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A Model Suggestion To Determine The Order Quantity In Supplier Selection Problems

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ABSTRACT

In this study, a model is suggested to determine the supplier selection for the firms which works with more than one supplier. AHP is used to give weights to the criteria and the alternatives. Today, firms want to develop different kind of strategies to outclass their oppenent. Firms can move faster because of these strategies. In this study, a mathematical model is suggested to obtain products more quickly and determine how much you need to order from the supplier. In the model, difference from other studies in literature, distance of firms to suppliers is considered. Model is applied in a real system and five scenarios were tested to determine the order quantity. The current situation and the results were compared by calculating the order cost of the created scenarios.

Keywords: *Supplier selection, AHP, linear programming.*

1. INTRODUCTION

In a company; Supply Department is responsible for production control, engineers and materials that need to ask for a list of the materials issued by the competent departments of the desired type and amounts[1].

Supply Chain is a process of from raw material to final product and then marketing up to delivery to ensure coordination and interaction within the complex structure of the process and involves the approach to increase the efficiency and quality service[2]. Supply chain management is observing the movement continues of products and the informations and is directed along the supply chain[3].

As many factors like quality, cost, warranty, delivery, technical capability and price affect the supplier performance[4]. In this case, supplier selection is multi-criteria decision problem that requires the balancing countable and uncountable factors that contradict themselves[5].

Some articles made previously in this regard like Hou and Su (2007), Liu and Hai (2005), Mendoza et al. (2008) and Garfamy (2006). Decisions were taken for the criterias in these studies were taking into account. These criterias vary in these studies.

These criterias are determined by the wide range of Dickson. Dickson (1996) has discussed with his 273 purchasing responsible for the work. Important values in the supplier evaluation has identified 23 criteria applied by the questionnaire. Quality, delivery, performance history, warranty, insurance policy and capacity production of tools have been identified as the most important criterion, respectively. The research resulted in; quality, price, delivery, service, flexibility, technology, technical and distance has been identified as the most preferred criteria[6].

Using the above criterias in the literature, 'Supplier Selection' is made with various method. In some studies, only multi-criteria decision making methods are used. While others have benefited from mathematical models with these models.

'Quality', 'price', 'service', 'delivery' and 'technology' criterias are used in these studies; Nydick and Hill (1992), Baker and Talluri (1997), Ghodspour and O'brien (1998),

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Chan and Chan (2004), Forker and Mendez (2001), Dağdeviren and Eren (2001), Wang et al. (2004), Liu and Hai (2005), Pehlivan (2007), Tam and Tummala (2001). 'Quality', 'distance', 'finance', 'relationship' and 'service criterias are used in these studies; Akarte et al. (2001), Ecer and Küçük (2008), Paksoy and Güleş (2006), Braglia and Petroni (2000), Saen (2006), Boer et al. (1998), Akyüz (2012).

In the literatue, 'Supplier Selection' studies on methods are classified in terms. Studies and methods used are given in Table 1.

THE METHOD	ARTICLE
AHP	Nydick and Hill (1992), Yahya and Kingsman (1999), Tam and Tummala (2001), Dağdeviren et al. (2001), Akarte et al. (2001), Muralidharan (2002), Chan and Chan (2004), Özcan (2005), Liu and Hai (2005), Paksoy and Güleş (2006), Hou and Su (2007), Ecer and Küçük (2008), Özdemir (2010)
AHP and Linear Programming	Ghodspour and O'Brien (1998), Baran and Erol (2012)
AHP and Goal Programming	Dağdeviren and Eren (2001), Wang et al. (2004), Özdemir (2007), Pehlivan (2007), Mendoza et al. (2008)
Data Envelopment Analysis	Baker and Talluri (1997), Braglia and Petroni (2000), Forker and Mendez (2001), Garfamy (2006), Saen (2006)
ANP	Sarkis and Talluri (2002), Dağdeviren et al. (2005), Gencer and Gürpınar (2007), Kirytopoulos et al. (2008)
Fuzzy AHP	Akman and Alkan (2006), Durdudiler (2006), Chan and Kumar (2007), Seçme and Özdemir (2008), Chan et al. (2008), Ku et al. (2010), Arda (2010), Deng et al. (2014)
Fuzzy TOPSIS	Chen et al. (2006), Bagheri and Tarokh (2010), Özçakar and Demir (2011)
ELECTRE	Boer et al. (1998), Şevkli (2010)
PROMETHEE	Dağdeviren and Eraslan (2008)
ANP, TOPSIS and Linear Programming	Lin et al. (2011)
AHP, TOPSIS and Non-linear Programming	Fazlollahtabar et al. (2011)
Non-linear Programming	Ware, Singh and Banwet (2014)
Fuzzy VIKOR	Akyüz (2012)

Table1. The Methods and Articles

Studies carried out to date have been examined. Except one study, other studies were found to be the sole supplier of determination. In Lin et al.(2011) study, it is intended to work with multiple suppliers and also what amount to be received from each supplier is determined.

