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Criteria Based Supplier Selection Model By Integer Linear Programming- A Case Study In A Manufacturing Organization

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Abstract

In any organization, supplier selection is a crucial decision making process and number of factors needs to be evaluated. It is a strategic decision making process that influences the functional accomplishment of an organization. In the competitive business environment, the sourcing of suppliers is not based on lowest price offered but depends on several parameters as there is no chance for intolerance to failures. Suppliers need to fulfill tangible and intangible criteria to reinforce supply chain management of an organization. Several supplier selection models have been developed in the past considering all the criteria, the proposed methodology adopts combination of preference weights of analytic hierarchy process and integer linear programming techniques. The methodology mainly focused on selection of suppliers based on each criterion. The model was validated by considering a supplier selection process in a manufacturing organization.

Keywords: Analytic Hierarchy Process (AHP), Integer linear programming (ILP), Preference weighs, Criteria, Suppliers, Constraints

Introduction

Supplier selection process is a regular, continous and dynamic. Supplier qualification, selection and evaluation are the three basic steps involved. In manufacturing firms, the major portion of cost of production is towards material cost and it is paramount to organizations to maintain long term relationship with the suppliers. The quality, lead time and price are the most common and repeatedly used criteria in supplier selection. Supplier selection models developed in the past mainly concentrated on selecting first tier suppliers but attempts are not made to contemplate second tier suppliers to avoid

risks associated with purchasing [1].Materials delivery, quality, cost/price, financial position, communication and technology is recognized as the commonly used criteria from previous literature; in addition to this criteria such as ISO certification, reliability, credibility, good references and product development were are also necessary. This shows that the attention is slowly shifted towards qualitative criteria [2].Supplier selection mechanism envelops functional wings of an organization such as purchasing, quality etc.It comprises of many tangible and intangible factors. Supplying the right amount of materials at the right time, at right price and the right quality are the prerequisites of an efficient supplier [3].

Selection of suppliers is intricate process as it encompasses numerous criteria. A survey conducted in industries indicated that quality and on-time delivery are the decisive factors while supplier selection. Optimum cost, joint development, culture, forward engineering, trust, supply chain management, quality and communication were also equally important [4-5]. Cost, quality and prompt service are the influential factors in supplier selection process and the process of suppler selection lead the cost and quality [6]. An important aspect of supply chain management is selection and management of supplier. In fact, success in providing outside suppliers start with the correct selection and in long-term is directly dependent on managing of the relations with suppliers because suppliers play an important role on a company's success or failure [7].Supplier criteria, product performance, Service performance and cost are the main parameters for supplier selection [8].

Number of models has been developed for supplier selection by using statistical and optimization techniques. Mathematical programming and the data envelopment analysis applied to evaluate different suppliers[9].Goal programming technique was applied to minimize costs and maximize quality and delivery reliability when selecting suppliers vendors and allocating orders between them[10].Suppliers performance regarding to price, quality, and delivery was evaluated by using a Taguchi loss function and it then sum up these measurement into a single performance measure, giving different weights to the different criteria as required by the purchaser[11].A model was developed for supplier selection in the garment industry which is suitable to mixed-model production. In this model, selecting apt supplier from a large number of eligible ones through grouping into clusters; analytic hierarchy process and cluster analysis are the techniques applied [12]. A study was conducted to evaluate of suppliers in Iran automotive industry by using a two phase analytic network process and Technique for Order Preference by Similarity to Ideal Solution; the results indicate advantages such as: Long-term relationship, consist quality, lower cost, and special attention [14]. Data envelopment analysis was applied to select suppliers after calculation of efficiency on the basis of six inputs and five outputs; the study was extended on the basis of three parameters: price, quality and delivery [16]. The criteria for selection of automobile spares was found by developing a questionnaire and analyzed by applying factor analysis. The results have indicated that human resource, production, quality and organizational characteristics played important role on selection strategy. Analytical network process and fuzzy goal programming are applied to choose the appropriate alternative among various choices [19].

