and selection problems in the purchasing function of a business. A good selection of supplier makes a significant difference to an organization future to reduce wastage, operational costs and improve the quality of its end products. Quality, flexibility and quick response have become important for the manufactures in regard to customer satisfaction in today's competitive environment. In order to keep the promises to customer; it is required to realize lean production, with necessary qualification and without any cease. It became a necessity to work with supplies to provide quality and just in time delivery by supplying raw materials, part and products. In supply chain suppliers selection process determine on help to choose suitable suppliers which can provide the good quality products at the right price, at the right time and in the right quantities to the buyers. It begins with realisation of the need for new suppliers; formulation and determination of decision criteria; pre-qualification such as drawing up and initial screening a selection of potential suppliers from a long list; final supplier selection; and the monitoring of the suppliers selected. Supplier selection is a multi-objective problem involving both intangible and tangible factor, some of which may conflict like low price versus high quality (Ozden and Ezgi, 2008). Several methods, data envelopment analysis (DEA), notably statistical models, artificial intelligence, analytic hierarchy process (AHP), and mathematical programming, tend to treat each of the selection criteria and alternative suppliers as an independent entity. In particular, AHP method has been extensively used to solve multi-criteria decision making (MCDM) problems (Chan et al., 2008). Yet the method is marked with a major limitation which is its assumption of independency among various criteria.

2. LITERATURE REVIEW

Vendor evaluation is a common problem for obtaining the necessary materials to support the outputs of organizations. The problem is to find out most suitable vendors for the organisation and to evaluate periodically based on various vendors capabilities. This usually happens when the price value is high, purchase is complex, and perhaps critical (Dobler and Burt, 1996). The process for vendor evaluation is actually a problem-solving process, which covers the formulation of criteria, works of problem definition, qualification, and choice (Ganeshan et al., 1999). Supplier selection processis divided principally into two phases:

(I) Pre-selection phase and

(II) Selection phase.

Further, they have divided the pre-selection phase into three phases:

(a) Problem definition,

(b) Formulation of criteria and

(c) Qualification.

Among other things, they have suggested the functionality of a number of methods for the qualification sub-phase (De Boer et al., 2001).23 supplier criteria were identified in various vendor selection problems, which managers trade off when selecting a supplier(Dickson, 1966). Two main groups were defined as supplier characteristics based on location and size and bid characteristics based on location and size in identifying supplier selection criteria (Hakansson and Wootz, 1975). Some factors which were mostly used in supplier evaluation methods included proposed quality, supplier certification, facilities, continuous improvement, physical distribution, and channel relationship (Weber et al., 1991). Min (1994) considered several critical parameters in the supplier selection process such as financial stability, perceived risks, quality assurance, buyer-supplier partnerships, service performance, trade restrictions, and cultural and communication barrier. Selecting the best suppliers significantly reduces the purchasing cost, wastage of materials and improves corporate competitiveness in global market (Choy et al., 2004). There are four traditional methods for evaluating the performance of suppliers such as categorical, weighted point, cost-ratio, and dimensional analysis.

While using categorical method, firstly the list of attributes which are used for evaluation process is established, then the suppliers evaluation on each attribute is defined in categorical terms such as “good”, “fair”, and “poor”. Those suppliers who receive the most number of “good” ratings are considered the best suppliers(Willis and Huston, 1990). The linear weighted average method gives a relative importance weight to each important factor and rates the performance of suppliers with respect to each criterion. The supplier performance ratings are important factors to calculate a weighted score. The summed weighted scores are used to find one aggregate weighted score for each supplier. The supplier with the highest weighted score is the best (Timmerman, 1986).In cost-ratio method, the total cost related to quality, delivery and service is calculated, and is expressed as a proportion of the total firm’s purchase price. The supplier who can provide the lowest cost is the best. This method is more precise compare to the other aforementioned methods. However, it requires a comprehensive cost-accounting system to identify the precise cost data (Thompson, 1990).The vendor profile analysis is a modified weighted average method, and is used to reduce the uncertainty involved in the assignment of the ratings. A Monte Carlo simulation technique is used to replace the rating, based solely on intuitive judgment. The use of Monte Carlo simulation has two advantages over the weighted average technique. It simplifies the decision maker’s input to the evaluation process and provides output that has considerably more information for the decision maker. Dimensional analysis model has distinct advantages over the three traditional models for evaluating suppliers. The main advantage of the model is that it is not mandatory to express the performance measures in the same units. It integrates multiple criteria or attributes into a single dimensionless entity for each supplier. The buyer then selects the supplier considering the beneficial of the judged item from a cost standpoint and service.

