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APPLICATION OF ANALYTIC HIERARCHY PROCESS AND GOAL PROGRAMMING IN SUPPLIER SELECTION PROBLEM

(TEDARİKÇİ SEÇİMİ PROBLEMİNDE HEDEF PROGRAMLAMA VE ANALİTİK HİYERARŞİ PROSESİNİN UYGULAMASI)

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ABSTRACT/*ÖZET*

In this paper, a goal programming (GP) approach was utilized to solve the problem of materials' supplier selection for a company operating in textile industry. The proposed approach determines the company's objectives and assigns their relative importance to be used for Analytic Hierarchy Process (AHP). Weighted GP approach was used to develop two alternative mathematical models for selecting the suppliers. One of the alternatives restricts the number of suppliers to be selected to two for each material; the other one does not put any restrictions on this subject. The results are compared within each other and with the current system in terms of the objectives determined at the beginning.

Bu çalışmada bir tekstil firmasının tedarikçi seçimi problemini çözmek üzere bir hedef programlama yaklaşımı geliştirilmiştir. Geliştirilen yöntem firmanın amaçlarını ve önem derecelerini belirler. Bu veriler Analitik hiyerarşi süreci ile ağırlıklara dönüştürülür. Yöntemin ikinci aşamasında hesaplanan değerler ile ağırlıklı hedef programlama modeli çalıştırılır. Model iki alternatif sonuç oluşturur. Birincisinde her malzeme için tedarikçi sayısı iki ile sınırlandırılmıştır. İkincisinde ise tedarikçi sayısı üzerinde herhangi bir kısıt yoktur. Her iki alternatifin sonuçları birbiriyle ve firmanın mevcut durumuyla belirlenen amaçlar doğrultusunda karşılaştırılmıştır.

KEYWORDS/*ANAHTAR KELİMELER*

Supplier selection, Goal programming, Analytic hierarchy process
Tedarikçi seçimi, Hedef programlama, Analitik hiyerarşi prosesi

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1. INTRODUCTION

Purchasing activities of a company constitute a very important part in the overall operation of the company. The quality and the delivery capabilities of any manufacturing firm depend heavily on the performance of its suppliers (Watts et al., 1995). In addition, a large amount of the product’s total cost is made up of the purchasing cost of its materials. Therefore effective purchasing is of crucial importance and can bring competitive advantages to the firm. However, most of the time, suppliers cannot provide the highest quality parts on-time at the lowest costs in the market. In other words, quality, delivery and cost objectives conflict with each other. Therefore alternative suppliers of the firm should go through careful analysis and the firm should select the best supplier/s in terms of its strategies.

The aim of this study is to propose an approach to solve the supplier selection problem of a company operating in textile industry. Since supplier selection problem is multi-objective in nature, GP is used to solve the problem. The main reasoning behind GP is that it realizes many objectives at the same time and tries to work them out together. The advantage of GP over other multi-objective programming techniques is that it only tries to reach the target values that are satisfactory for the decision maker. Other techniques try to choose the best solution among a large number of efficient solutions. Therefore GP is a more effective method compared to other traditional multi-objective programming techniques (Cabarello et al., 1998).

In the proposed approach, first the objectives of the company and the selection criteria to evaluate suppliers are identified. Then, the relative importance of the objectives is found using AHP. The performance of all suppliers is computed and finally, GP models are employed to select the right suppliers for the company. The rest of the paper is organized as follows. In section 2 a brief review on supplier selection problem and its applications are given. In section 3, the GP approach to solve the problem of materials’ supplier selection for the company is presented. Determination of goals, their relative importance, and the models built are given at this section. Finally, section 4 gives the results and conclusions.

2. SHORT REVIEW ON SUPPLIER SELECTION

The question of ‘who to buy from and how much to buy’ is simply the ***Supplier Selection Problem.*** Selection offers enormous potential for decreased costs and effective control of resources. Many people who spent considerable time on this subject agree that selecting the sources of supply is the most important function of purchasing department. Dobler, Burt and Lee express this issue in their book with the following words: “Selecting capable suppliers is one of a purchasing manager’s most important responsibilities” (Dobler et al., 1984).

