Demand Assignment: A DEA and Goal Programming Approach

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Abstract: - Assignment problem has always been a popular problem for production and operations research. There have been developed many methods and heuristics for these kinds of problems. This research deals with the problem of an automotive company's driver belt assembly supply from its by-industry suppliers. Firstly, the suppliers are evaluated by data envelopment analysis (DEA), which is a mathematical modelling approach finding the relative efficiencies of the decision making units (DMUs). Later on, the suppliers that are found inefficient are eliminated and only the efficient suppliers are included for the assignment problem. Preemptive goal programming (PGP) is applied for the assignment of demand in order to satisfy the goals and the demand of the company by taking into account the priorities given by the company.

Key-Words: - DEA, Preemptive Goal Programming, Demand Assignment

1 Introduction

High competition reality in today's world forces the companies to work with lower costs, higher efficiencies and higher qualities. This reality is also the reason for the companies to make cooperation with suppliers which help them to achieve these goals. Selecting the suppliers satisfying this requirement and assigning them the demands are leading to the assignment problems for the companies. Especially, in the automotive industry, where just in time manufacturing is performed, supply problems have a great importance. This paper proposes a two step solution to the demand assignment problem of an automotive company for driver belt assemblies.

Assignment problem has always been a popular problem for production and operations research. There have been developed many methods and heuristics for these kinds of problems. These problems usually include a company, which is trying to assign the demand to the suppliers, therefore some suppliers, criteria, goals and constraints. In order to solve the assignment problems, transportation methods can also be used such as, northwest corner, minimum cost and vogel methods. The basic assignment method is the Hungarian method, which can be efficiently used for solving m*m assignment problems [1]. But these are ued for the cases where there is only one objective, usually cost, distance minimization or profit maximization. If there are many and complex constraints and objectives, superior methods are necessary. Actually, once the problem is modelled mathematically, many operations research solving techniques can be applied. If there are more than one goal, then goal programming model which is one of the mathematical modelling applications can be of use. Since these problems also include selecting the right supplier, considering some criteria, multi criteria decision making (MCDM) methods also take place in the decision process. There are so many MCDM techniques such as, Analytical Hierarchy Process (AHP), TOPSIS (Technique for Order Preference by Similarity to Ideal Solution), ELECTRE I, II, III, (Elemination and Choice Translating Reality English), PROMETHEE I,II etc. When Data Envelopment Analysis, which is the technique, applied in this research, is compared to other MCDM methods, it is seen that, it requires less information from decision makers and analysts and it provides ranked alternative valuations that may be useful for some decision makers [2]. MCDM techniques are not used in the decision process in the research, because the main idea of the decision is collaborating with the efficient suppliers, which minimize their input values. Therefore Data Envelopment Analysis (DEA), which has been employed successfully for assessing the relative performance of a set of firms, usually called decision-making units (DMU), which use the same inputs to produce the same outputs [3], is applied to the input values of suppliers in order to evaluate their relative efficiencies which will help the decision of supplier selection before moving to the assignment problem.After selecting the efficient suppliers by DEA, preemptive goal programming model is used to solve the multi-objective assignment problem of the automative company.

The composition of the paper includes literature review on supplier evaluation and DEA firstly and on preemptive goal programming secondly. After literature review, problem definion and applicaiton of the models

and their results are presented. Finally results are discussed and conclusion and further research ends the paper.

2 Literature Review

2.1 Supplier Evaluation And DEA

Modern supply chain management, which is defined as the coordination and intergration of the products and information from raw material to the final customer, emphasizes the importance of purchasing, additionally implementation of just in-time production resulted in the analysis of purchasing management once again [4]. It has been reported that a majority of quality problems of an organization are due to defective material and carefully selected, competitive suppliers can go a long way in minimizing adverse impacts and in fact in enhancing positive impacts on the quality of output of an organization, which lieads to the fact that, supplier selection is a crucial part of the functioning of an organization [3]. Weber and some other researchers scanned many articles on supplier evaluation in 1991 and 1993 and investigated the effect of JIT strategy over supplier evaluation using Dickson's 23 criteria; among 74 articles, net price, delivery and quality were discussed mostly with the percentage of 80, 59 and 54 respectively [5]. Therefore, these three criteria are used as inputs for the supplier selection part of the problem also adding the reputation criteria, which has a high importance for the company, since the company has a very reputable brand all over the world, applying data envelopment analysis (DEA), which is the first step.