The criteria such as reliability, credibility, good references and product development were also identified as important criteria for supplier selection as these criteria had existed before but did not receive the same attention in previous researchers; indicates the attention is shifting towards qualitative criteria[13].A study was conducted in Indian industries to evaluate different facets of green supply chain implementation and the results shows that supplier selection was least prioritized. The criteria quality, environment performance assessment, green manufacturing, and customer co-operation are the priority factors. This showed that Indian industries compromise on cost in order to procure and thus produce products of better quality and environmentally friendly [15]. A study conducted in Egypt construction industry show that collaboration and long term relationship is lacking between contractors and suppliers. To avoid purchase risks, it is suggested to produce items internally [17].Previous researches on supplier selection are based on buyers prospective and coordination models can be developed considering both the suppliers/ buyer's objectives. The benefits of coordination models are limited annual production rate is added to each supplier, number of deliveries per inventory cycle at each supplier can be greater than one and inventory holding cost of each supplier is taken into account[18].

Supplier selection is marred with twin problems viz. single supplier's ability of satisfying the buyer's needs (single sourcing) and secondly no supplier can satisfy buyer's needs (multi sourcing). Thus to overcome these multi criteria problem that includes tangible and intangible criteria; often management decides to split the quantities to be ordered which will foster the competitive environment [20].To address tangible and intangible criteria, AHP may be an alternative. This will enable the users to visualize the problem systematically while taking the criteria and sub-criteria in to consideration. This will entail the user to compare and determine the priorities of the criteria and alternatives effectively. The combination of AHP and LP may be considered to take tangible as well as intangible criteria and to optimize order allocation among suppliers [6].In the present study, AHP along with integer linear programming models were adopted for selection of wholesalers due to more flexibility.

Problem Formulation (Case Study)

The current study is based on the problem of supplier selection for a manufacturing firm [21].A study was conducted in a manufacturing organization for supplier selection and the criteria have been finalized after extensive literature survey and discussions with industrial experts/academicians.AHP method is then applied on that questionnaire survey collected from interview. First the goal has been decided and then selection of some criteria with respect to decided goal, some alternatives has been considered that satisfy those criteria. Pair wise comparisons have been done of those alternatives satisfying the criteria. Then using the CGI software priorities of criteria has been calculated with respect to goal. The individual priority of the alternatives was calculated and after calculating their global priority finding the supplier, having highest priority is selected. Eight criteria considered in the supplier

selection problem are on time delivery (OTD), product quality (PQ), price/cost(PC), facility and technology(FT), responsiveness of customer needs(RCN), professionalism of sales person(PSP), quality of relationship(QR) and performance history(PH). The preference weights of suppliers basing on criteria are shown in Table 1.

Table 1: Preference Weights of Criteria

Criteria									
Supplier	**OTD**	**PQ**	**PC**	**FT**	**RCN**	**PSP**	**QR**	**PH**	**Total**
S1	0.184	0.096	0.022	0.055	0.022	0.031	0.086	0.021	0.517
S2	0.030	0.039	0.022	0.009	0.009	0.008	0.014	0.003	0.134
S3	0.075	0.016	0.065	0.022	0.085	0.042	0.035	0.008	0.348

Sum of priorities for the supplier S1, S2 and S3 is 0.517, 0.134 and 0.348 respectively. Therefore, it was suggested that supplier S1 may be considered as the best supplier for the firm. In the study, total priorities of all criteria are considered to select the supplier but an individual criteria that is the strong areas of the supplier was ignored. Though the sum of the priorities of suppliers S2 and S3 is less when compared to S1but in few criteria they are strong. Basing on this, an attempt was made to identify suppliers selection on criteria wise by using ILP.It is not possible for the suppliers to dominate all the criteria in multi criteria and multi supplier environment.