In this study, a model has developed to determine what amount will be taken from suppliers for the companies who don't want to be dependent on a single supplier and working with multiple suppliers. And this model also take into account the distance to the company,

2. MODEL

In case of working with multiple suppliers at same time, it is important to decide what amount has to be ordered from which suppliers For these kinds of problem, performance value for suppliers should be identified in mathematical model. Supplier selections that maximize overall performance is realized. Mathematical model is given below.

Max $\sum_{i=1}^{n} TiXi$…….....(1)

$\sum_{i=1}^{n} Xi = Q$…….....(2)

$\sum_{i=1}^{n} Xi \,.\, \mathrm{ri} \leq ZQ$…….....(3)

$\sum_{i=1}^{n} Xi \,.\, \mathrm{di} \leq BQ$…….....(4)

$\sum_{i=1}^{n} Xi \,.\, \mathrm{ki} \leq AQ$…….....(5)

$\sum_{i=1}^{n} Xi \,.\, \mathrm{mi} \leq SQ$…….....(6)

$X_i \leq C_i$.....(7)

$X_i \geq 0$, i=1,2,.....,n

The objective function is given in equation (1). The purpose of the model is so as to maximize the total supplier performance, what amount of product order should be done from a supplier must be determined. In objective function; order quantity is X_i and supplier performance value is indicated with T_i. Equation (2) is satisfying the demand constraint. Here, Q indicates the amount demanded. Equation (3) is the constraint that manufactured products shouldn't be under the determined quality. Z is the maximum delay time rate to accept for company. Supplier i's delay rate is r_i. Equation (4) is the delivery constraint. B is the maximum defect manufactured product rate that the company can accept. Supplier i's defect product rate is d_i'dir. Equation (5) indicates price constraint. Maximum unit product price that the company can accept is A. Supplier i determines the unit price by k_i'dir. Equation (6) indicates the distance constraint. Maximum distance that the company can accept is S. Supplier i's distance to company is m_i. Equation (7) indicates capacity constraint. Supplier i's capacity is C_i.

3. APPLICATION

When the studies in the literature about Supplier Selection Problem is examined, many sectors applications are encountered. In this study, one of a firm that leads their sector in Ankara was examined. The model developed for the study to decide what would be the amount which the supplier of the product 3500 orders were applied.

A hierarchical structure is created for the solution of supplier selection. Firstly, it was decided the criteria that which is planned to be used. Then considering these criteria, suppliers are weighted by AHP method.

In this study, information about the path followed by employees in the company is determined. The company has some of the tests applied to candidate suppliers. These tests are located in 5 main criteria. These criteria are Harmony of Amount(HA), Harmony of Termin(HT), Material Input Quality(MIQ), Quality System Certification(QSC) and Extreme Freight(EF).

Test applied by the company are not shared with other persons or entities because of firm principles. Four candidate suppliers that these tests applied has scores and these are shown in Table2.

Suppliers	P_i
A	91,2
B	89,3
C	90,1
D	89,7

Table2. Test Points

When criteria and sub-criteria are independent from each other, AHP should be used and otherwise ANP should be used[7]. In this study, assuming that independently of the criteria and sub-criteria, AHP is preferred instead of ANP. AHP is preferred because

Severity ratings of criteria are determined by interviews with employees who works in purchase department in company. Seperately by the company's employees were asked to give values to each other for supremacy. These criteria are graded on the basis of alternative suppliers in the same way by working with each other for supremacy. Weights of the criteria and candidate suppliers can be obtained by various methods, when multiple decision are used. In the literature, when multiple-decision makers are used, values are determined by taking the arithmetic mean or geometric mean. The geometric mean is taken into account in the study. Coupling with geometric mean is implemented in two ways. First way is to find geometric means of matrix which is made by decision-makers decision. And second way is to find geometric means of matrixes seperately[8]. In this study, first way is chosen. Combined criteria weights are given in Table3.

	HA	HT	MIQ	QSC	EF
HA	1	1	2	3,94	5,96
HT	1	1	2	2,92	6
MIQ	0,50	0,50	1	2	3,94
QSC	025	0,34	0,50	1	2
EF	0,17	0,17	0,25	0,50	1

Table3. Combined Criteria Weights

Basis on 5 criteria candidate supplier priorities are determined by company employees and combined candidate supplier weights are given in Table4.