DEA is able to measure multiple inputs and outputs, which means it can operate as a multi criteria decision making (MCDM) tool but DEA does not require assigned numeric weights or modeling preferences for analysis, although these could be introduced if/when desired [2]. This advantage and the objectivity property of DEA with the efficiency calculations is the main reason of using DEA for supplier selection which is the first step of the problem solution. Charnes et al. (1978) first proposed DEA as a generalization of the framework of Farrell (1957) on the measurement of productive efficiency [6, 7]. DEA is a method for mathematically comparing different decision-making units' (DMUs) productivity, based on multiple inputs and outputs [6]. It is based upon the economic notion of Pareto optimality; a given DMU is not efficient if some other DMU, or some combination of other DMUs can produce the same amounts of outputs with less of some resources and not more of any other [7]. Multiple input, single output DEA model, utilizing the Pareto-Koopmans efficiency measure, will be used in this study referencing to Weber (1996) [8].

2.2 Preemptive Goal Programming

Goal programming (GP) which is a multi-objective decision making method is first proposed by Charnes and Cooper in 1961. It was improved by Lee in 1972 and by Ignizio in 1976 [9]. Nowadays GP is acknowledged as one of the most effective strategies used in multi-objective optimization problems [10]. GP attempts to reach all the goals at the same time, which may affect each other negatively. When one goal reaches the targeted value, another one may move away from its own target, therefore objective function in GP models is usually minimizing the deficiencies from the aimed values. Some priorities can be put for the goals, so that the deficiencies that should be minimized have a sequence to be satisfied, this type of goal programming models are called preemptive goal programming models. In an initial step a first part model is solved which only incorporates the first-priority goals; if the execution of the initial step leads to more than one optimal solution of the first part model, a second part model incorporating the second-priority-goals is solved keeping the optimal achievement-level of first-priority-goals constant; lower-priority-goals are not considered unless the higherpriority-goals are optimally satisfied and this optimal solution is many-valued [11]. Preemptive goal programming is used in the second step of the problem, which tries to find the optimal assignment of the demand to the efficent suppliers, found in the first step by DEA, satisfying the constraints and goals of the company.

3 Problem Definition And Application Of The Model

This paper proposes a two step solution to the demand assignment problem of an automotive company for driver belt assemblies. The company is trying to make the assignment of the demand to the suppliers while satisfying some goals and constraints. There are 5 suppliers that the company works with, Table 1 shows the criteria values, which are determined by the literature review and company experts as, price, quality (rejection rate), delivery (late delivery rate) and reputation. Price is measured in USDs, rejection and delivery rates are measured as percentages of total materials supplied from that supplier –which are kept in the database of the company- and reputation is measured in 1-5 scale where 1 denotes the highest reputation. The first step is to find the efficient suppliers by using DEA and the second step is to assign the demand to the efficient suppliers by preemptive goal programming.

Table 1: Input values of the suppliers

	Supplier1	Supplier2	Supplier3	Supplier4	Supplier5
Price ($)	20	22	23	23	22
Rejection %	1,2	1,5	1	1,5	1,3
Late delivery %	2	7	2	7	3
Reputation	1	2	2	3	2

Multiple input, single output DEA model, utilizing the Pareto-Koopmans efficiency measure, will be used in this study's first step, referencing to Weber (1996). This form of the model measures the efficiency of DMUs by how well they minimize multiple input criteria to produce a single unit of output [8] :

Min $x_k - \varepsilon(\sum_{i=1}^{m} s_i)$ (9)

s.t.