3. MODEL FORMULATION

In this model by integration of the distances between the manufacturer and the different suppliers and our objective in the model is to minimize the total cost and lead-time criteria under suppliers, buyer and transportation constraints. Total cost includes transportation, ordering, potential losses cost, scrap value cost and inventory costs. Total purchasing cost of raw material is not considered here because we assume that the raw material, which is purchased over a given horizon of time, has the same price for each unit from all the suppliers. Let us note that cost and lead-time criteria are chosen here because they are much related to the transport policies. The model simultaneously finds the optimum number of suppliers in order to allocate the optimal order quantities to them, taking into account the transportation. This paper is design as follows.

In this model, we present our model in the mathematical form which we give a solution methodology of our MOM (multi-objective model). With the help of using MATLAB, the result of computational experiments made software specialized in optimization to solve the model.

In a multiple sourcing network, a buyer must select a choice among number of suppliers and decide on the order quantities to split among them. The model proposed considers the criteria such as total product cost and lead time which take into account transportation. The objectives to minimize concurrently are these two criteria. Total cost includes ordering cost, transportation cost and storage cost, and lead-time required by each supplier and lead-time for the buyer. We assume that the demand of the buyer is known i.e. constant and that the capacity of transportation is unlimited. Following are the symbols used for various variables:

η = number of suppliers

D = unit time demand of buyer

Q = ordered quantity to all suppliers in each period

Q_i =ordered quantity to ith supplier in each period

A_i = ordering cost per order, of ith supplier

P_i= purchase price of ith supplier

C_i= production capacity of ith supplier

L_i= lead-time required by ith supplier

T_i= average transit time from ith supplier to buyer

L = lead-time imposed by the buyer

R_o=holding rate of the buyer

R_i= holding rate of *i*th supplier

R_{ti}= in-transit holding rate of *i*th supplier

d_i= distance from *i*th supplier to buyer

C_{fi}= fixed shipping cost of *i*th supplier, and

C_{vi}= variable shipping cost of *i*th supplier.

Decision variables include the following:

X_i = fraction of Q allocated to *i*th supplier

$$Y_i = \begin{cases} 1 \text{ if } X_i \emptyset 0 \; i \text{ th supplier is selected} \\ 0 \qquad if\ X_i = 0 \end{cases}$$

In addition, *D*/*Q* is the number of periods during the time considered.

The total cost (C_{total}) can be written as:

$$C_{total}=\sum_{i=1}^{n}\left[\left(\frac{D}{Q}\right)\left(d_iC_{fi}Y_i + QX_iC_{vi}\right) + \left(\frac{D}{Q}\right)A_iY_i + DX_IP_i(R_{ti}T_i + \frac{(R_i+R_o)X_iQ}{2D})\right]$$

The first term in the above expression is the total transportation costC_{total}. The fixed shipping cost C_f is independent of aload and includes cost of stop and cost per unit distance. The variable shipping cost $C_v$is a cost per load and it is independent of the distance covered. The second term represents the total ordering cost. In a transportation network, inventory includes items waiting to be shipped from each supplier, items in transit to buyer and items waiting to be used by buyer. It is supposed that the rate of production of each supplier items is constant and the production planning is synchronized with the transport. The average time required to produce $Q_i$shipment size by *i*thsupplier is Q_i/D. Each item in the load waits on average half of this time before being shipped $Q_i/2D$. After arriving, before used each item waits on average is($Q_i/2D$) and the average time spent by an*i*th supplier to buyer to transport an item is $Q_i/D + T_i$. As*Q*is the optimum order quantity, it can be calculated by using the derivative ofC_{total} as:

$$\frac{dC_{total}}{dQ} = 0 \Rightarrow Q = \sqrt{2D\frac{\sum_{i=1}^{n}\left(A_i + d_iC_{fi}\right)Y_i}{\sum_{i=1}^{n}P_iXi^2\,(R_i + R_o)}}$$

$$C_{total}=\sqrt{2D(\sum_{i=1}^{n}\left(A_i + d_iC_{fi}\right)Y_i)(\sum_{i=1}^{n}P_iXi^2\,(R_i + R_o)} + \sum_{i=1}^{n}DX_i(R_{ti}T_iP_i + C_{vi}) \quad (1)$$

An appropriate performance measure for delivery to the buyer is given in the expression below:

$$L_{total} = \sum_{i=1}^{n} l_iX_i$$

This expression must be less than the lead-time required by the buyer. It implies that the supplier who takes long lead-time is compensated by the short lead-time of other suppliers. The mathematical formulation of the NMOP (nonlinear multi-objective program) model is given as follow:

Min Z= (C_{total}, L_{total})

Such that

$$X_iD \leq C_i i=1, n \qquad (2)$$

$$\sum_{i=1}^{n} l_iX_i \leq L \qquad (3)$$

$$\sum_{i=1}^{n} X_i = 1 \qquad (4)$$

$$\epsilon Y_i \leq X_i \leq Y_i \quad i = 1, n \qquad (5)$$

$$Y_i=0, 1i=1, n \qquad (6)$$

Equation (1) clearly expresses the multi-objective function and constraint (2) represents the supplier production capacity restriction. Constraint (3) is an aggregate performance measure for delivery for all suppliers. This expression is given by several authors (Chaudhury et al., 1993) and must by less than the lead-time required by the buyer. Constraint (4) indicates that demand is placed with the set of *n* suppliers. Constraint (5) requires that an order is placed with a supplier if only he is selected; 1 is a positive number, slightly greater than zero. Constraint (6) imposes binary requirements on the Y_i variables.

4. SOLUTION METHODOLOGY

The multi-objective programming is often used to find an aggregate solution, which satisfies a number of supplier selection design criteria. With the help of this model our classical methods reduce them into a single objective of minimizing a weighted sum of deviations from goals. In our model since the cost and lead-time criteria have different orders in magnitude so we useabsolute values of the relative variations of each objective in order to normalize the objectives compared to its goal. Thus, the multi-objective function (1) can be rewritten as:

$$\text{MinZ} = \omega\frac{\sqrt{2D(\sum_{i=1}^{n}A_i+aiC_{fi})(\sum_{i=1}^{n}P_iiXi^2(R_i+R_o))}+\sum_{i=1}^{n}DX_i(R_{ti}T_iP_i+C_{vi})-G1}{G1} + (1-\omega)\frac{\sum_{i=1}^{n}l_iX_i-G2}{G2}$$

This equation is a single objective function and our NMOP can be solved as a single objective optimization problem subject to constraints defined by equations (2)-(6). *G*1, *G*2, (1- ω), and ω respectively, are the cost, lead-time goals and the weighting factors for the absolute values of the relative variations of each criterion. To find G1, we solve “Model formulation” by considering the cost as the only objective function (Z = C_{total}), even thing for *G*2 (Z =L_{total}).

5. CONCLUSION

In a multiple sourcing network, the buyer has to employ more suppliers simultaneously. In this case, several problems occur such as the determination of the optimum number of selection of suppliers and the order to allocate each supplier. We note that there has been very little work that completely examines the role of the transportation in the selection of supplier in supply chain management. In this review paper, we demonstrated the use of a multi objective programming approach for enhancing the importance of transportation in supplier selection problem. Our model can help the manufacturer in selecting the appropriate suppliers and to determining the numbers of quantities to split among them. The proposed comprehensive approach is also likely to find multiple solutions to the problem, each corresponding to a different setting of the weight factor and to the type of shipment used to move products from selected suppliers to buyer.

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