Methodology

Integer Linear Programming

A zero one ILP is a special case integer programming model in which all decision variables are binary numbers. ILP is useful in making decisions such as accept or reject and yes or no type answers..All decision variables are restricted to take only binary values. The decision variables in ILP should be integers. Supplier selection problem is formulated using general assignment problem. The general assignment Problem [22] can be superimposed onto the current supplier selection problem. The preference of each supplier of all the criteria is found out by Analytical hierarchy process. The mathematical model developed here to illustrate the objective functions involving the allocation of criteria to suppliers and vice versa, there's a scope for maximizing the preference weightage while carrying out this assignment. The required number of suppliers for each criteria depends upon the requirement of the buying organization. This is considered as the first constraint.

The formulated ILP model is presented hereunder.

Decision variable: Xij = {1, supplier is allocated to criteria j, zero otherwise}

Where,

I = supplier index, i =1, 2…K, K= Total number of suppliers in a set

J = criteria index j =1, 2… L, L= Number of criteria in a set

Wij = Preference weightage of supplier 'I' for the criteria 'j'
M= Minimum requirement of suppliers for criteria 'j'
N = Maximum number criteria allocated to supplier i
S = Total number of supplier assignments needed for 'L' number of criteria

$$\text{Maximize } Z=\sum_{i=1}^{K}\sum_{j=1}^{L} W_{ij}X_{ij} \quad \ldots\ldots\ldots \quad (1)$$

The objective function in equation (1) represents the maximization of the preference weightage subject to,

Constraint 1
Sum of all the characteristics of all individual suppliers should be greater than equals to 1, so the constraint represented in equation (2),

$$\sum_{I=1}^{K} X_{ij} \geq 1 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Constraint 2
Each characteristics must assign to only one supplier so that sum of all the suppliers of all individual characteristics must be equals to 1, so the constraint represented in equation (3),

$$\sum_{j=1}^{L} X_{ij} = 1 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

Constraint 3
Sum of all suppliers with respect to criteria should be equal to L, so the constraint is represented in equation (4),

$$\sum_{i=1}^{K}\sum_{j=1}^{L} X_{ij} = L \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

Constraint 4
The equation (5) ensures non negative restrictions

$$X_{ij} = 1 \text{ or } 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

Problem Solution

The preference weights of the AHP method used to formulate the objective function in ILP, and then the objective function to Maximize Z is,

0.184X11+0.096X12+0.022X13+0.055X14+0.022X15+0.031X16+0.086X17+0.021X18+0.03X21+0.039X22+0.022X23+0.009X24+0.009X25+0.008X26+0.014X27+

0.003X28+0.075X31+0.016X32+0.065X33+0.022X34+0.085X35+0.042X36+0.035 X37+0.008X38---------- (6)

Constraint 1:
Sum of all the characteristics of all individual suppliers should be greater than equals to 1, so the constraints are as follows,

X11+X12+X13+X14+X15+X16+X17+X18>=1 (7)

X21+X22+X23+X24+X25+X26+X27+X28>=1 (8)

X31+X32+X33+X34+X35+X36+X37+X38>=1 (9)

Constraint 2
Each criteria must assign to only one supplier so that sum of all the suppliers of all individual criteria equals to 1, so the constraints are as follows,

X11+X21+X31=1..... (10)

X12+X22+X32=1 ……. (11)

X13+X23+X33=1……. (12)

X14+X24+X34=1…….. (13)

X15+X25+X35=1……. (14)

X16+X26+X36=1 ……. (15)

X17+X27+X37=1…….. (16)

X18+X28+X38=1…… (17)

Constraint 3:
As there are eight criteria, sum of all suppliers with respect to criteria should be equal to eight. The constraint is as follows

X11+X12+X13+X14+X15+X16+X17+X18+X21+X22+X23+X24+X25+X26+X27+X28+X31+X32+X33+X34+X35+X36+X37+X38=8……. (18)

Constraint 4:

X11,X12,X13,X14,X15,X16,X17,X18,X21,X22,X23,X24,X25,X26,X27,X28,X31,X32,X33,X34,X35, X36, X37, X38=1 or 0…… (19)

All the decision variables are binary.

The equations 6 to 19 are solved by ILP using LINDO v6.1 software and the results are shown in Fig.1 and the allocation of suppliers based on criteria is shown in Table 2.