In order to take out the capable suppliers out of all alternative ones, they should be evaluated according to purchaser’s objectives. Hence the evaluation criteria to identify the suppliers should be settled. Many researchers have studied these criteria. G.W. Dickson found out 23 criteria to evaluate suppliers. Other classifications also exist in the literature such as Narasimhan and Barbarosoğlu and Yazgaç (Narasimhan, 1983; Barbarosoğlu and Yazgaç, 1997). But, Dickson criteria have gound the largest application in literature. Table 1 gives a list of these criteria. The mean rating gives the importance of criteria. As the rank increases the importance also increases.

Once the selection criteria are settled, different methods can be applied to solve the problem. Some of the studies carried out on supplier selection are as follows:

Chaudry, Forst and Zydiak used an integer GP model in a vendor selection problem of a blended gasoline purchaser (Chaudry et al., 1991). Four goals are identified. These are quality, lead time, service and price goal. The priorities are in the same order.

Table 1. Dickson's supplier selection criteria (Weber et al., 1991)

Rank	Factor	Mean Rating	Rank	Factor	Mean Rating
1	Quality	3.508	13	Management Organization	2.216
2	Delivery	3.417	14	Operating Costs	2.211
3	Performance History	2.998	15	Repair Service	2.187
4	Warranties and Claim Policies	2.849	16	Attitude	2.120
5	Production Capacity	2.775	17	Impression	2.054
6	Price	2.758	18	Packaging Ability	2.009
7	Technical Capability	2.545	19	Labor Relations Record	2.003
8	Financial Position	2.514	20	Geographical Location	1.872
9	Procedural Compliance	2.488	21	Amount of Past Business	1.597
10	Communication System	2.426	22	Training Aids	1.537
11	Position in Industry	2.412	23	Reciprocal Arrangements	0.610
12	Desire for Business	2.256			

Weber and Current employed a multi objective approach to solve vendor selection problem of a Fortune 500 company (Weber and Current, 1993). Three objectives are identified which are to minimize the purchasing costs, total late deliveries and total rejected units. A linear combination of these objectives becomes the objective function. Mixed integer problem is developed and solved.

Ghodsypour and Brien also employed AHP to deal with both qualitative and quantitative factors (Ghodsypour and Brien, 1998). In their methodology, at first step, the criteria for supplier selection are defined and their weights are computed using AHP. All the suppliers are evaluated and their total scores are computed. In the last step, a linear programming model is built and solved.

Ulusam and Kurt applied fuzzy GP in a hydraulic gear pump purchasing problem (Ulusam and Kurt, 2002). They defined cost, quality, and delivery reliability goals as fuzzy goals. These are transformed into a linear programming form and solved.

In this study AHP procedure and gola programming is integrated. The weights obtained from AHP for the goals selected by the company are incorporated into the gola programming model and solved.

3. PROPOSED APPROACH FOR A REAL LIFE SUPPLIER SELECTION PROBLEM

The application is carried out at a firm manufacturing textile products in Turkish Industry. The company produces sports outer clothing out of knitted fabric. As a nature of textile industry the number of materials is quite low whereas product variety is quite high. However, there is no defined procedure used for materials purchasing in the firm. The required materials are ordered traditionally from accustomed suppliers. Therefore, most of the time, the company faces problems like late delivery of materials or rejected lots due to low quality. These problems move the company towards higher costs, delayed production, low customer satisfaction etc. Therefore a new and objective method for supplier selection is necessary for the company.

3.1. Methodology

The proposed approach in this study uses weighted GP and AHP to solve the problem. At first the goals of the firm are determined by the decision makers of the problem. Then necessary criteria to evaluate the suppliers are determined. In weighted GP, the important part is to determine the goals as well as their relative importance to the firm. To assign this relative importance, i.e. the weights, to the goals AHP is used which is one of the multi-criteria decision making aids. At this step, "Expert Choice", which is AHP software, is used. Then, performance measures associated with the selection criteria and the target values associated with the goals are calculated.

The next phase is modelling. Two alternative mathematical models are developed and solved. The first model does not put any limits on the number of selected suppliers. On the other hand, the second model limits the number of suppliers selected to two. The last step is to find the results of the models and compare them with the current system. The flow of the algorithm for the proposed approach can be seen in Figure 1 (Mızrak, 2003).

