

Supplier Selection on Retail: Analysis with Two Multi –Criteria Evaluation Methodologies

H. Ahmet AKDENİZ,

Prof. Dr., Department of Econometrics, Faculty of Economics and Administrative Sciences, Dokuz Eylül University

Timur TURGUTLU

Ph.D. Candidate, Department of Econometrics, Faculty of Economics and Administrative Sciences, Dokuz Eylül University

Abstract

The evaluation of the supplier performance has recently witnessed a considerable interest since their efficiency plays a key role on the productive efficiency of the supply-chains. Managers aim to determine the best practice supplier network to improve allocation of resources and firm performance. In literature, widely used traditional methods, based on accounting and financial systems has been gradually alienating the stage to multiple criteria decision making methods. The objective of this paper is to determine the performance of the suppliers of a nation-wide retail company in Turkey using Data Envelopment Analysis (DEA), a multiple criteria decision making method developed by Charnes et al (1978) and using Analytic Hierarchy Process (AHP), developed by Saaty (1980). In literature, there exist many applications of these two methods comprising various industries (Baby Food Manufacturing

Industry, Weber (1996); Agricultural and Construction Equipment Industry, Liu et al. (2000), Telecommunications Industry, Narasimhan et al. (2001); Wooden Furniture Industry, Yahya and .Kingsman (1999); etc.). However, to the author's best knowledge, this will be the first study evaluating the supplier performance of a retail company through DEA and AHP. To this end, retail-specific input and output measures will be developed. Moreover, we expect to display the critical factors to design an efficient supplier network for the managerial units. Finally, we compare and interpret the results obtained from two multi-criteria methods.

Keywords: Data Envelopment Analysis, Analytic Hierarchy Process, Supplier Evaluation, Supply Chain, Efficiency, Retail

Introduction

Today, the competition between corporations is growing fast. In this highly competitive environment, the corporations which design and manage its supply chain best, will be more profitable and hence stronger. "Supplier" is one of the most important chain of the supply chain. The corporations which develop good relationships with its suppliers, gain cost advantages, on time and desired quality deliveries. Therefore, supplier evaluation has a strategic importance for the corporations. The results reached by using the right performance criteria and evaluation method would produce robust solutions towards improving the performance of suppliers. Dickson (1966) presented 23 supplier selection criteria, and assigned the rankings of these criteria. Some recent supplier evaluation and selection studies in various industries are, Baby Food Manufacturing Industry, Weber (1996); Wooden Furniture Industry, Yahya and .Kingsman (1999); Agricultural and Construction Equipment Industry, Liu et al. (2000), Telecommunications Industry, Narasimhan et al. (2001); Food Manufacturing Industry, Çebi and Bayraktar (2004). There are few studies, comprising performance evaluation in retail industry (Wagner vd. (1989).

Retail, in Turkey and worldwide, is a rapidly developing industry where competition is significantly high. Since the retail process does not involve any production phase the supplier relations have a dominant role. To this end, this study, first, aims to propose performance criteria for the suppliers in retail industry. Another objective of this study is to propose and compare two methods that can be used in performance evaluation. The first method is a mathematical programming method, Data Envelopment Analysis (DEA). A multiple-criteria based decision-making method, Analytical Hierarchy Process (AHP) is the other method. In this study, both methods are used to evaluate the performance of the suppliers of a national retailing firm in 2005 and the results are analyzed in detail. The consistency of the findings of these methods is also tested statistically.

This study is organized as follows. In second section, the two methodologies used in supplier evaluation are briefly described. The data set and analytical results of the application are presented in the third section. Finally, the conclusions are given in the last section.

1. Supplier Evaluation and Selection Approaches

The first step of supplier evaluation is, stating the performance criteria. In his study Dickson (1966) presented 23 performance criteria, with interviewing 273 purchasing responsible and managers in USA and Canada. The most important three criteria presented by his study, were, “quality”, “delivery” and “price”. Weber, Current and Benton (1991), stated that, in 74 supplier evaluation and selection studies since 1961, the “net price” used in 61 supplier papers, followed by “delivery” with 44 studies and “quality” with 40 studies.

In literature there exist few studies, comprising performance evaluation in retail industry. In his study, Wagner et al. (1989) , presented “markup”, “delivery” and “selling history”, as “highly important” performance criteria for retail buyers.

Timmerman (1986), classified traditional supplier evaluation techniques in three categories: Categorical methodology, cost-ratio

methodology and simple linear weighted average methodology. The subjectivity and complexity of the traditional methodologies directed researchers to different performance measurement methodologies like mathematical programming techniques, Weber and Current (1993), Ronen and Trietsch (1988), Weber (1996), Mandal (1993) , and multiple criteria decision methodologies, Narashiman (1983).