$x_k w_{ik} - \sum_{j=1}^{n} w_{ij} y_j - s_i = 0$ for all i=1,…,m (10)

$\sum_{j=1}^{n} y_j = 1$ (11)

$y_j \geq 0$ for all j = 1,…n (12)

$s_i \geq 0$ for all i = 1,…m (13)

x_k unconstrained but assumed positive

Where:

x_k is Farrell's efficiency measure for supplier k,
s_i are input criteria slack variables,
y_j are reference weights associated with vendor j,
Є is an infinitely small number,
w_{ij} is the input criteria value for the *i*th criteria and the *j*th supplier,
m is the number of criteria
n is the number of suppliers

The model above are written for each supplier k using the data in Table 1. The m and n values are as : n=5 there are 5 suppliers; m=4 there are 4 inputs (price, rejection, late delivery and reputation). The efficiencies derived after solving the all 5 models are seen in Table 2. Supplier 1 and Supplier 3 are relatively efficient in the given data set compared to other suppliers as their efficiency values are 1.000. Actually, the efficiency values of the other suppliers are not very low, Supplier 2 has the efficiency value 0.909, Supplier 4 has the efficiency value 0.870 and Supplier 5 has the effcency value 0.916.

Table 2. Supplier efficiencies

Supplier	Efficiency
Supplier 1	1,000
Supplier 2	0,909
Supplier 3	1,000
Supplier 4	0,870
Supplier 5	0,916

For the second step of the problem, a preemptive goal programming model is formed and solved. There are two functional constraints of the company. One is about satisfying the demand and the other is about the budget. Demand of the company is 10.000 pieces per month (equation 2). Budget constraint is $ 210.000 per month. (equation 3). There are three goal constraints of the company. The goal about the quality has the first priority, and the company does not want the rejection rate to be more than 1.1 percent (equation 4). The second goal of the firm is keeping the late delivery rate under 1.5 percent (equation 5). The last goal of the company is about the reputation of the suppliers and its preference is working with suppliers having reputation degree of 1 and 2 over 5 (equation 6). Equation 1 is the objective function of the preemptive goal programming model.

x_i = Number of driver belt assemblies bought from supplier i; i = 1,2 (1: Supplier 1, 2: Supplier 3)

Min $P_1 s_1^+$, $P_2 s_2^+$, $P_3 s_3^+$ (equation 1)

x1 + x2 $\geq$ 10.000 (equation 2)
20x1 +23x2 $\leq$210.000 (equation 3)
1.2x1+1x2 + $s_1^- - s_1^+$ =11.000 (equation 4)
2x1 + 2x2 + $s_2^- - s_2^+$ = 15.000 (equation 5)
1x1 + 2x2 + $s_3^- - s_3^+$ = 20.000 (equation 6)

After solving the goal model it is found that, 6667 belt assemblies should be bought from Supplier 1 and 3333 belt assemblies should be bought from Supplier 2. This result leads to positive deficiency of 333 from the first goal and positive deficiency of 5000 from the second

goal and there is no positive deficiency from the third goal, therefore the objective function results in 5333.

4 Conclusion

Assignment problem has always been a popular problem for production and operations research. There have been developed many methods and heuristics for these kinds of problems. This paper represents a two step solution for the assignment problem of an automotive company for purchasing driver belt assemblies where, these problems have a great importance because of the just in time manufacturing. Firstly, the 5 suppliers of the material are evaluated by data envelopment analysis (DEA), which is a mathematical modelling approach finding the relative efficiencies of the decision making units (DMUs).

The criteria are determined by the literature review and company experts as, price, quality (rejection rate), delivery (late delivery rate) and reputation. Multiple input, single output DEA model, utilizing the Pareto-Koopmans efficiency measure, is used for supplier evaluation. Later on, the suppliers that are found inefficient are eliminated and only the 2 efficient suppliers are included for the assignment problem. Preemptive goal programming (PGP) is applied for the assignment of demand in order to satisfy the goals about the criteria by taking into account the priorities given by the company and the constraints about budget and demand constraints. The solution of the goal model assigns the demand to the suppliers.

The two step solution used in this paper prevents the company to make the assignment among all suppliers and allows the company to make the assignment among only the efficient suppliers and DEA is an effective way of comparing the efficiencies of units.

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