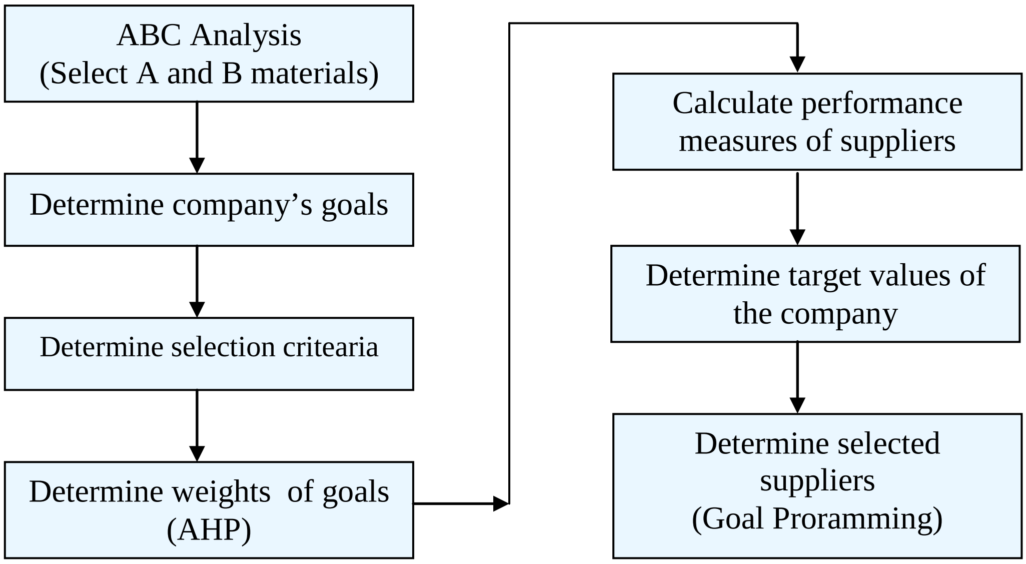

Figure 1. Algorithmic flow of the proposed approach

3.2. Model Development

The first thing done was to carry out an ABC analysis. Looking at the total yearly purchasing cost of all materials, class A and class B materials are handled in the supplier selection problem.

3.2.1. Determination of the Company's Goals

According to the company strategies, their goals are determined by the decision makers of the company.

- Maximize the number of accepted units in the incoming quality control.
- Maximize the number of units arriving on-time.
- Maximize the number of delivered units by the suppliers.
- Maximize the capacity utilization of suppliers.

3.2.2. Determination of the Selection Criteria

The next step is to determine the selection criteria according to the firm's strategies. These are determined to be:

- Quality (K): Ratio of accepted units in the incoming quality control.
- Lead-Time (L): Ratio of units arriving on-time.
- Delivery Performance (D): Ratio of delivered units to ordered units.
- Capacity Utilization (R): Ratio of the capacity of the supplier used for the company.

3.2.3. Determination of the Weights of the Goals

Weights of the goals represent their relative importance according to firm's strategies. At first, purchasing experts of the firm are asked to fill the questionarres about the pairwise comparisons of the objectives. Then these are averaged to take a single value for eash comparison. Finally AHP and Expert Choice software is used to determine the weights of the goals. Determined weights turned out to be:

- Quality (K): 0,443
- Lead-Time (L): 0,316
- Delivery Performance (D): 0,169
- Capacity Utilization (R) : 0,072

3.2.4. Calculation Of Performance Measures

Performance measures are necessary in order to evaluate the suppliers in terms of the selection criteria. A performance measure for each selection criterion exists. Below are given the performance measures for materials' suppliers.

- Quality (K): Ratio of accepted units in the incoming quality control:

$$\text{Kij} = \frac{\text{Number of Accepted Units of Material i (delivered by supplier j)}}{\text{Total Units (of material i) Delivered by Supplier j}} \tag{1}$$

- Lead-Time (L)=Ratio of units arriving on-time :

$$\text{Lij} = \frac{\text{Number of Units of Material i On - time (delivered by supplier j)}}{\text{Total Units (of material i) Delivered by Supplier j}} \tag{2}$$

- Delivery Performance (D): Ratio of delivered units to ordered units.

$$\text{Dij} = \frac{\text{Total Units of Material i (delivered by supplier j)}}{\text{Total Units (of material i) Ordered to Supplier j}} \tag{3}$$

- Resources (R): Capacity percentage of the supplier used for the firm.

$$\text{Rij} = \frac{\text{Total Units Received of Material i (from supplier j)}}{\text{Yearly Capacity of Supplier j (for material i)}} \tag{4}$$

All suppliers are analyzed according to the selection criteria of each material they supply to the firm.