Methodology

The two different supplier evaluation methodologies utilized in these studies are DEA and AHP. Brief descriptions of two methods are given below.

DEA is a mathematical programming technique which developed by Charnes et al. (1978). DEA calculates the relative efficiencies of decision making units (DMU's) based on multiple inputs and outputs. The most efficient DMU's, determine the efficiency frontier, than the efficiencies of other DMU's are being calculating relative to this frontier. The DEA model used in this study is the model which was developed by Charnes, Cooper and Rhodes (CCR) in 1978, based on the assumption of constant returns to scale. The model is given below;

$$\begin{aligned} & \min \theta \\ & s.t. \\ & \sum_{j=1}^n x_{ij} \lambda_j \leq \theta x_{i0}, \quad i = 1, \dots, m \\ & \hspace{15em} (1) \\ & \sum_{j=1}^n y_{rj} \lambda_j \geq y_{r0}, \quad r = 1, \dots, s \\ & \lambda_j \geq 0 \quad j = 1, \dots, n \end{aligned}$$

A DMU's to be efficient must have an efficiency score equals to 1 and, slack values equal to zero's.

AHP is a multiple-criteria decision methodology developed by Saaty (1980). AHP can also be used to determine the relative importance of a set of units. The basic steps of AHS are presented below;

- a. Structuring the problem hierarchy:
- b. Pair wise comparisons and consistency check
- c. Calculation of priorities and synthesis
 - i. Calculation of the weights
 - ii. Consistency check
 - iii. Calculation of priorities

Data Set and Empirical Results

The two methodologies presented above are applied to a nationwide retail firm in Turkey. A strategic commodity group with 9 suppliers and 5 millions USD purchasing-selling volume for 2005 is chosen. The application is performed using the year 2005 data of the firm.

The supplier performance criteria are chosen based on Wagner et al. (1989) and with discussion with the firms purchasing managers. The criteria used are markup, delivery and selling history.

The input oriented CCR model is used in the application. The inputs and output are as follows:

Inputs:

Markup (X_1): The markup percent obtained by supplier for selected commodity group in 2005. Since markup was an input variable, the smaller the better, the difference of the markup from 100 was used in the model.

Delivery (X_2): The on-time delivery percent by supplier for selected commodity group in 2005. Since the delivery is also an input variable, the percent of the late deliveries is used in the model.

Selling History (X_3): The selling volume by supplier after returns for selected commodity group in 2005. Since selling history is an input variable, the reciprocal of selling history is taken and multiplied with one million and used in the model.

Output:

Purchased quantity (kilo's) (Y): The single output of the model is the net purchasing quantities by supplier for selected commodity group in 2005. The DEA results are given on the Table 1

Table 1. Supplier efficiency scores and slack values (DEA)

Supplier	Efficiency Score	Slack Value (X ₁)	Slack Value (X ₂)	Slack Value (X ₃)
S ₁	1	0	0	0
S ₅	1	0	0	0
S ₃	0.792	1.805	0	0
S ₂	0.763	0	0.035	0.27
S ₇	0.526	0	0	2.78
S ₆	0.35	0	0	1.891
S ₈	0.173	0	0	4.901
S ₉	0.082	0	0	1.624
S ₄	0.027	0	0.301	2.099

S_i:Suppliers

Table 1 shows that, S₁ and S₅ are the best suppliers with efficiencies scores 1 and slack values 0. S₄ is the worst performing supplier with the efficiency score 0.027. Table 1 shows that, S₁ and S₅ are efficient suppliers and S₃, S₂, S₇, S₆, S₈, S₉ ve S₄ are inefficient suppliers.

The reference supplier for inefficient suppliers and their reference weights is given on the Table 2.

Table 2. Supplier reference group and reference weights

Supplier	1. Reference	1.Reference Weight	2. Reference	2. Reference Weight
S ₁	S ₁	1		
S ₂	S ₁	0.769		
S ₃	S ₅	0.327	S ₁	0.432
S ₄	S ₁	0.026		
S ₅	S ₅	1		
S ₆	S ₅	0.247	S ₁	0.096
S ₇	S ₅	0.523		
S ₈	S ₅	0.176		
S ₉	S ₅	0.044	S ₁	0.035

S_i:Suppliers

Table 2 shows that, S₁ is the reference supplier for S₂ and S₄ . S₅ is the reference supplier for S₇ and S₈. A virtual supplier with combination of the suppliers S₁ and S₅ is the reference supplier for suppliers S₃, S₆, S₉. The reference weights in Table 2 are used to calculate the target inputs values for inefficient suppliers to be efficient.