HA	**A**	**B**	**C**	**D**
A	1	1,19	1,68	1
B	0,84	1	1,41	1,19
C	0,59	0,71	1	1,19
D	1	0,84	0,84	1
HT	**A**	**B**	**C**	**D**
A	1	1,41	0,71	1
B	0,71	1	1,68	1,68
C	1,41	0,59	1	1,41
D	1	0,71	0,71	1
MIQ	**A**	**B**	**C**	**D**
A	1	0,35	2	1,19
B	2,83	1	1,19	0,50
C	0,50	0,84	1	1,68
D	0,84	2	0,59	1
QSC	**A**	**B**	**C**	**D**
A	1	0,35	1	1,19
B	2,83	1	0,71	0,71
C	1	1,41	1	2
D	0,84	1,41	0,50	1
EF	**A**	**B**	**C**	**D**
A	1	1	0,84	1
B	1	1	1,19	1
C	1,19	0,84	1	1,19
D	1	1	0,84	1

Table4. Combined Alternative Weights

Criteria and alternatives' priorities are determined by using these weights in AHP method. Sum of columns are given in Table5.

Sum Columns	2,92	3,01	5,75	10,36	18,90

Table5. Sum of Columns

Normalized matrix is given on Table6 and mean row of normalized matrix is given on Table7.

	HA	**HT**	**MIQ**	**QSC**	**EF**
HA	0,343	0,332	0,348	0,380	0,315
HT	0,343	0,332	0,348	0,282	0,318
MIQ	0,171	0,166	0,174	0,193	0,208
QSC	0,085	0,113	0,087	0,096	0,106
EF	0,058	0,006	0,043	0,048	0,053

Table6. Normalized Matrix

HA	0,35
HT	0,33
MIQ	0,18
QSC	0,10
EF	0,04

Table7. Mean of Normalized Matrix Row

After calculating the mean of normalized matrix row, consistency of pairwise comparison has to be controlled[9]. Firstly weighted sum of vector is calculated. Then, mean of normalized matrix row and criteria priorities are weighted. Weighted normalized matrix is given in Table8.

	HA	**HT**	**MIQ**	**QSC**	**EF**
HA	0,35	0,33	0,36	0,394	0,239
HT	0,35	0,33	0,36	0,292	0,24
MIQ	0,175	0,165	0,18	0,20	0,158
QSC	0,088	0,113	0,090	0,10	0,08
EF	0,056	0,056	0,045	0,05	0,04

Table8. Weighted Normalized Matrix

Weighted sum of vector is obtained from Table8 and is given in Table9.

1,673
1,572
0,878
0,471
0,247

Table9. Weighted Sum of Vector

Weighted sum of vector is divided to priorities of corresponding elements and the values are given in Table10.

Harmony of Amount	4,78
Harmony of Termin	4,76
Material Input Quality	4,87
Quality System Certificate	4,71
Extreme Freight	6,175

Table10. Criteria Priorities

Obtained matrix's consistency should be determined. The reason of doing that in this phase is to determine how close priorities to the reality. These are perceptible just in case with consistency test. Pairwise comparison matrix's consistency policy is that the most eigenvalue λ_{max} must be equal to the matrix's length(n).

Firstly weighted sum of vector is determined by multiplication of pairwise matrix's column and priority and their sums. Then determined weighted sum of vector elements are divided to priority. And these determined values' arithmetic mean gives us λ_{max}.

λ_{max} value is used in CR(consistency ratio)'s calculation. CR value must be under 0,10. CR value is determined below;

$$CR=\frac{\lambda-n}{(n-1).RI} \quad \text{.....(8)}$$

$$CI=\frac{\lambda_{max}-n}{n-1} \quad \text{.....(9)}$$

When this formulation is used;

$$CR=\frac{CI}{RI} \quad \text{.....(10)}$$

CR is calculated with this formulation.

In this study;

$$\lambda_{max}=\frac{4,78+4,76+4,87+4,71+6,175}{5}=5,061282828$$

CI=0,015320707

CI is calculated with these formulations.

In equation (10) RI value is specified random index. RI value is determined by value of n and it consists of steady numbers. RI values are given in Table11.

N	1	2	3	4	5
RI	0	0	0,58	0,9	1,12
N	6	7	8	9	10
RI	1,24	1,32	1,41	1,45	1,49

Table11. Random Index Value

If equation (10) is used;

CR=0,013679202

is calculated as over.

Since CR value is smaller than 0.10, matrix is consistent.

In next step, basis on criteria weight of alternatives are calculated. And alternative supplier priorities are given in Table12.