3.2.5. Determination Of Target Values

Target values represent the desired levels of performance measures. The target values are decided to be based on the performance of the best two suppliers. Target value for each criterion is determined by adding 80% of the best performance value and 20% of the second best performance value by the decision makers of the problem.

3.2.6. Mathematical Model Formulations

Two alternative GP models are developed. The only difference between them is that the first model poses no restrictions on the number of suppliers selected whereas the second model restricts the number of suppliers selected to two. The notation used within the model formulations are given in Table 2 below.

Model 1 is given with equations 5 to 12 below. Objective function is to minimize weighted sum of negative deviations from the target values of the company. Goal constraints are given in constraints 6 to 9. The first one corresponds to quality goal. That is the sum of quality performances of the selected suppliers plus the negative deviation should add up to the target quality value of the company. Similarly lead time, delivery performance and capacity utilization goal constraints are given by 7, 8 and 9 respectively. Constraints 10 state that the sum of ordered quantities from the suppliers should be equal to the demand. Capacity surpasses of suppliers are avoided by constraint set 11. Finally, decision variables are defined to be integers by constraint set 12.

Model1

$$\min \sum_{k}\sum_{j}\sum_{t} w_k sa_{kjt} \tag{5}$$

subject to

$$\sum_{i} K_{jt} Y_{jit} + sa_{1jt} - se_{1jt} = TK_j \sum_{i} Y_{jit} \qquad \forall \mathrm{j,t} \tag{6}$$

$$\sum_{i} L_{jt} Y_{jit} + sa_{2jt} - se_{2jt} = TL_j \sum_{i} Y_{jit} \qquad \forall \mathrm{j,t} \tag{7}$$

$$\sum_{i} D_{jt} Y_{jit} + sa_{3jt} - se_{3jt} = TD_j \sum_{i} Y_{jit} \qquad \forall \mathrm{j,t} \tag{8}$$

$$\sum_{i} R_{jt} Y_{jit} + sa_{4jt} - se_{4jt} = TR_j \sum_{i} Y_{jit} \qquad \forall \mathrm{j,t} \tag{9}$$

$$\sum_{i} Y_{jit} = QD_{jt} \qquad \forall \mathrm{j,t} \tag{10}$$

$$\mathrm{MR_{ij}} \geq Y_{jit} \qquad \forall \mathrm{j,i,t} \tag{11}$$

$$Y_{jit} \geq 0 \text{ and integer} \quad \forall j, i, t \tag{12}$$

Table 2. Notation used in model formulations

Sets
j : Number of materials.
i_j : Number of suppliers for material j.
t : Number of periods.
Parameters
K_{ij} : Ratio of lots accepted of supplier i for material j.
L_{ij} : Ratio of lots delivered on time by supplier i of material j.
D_{ij} : Ratio of delivered units to ordered units of supplier i for material j.
R_{ij} : Capacity utilization ratio of supplier i for material j.
TK_j : Target value for the ratio of lots accepted for material j.
TL_j : Target value for the ratio of lots delivered on time for material j.
TD_j : Target value for the ratio of units delivered for material j.
TR_j : Target value for the capacity utilization ratio for material j.
w_m : weight of goal m found using AHP.
$[w_1\ w_2\ w_3\ w_4] = [0{,}443\ \ 0{,}316\ \ 0{,}169\ \ 0{,}072]$
MR_{ij} : Monthly capacity of supplier i for material j.
QD_{jt} : Quantity demanded of material j in month t.
P_{jit} : Purchasing cost of material j bought from supplier i in month t.
Decision Variables
Y_{jit} : units of material j ordered from supplier i in month t.
Deviational Variables :
sa_{mjt} : Negative deviation from the goal m of jth material on month t.
se_{mjt} : Positive deviation from the goal m of jth material on month t.

Model 2:

In addition to model 1 formulation, the decision variables and system constraints below are used.