From Table 3 to Table 11, original input values, target values, radial movement values and slack movement values are presented for each supplier.

Table 3. DEA results for supplier S₁

Variable	Original Value	Radial Movement	Slack Movement	Target Value
Y	258287.000	0.000	0.000	258287.000
X ₁	94.710	0.000	0.000	94.710
X ₂	7.700	0.000	0.000	7.700
X ₃	2.515	0.000	0.000	2.515

Y: Purchased quantity (kilo's), X₁: Markup, X₂: Delivery, X₃: Selling History

Table 3 shows that, the original values and the target values of the efficient supplier S₁ are all same.

Table 4. DEA results for supplier S₂

Variable	Original Value	Radial Movement	Slack Movement	Target Value
Y	198588.000	0.000	0.000	198588.000
X ₁	95.380	-22.561	0.000	72.819
X ₂	7.800	-1.845	-0.035	5.920
X ₃	2.886	-0.683	-0.270	1.934

Y: Purchased quantity (kilo's), X₁: Markup, X₂: Delivery, X₃: Selling History

S₂ is not on the efficiency frontier with 0.763 efficiency score. Table 4 shows improvement targets for all three performance criteria. S₂, in order to move on to the efficiency frontier should reduce X₁ 22.561 point, X₂ 1.845 point and X₃ 0.952 point.

Table 5. DEA results for supplier S₃

Variable	Original Value	Radial Movement	Slack Movement	Target Value
Y	154789.000	0.000	0.000	154789.000
X ₁	93.330	-19.411	-1.805	72.115
X ₂	4.200	-0.874	0.000	3.326
X ₃	3.271	-0.680	0.000	2.591

Y: Purchased quantity (kilo's), X₁: Markup, X₂: Delivery, X₃: Selling History

S₃ is a supplier which is not on the efficiency frontier with 0.763 efficiency score. Table 5 shows improvement targets for three performance criteria.

Table 6. DEA results for supplier S₄

Variable	Original Value	Radial Movement	Slack Movement	Target Value
Y	6726	0	0	6726
X ₁	90.93	-88.464	0	2.466
X ₂	18.5	-17.998	-0.301	0.201
X ₃	79.815	-77.65	-2.099	0.065

Y: Purchased quantity (kilo's), X₁: Markup, X₂: Delivery, X₃: Selling History

Table 6 presents the target values for supplier S4 which has the minimum efficiency score 0.027.

Table 7. DEA results for supplier S₅

Variable	Original Value	Radial Movement	Slack Movement	Target Value
Y	132103.000	0.000	0.000	132103.000
X ₁	95.390	0.000	0.000	95.390
X ₂	0.000	0.000	0.000	0.000
X ₃	4.599	0.000	0.000	4.599

Y: Purchased quantity (kilo's), X₁: Markup, X₂: Delivery, X₃: Selling History

S₅ is an efficient supplier like S₁.

Table 8. DEA results for supplier S₆

Variable	Original Value	Radial Movement	Slack Movement	Target Value
Y	57351.000	0.000	0.000	57351.000
X ₁	93.200	-60.556	0.000	32.644
X ₂	2.100	-1.364	0.000	0.736
X ₃	9.332	-6.063	-1.891	1.378

Y: Purchased quantity (kilo's), X₁: Markup, X₂: Delivery, X₃: Selling History

Table 8 gives improvement targets for supplier S₆.

Table 9. DEA results for supplier S₇

Variable	Original Value	Radial Movement	Slack Movement	Target Value
Y	69114.000	0.000	0.000	69114.000
X ₁	94.850	-44.944	0.000	49.906
X ₂	0.000	0.000	0.000	0.000
X ₃	9.856	-4.670	-2.780	2.406

Y: Purchased quantity (kilo's), X₁: Markup, X₂: Delivery, X₃: Selling History

Table 9 shows the improvement targets for supplier S₇.

Table 10. DEA results for supplier S₈

Variable	Original Value	Radial Movement	Slack Movement	Target Value
Y	23240.000	0.000	0.000	23240.000
X ₁	97.080	-80.299	0.000	16.781
X ₂	0.000	0.000	0.000	0.000
X ₃	33.034	-27.324	-4.901	0.809

Y: Purchased quantity (kilo's), X₁: Markup, X₂: Delivery, X₃: Selling History

S₈ should reach 16.781 and 0.809 level, on the inputs X₁ and X₃ to move on to the efficiency frontier.