CRITERIA	SUPPLIER	WEIGHT
HA	A	0,30
	B	0,27
	C	0,21
	D	0,22
HT	A	0,24
	B	0,30
	C	0,26
	D	0,20
MIQ	A	0,24
	B	0,29
	C	0,22
	D	0,25
QSC	A	0,20
	B	0,28
	C	0,31
	D	0,21
EF	A	0,23
	B	0,27
	C	0,27
	D	0,23

Table12. Alternative Supplier Priorities

Criteria priorities given in Table10 and alternative priorities given in Table12 are multiplied and alternative supplier weights are determined. It is given in Table13.

A	0,26
B	0,30
C	0,25
D	0,19

Table13. Alternative Supplier Weights

These weights are used to calculate supplier performance value in scenarios below.

In this study, for 3500 unit product per week, what amount should be ordered from suppliers want to be determined. Firstly current state is determined and 5 different scenarios are created they applied to the mathematical model. Model is runned and the results are compared with each other.

Order quantities in current state is given in Table14.

A	1000
B	700
C	1200
D	600

Table14. Order Quantities for Current State

Scenarios are given below;

- Scenario-1: When T_i values are used as test points (p_i). In this situation p_i values are normalized and then used in the mathematical model.
- Scenario-2: When T_i values are used as alternative supplier weights(h_i).
- Scenario-3: When T_i values are used as multiple of test points(p_i) and alternative supplier weights(h_i).
- Scenario-4: When T_i values are used as arithmetic mean of test points(p_i) and alternative supplier weights.
- Scenario-5: When T_i values are used as geometric mean of test points and alternative supplier weights.

Required supplier information are taken from company and are given in Table15 and Table16.

Supplier	Quality Defect Rate	Delivery Defect Rate	Distance	Unit price	Capacity (unit/ week)
A	0,03	0,06	40	600	1000
B	0,02	0,04	30	620	900
C	0,03	0,05	50	550	1200
D	0,01	0,02	20	720	600

Table15. Supplier Information

Parameters	Value
Quantity of Demand (Q)	3500
Maximum Delay rate (Z)	0,064
Maximum Error Rate (B)	0,032
Maximum Unit Product Price (A)	800
Maximum Distance (S)	80

Table16. Parameter Values

For scenario-1, mathematical model is given below as an example;

Max $0{,}912X_1+0{,}893X_2+0{,}900X_3+0{,}897X_4$

S.T. $X_1+X_2+X_3+X_4=3500,$

$600X_1+620X_2+550X_3+720X_4\leq 2\,800\,000,$

$0{,}03X_1+0{,}02X_2+0{,}03X_3+0{,}01X_4\leq 112,$

$0{,}06X_1+0{,}04X_2+0{,}05X_3+0{,}02X_4\leq 224,$

$40X_1+30X_2+50X_3+20X_4\leq 280000,$

$X_1\leq 1000,$

$X_2\leq 900,$

$X_3\leq 1200,$

$X_4\leq 600,$

$X_1\geq 0,$

$X_2\geq 0,$

$X_3\geq 0,$

$X_4\geq 0.$

Current state and order quantities for 5 scenarios are determined. They are given with their costs in Table17.

STATES	SUPPLIERS				COSTS
	A	B	C	D	
Current State	1000	700	1200	600	2126000
Scenario-1	1000	700	1200	600	2126000
Scenario-2	1000	900	1200	400	2106000
Scenario-3	1000	900	1200	400	2106000
Scenario-4	1000	900	1200	400	2106000
Scenario-5	1000	700	1200	600	2126000

Table17. Order Quantities and Costs Under the Scenarios and Comparison with Current State

As seen in Table17; in 2nd,3rd and 4th scenarios, solutions are equaled to each other and their cost is 20000 TL less than current state. So preferred order quantities from supplier A,B,C and D must be respectively 1000, 900, 1200 and 400 products.

4. CONCLUSION

Nowadays the competition between companies is increasing with each passing day. When faced with difficult circumstances; preferred to be a business by preventing the rival firms, costs should be reduced as much as possible, improve quality in production, reduce the distribution time and provide access to it market presence. For these reasons mentioned, suggesting the process of supplier selection which has low cost before beginning of production process has become even more important. So companies are becoming more advantages over competitors.

In this study, a mathematical model is suggested to obtain products more quickly and determine how much you need to order from the supplier. Distances between company and candidate suppliers are used in the mathematical model.

The current situation is determined in a real company as an application of model., the mode is developed with creating 5 different scenarios and it is solved with package programme LINDO 6.1. Results are compared. The lowest cost scenarios are determined and this order programme is proposed for the company.

The model developed in this study can be generalized with applying some constraints like customer relationship, flexibility, innovation. According to the obtained results, company can make lower cost supplier selection, if Scenario-2, Scenario-3 or Scenario-4 are chosen.

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