Additional Decision Variables:

$$X_{jit} : \begin{cases} 1 \text{ if supplier i is selected for material j in month t.} \\ 0 \text{ otherwise} \end{cases}$$

Additional System Constraints:

$$\sum_i X_{jit} = 2 \qquad \forall j,t \tag{13}$$

$$X_{jit} M \geq Y_{jit} \qquad \forall j,i,t \tag{14}$$

$$0{,}1 \cdot QD_{jt} X_{jit} \leq Y_{jit} \qquad \forall j,i,t \tag{15}$$

$$X_{jit} \text{ are binary} \tag{16}$$

As stated earlier, the difference of Model 2 from Model 1 is that Model 2 incorporates an additional assumption to limit the number of selected suppliers to two. This is included in the model with constraints 13. As a natural result of this assumption, if a supplier is not selected, quantity ordered to that supplier should be 0. This is stated in the model with constraints 14 (M is a very large number). Also, in order to select two suppliers, the model may end up with ordering only one unit to the second supplier. To prevent this situation another rule is incorporated. That is, minimum number of units ordered from a selected supplier should be at least 10% of minimum demand which is given in the model by constraint set 15. Finally, X variables are defined to be binary by constraints 16.

4. COMPUTATIONAL RESULTS

All the mathematical models are written and solved in Lingo Optimization Software. The selected suppliers and the quantities ordered to them are found. As an example outcome, the quantities to be ordered of Item 7 found by Models 1 and 2 are given in Tables 3 and 4 respectively.

It is seen from the tables that selected suppliers are S1, S2, S4 and S6. This means that S3 and S5 are far below the target levels. However, in October and November the required amounts are ordered from three and four suppliers respectively by Model 1. On the other hand, model 2 only allows two suppliers every month. Therefore the quantity ordered from each supplier differs in alternative models.

Similarly, suppliers selected and the corresponding ordered quantities are found for all items. The solutions are compared with the current system in terms of total number of units accepted and on-time which are two of the firm's objectives defined at the beginning. In addition the solutions are compared in terms of total purchasing costs. The results are given in Table 5.

According to the table, all alternative model solutions have improved the number of units accepted, on-time and purchasing costs over the current system. Furthermore, it can be seen that the best improvement in terms of units accepted is achieved by Model 2 which selects exactly 2 suppliers for each item. The best improvement in terms of units on-time and total purchasing cost is achieved by Model 1 which does not have a limit on the number of suppliers selected.

5. CONCLUSION

To summarize, first the purchasing objectives and hence the selection criteria for suppliers are determined. Then relative importance of these criteria is computed using AHP. Finally, GP models are built and solved to select the best suppliers for the firm. In conclusion, proposed approach is proved to be more powerful than the current one in terms of all totals purchasing cost, total number of units accepted and total number of units arriving on-time. In other words using AHP and GP in a supplier selection problem provides beneficial solutions.

Table 3. Solutions obtained by Model 1 for Item 7 (Mizrak, 2003)

Item 7		SUPPLIERS					
		S1	**S2**	**S3**	**S4**	**S5**	**S6**
Quantity Ordered (in units)	**Jun.**		56343				5162
	Jul.		83333				106953
	Aug.		30298				2776
	Sept.		83333				80110
	Oct.	2811	83333				125000
	Nov.	166666	83333		7718		125000
	Dec.		83333				27173
	Jan.		83333				38725
	Feb.		54950				5034

Table 4. Solutions obtained by Model 2 for Item 7 (No. of suppliers is limited to 2 for each month) (Mizrak, 2003)

Item 7		SUPPLIERS					
		S1	**S2**	**S3**	**S4**	**S5**	**S6**
Quantity Ordered (in units)	**Jun.**		56343				5162
	Jul.		83247				107039
	Aug.		29774				3300
	Sept.	80196	83247				
	Oct.	127897	83247				
	Nov.				257717		125000
	Dec.		83247				27259
	Jan.		83247				38811
	Feb.		54950				5034

Table 5. Results of the proposed GP models and the existing system of the company (Mizrak, 2003)

	Model 1	**Model 2**	**Current System**
Number Of Units Accepted	19,212,015	19,216,374	18,629,421
Number Of Units On-Time	18,106,064	18,083,523	15,167,296
Purchasing Cost	1,051,583	1,078,297	1,104,403

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