Table 2: Allocation of Suppliers Basing on Criteria

S. No	Criteria	Supplier 1	Supplier 2	Supplier 3
1	On time delivery	✓		
2	Product quality	✓		
3	Price/cost			✓
4	Facility and technology	✓		
5	Responsiveness of customer needs			✓
6	Professionalism sales person			✓
7	Quality	✓		
8	Performance history		✓	

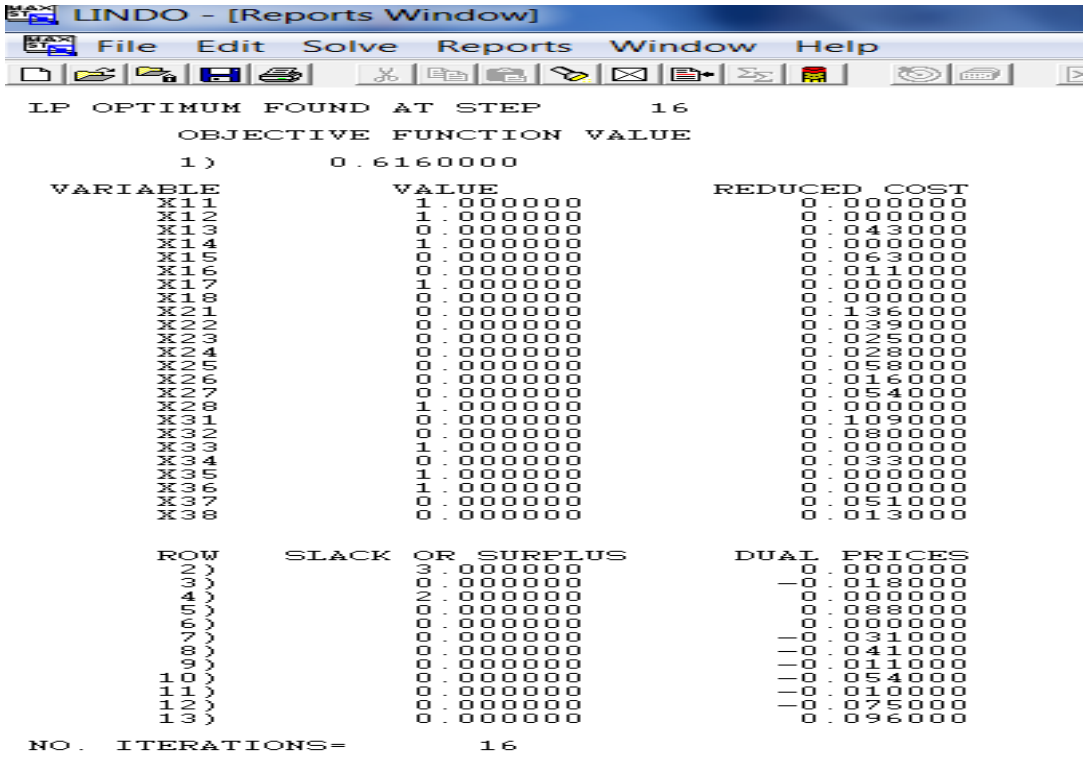

Figure 1: Results of analysis from LINDO software

Conclusion

Criteria based supplier selection is useful in multi supplier and multi criteria environment. It is not possible for the suppliers to accomplish all the criteria to maximum extent. Suppliers may be weak in meeting the requirements of certain criteria owing to internal and external factors. The results of the study shows clearly no supplier is fulfilling the eight criteria considered in the study .Though supplier (S1) is considered as the best supplier basing on sum of the priorities of AHP method ,the supplier is fulfilling only 50% of the criteria. It is also observed that the difference

between total priorities of suppliers (S1 &S3) is 0.17 as per AHP method but as per ILP, the supplier (S1) is ahead of supplier (S3) in only one criteria .Supplier (S2) past performance is better than other suppliers and failed to meet other criteria .The criteria based supplier selection is vital particularly for items requiring high reliability and safety during manufacturing process.

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