Table 11: DEA results for supplier S₉

Variable	Original Value	Radial Movement	Slack Movement	Target Value
Y	14916.000	0.000	0.000	14916.000
X ₁	91.670	-84.134	0.000	7.536
X ₂	3.300	-3.029	0.000	0.271
X ₃	23.298	-21.383	-1.624	0.291

Y: Purchased quantity (kilo's), X₁: Markup, X₂: Delivery, X₃: Selling History

Table 11 shows the improvement targets for supplier S₉. The application of the AHP is performed using same three performance criteria. The hierarchy structured is presented in Figure 1.

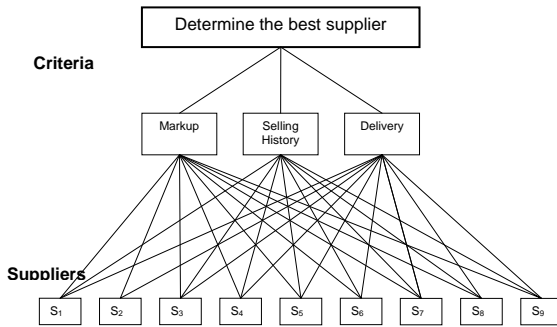


Figure 1. The structure of the supplier evaluation problem
 Since the markup, selling history and the delivery criteria are quantitative, the observed values are used in calculations and values are given in tables from 12 to 14. Only pair wise comparison is made for determining the criteria weights.

Table 12. Normalized Values for Markup

Suppliers	Normalized Values
S ₁	0.099
S ₂	0.086
S ₃	0.125
S ₄	0.170
S ₅	0.086
S ₆	0.127
S ₇	0.096
S ₈	0.055
S ₉	0.156

Table 13. Normalized Values for Selling History

Suppliers	Normalized Values
S ₁	0.255
S ₂	0.222
S ₃	0.196
S ₄	0.008
S ₅	0.139
S ₆	0.069
S ₇	0.065
S ₈	0.019
S ₉	0.027

Table 14. Normalized Values for Delivery

Suppliers	Normalized Values
S ₁	0.097
S ₂	0.097
S ₃	0.101
S ₄	0.086
S ₅	0.105
S ₆	0.103
S ₇	0.105
S ₈	0.105
S ₉	0.102

The calculated supplier priorities are given on the Table 15. The performance rankings of the supplier are given on the Table 16. All consistency ratios are calculated below 0.10.

Table 15. The supplier priorities based on performance criteria (AHP)

	M (0.320)	SH (0.557)	D (0.123)	SP
S₁	0.099	0.255	0.108	0.187
S₂	0.086	0.222	0.108	0.165
S₃	0.125	0.196	0.112	0.163
S₄	0.170	0.008	0.095	0.070
S₅	0.086	0.139	0.117	0.120
S₆	0.127	0.069	0.114	0.093
S₇	0.096	0.065	0.117	0.081
S₈	0.055	0.019	0.117	0.043
S₉	0.156	0.027	0.113	0.079

S_i:Suppliers, M: Markup SH: Selling History D: Delivery SP: Supplier Priorities

Table 16. The performance ranking of the suppliers

Suppliers	Performance Level
S₁	0.187
S₂	0.165
S₃	0.163
S₅	0.120
S₆	0.093
S₇	0.081
S₉	0.079
S₄	0.070
S₈	0.043

S_i:Suppliers

Table 16 states that S₁ is the best suppliers followed by S₂. The supplier with the worst performance is S₈.

The rankings obtained by two methodologies are given on Table 5.

Table 17. The rankings obtained by DEA and AHP

DEA Ranking	AHP Ranking
S ₁ (1)	S ₁
S ₅ (1)	S ₂
S ₃	S ₃
S ₂	S ₅
S ₇	S ₆
S ₆	S ₇
S ₈	S ₉
S ₉	S ₄
S ₄	S ₈

S_i Suppliers, Suppliers with (1) are the efficient suppliers.

Table 17 shows that S₁ is the best supplier for two methods. But since it is possible to have more than one DMU's on the efficient frontier S₅ is also best for DEA method. S₄ is the worst supplier obtained by DEA and S₈ the worst supplier for AHP methodology. The consistency of the two methodologies is tested with the Spearman's rank correlation test. The results are given on the Table 18

Table 18. The Consistency of DEA and AHP Results

Spearman's Rank Correlation Coefficient	Z-Statistics
0.845*	2.391

*, %5 statistically significance level

Table 18 shows that, the rank correlation coefficient is statistically significant at %85 level and implies a rank correlation of about 85 percent. This level of consistency states that, the results obtained by DEA and AHP are highly consistent, but there is no %100 consistency between the results of the two methodologies.

There are two main reason of the difference of the results obtained by two methodologies. The first reason is, in AHP the weights of the performance criteria are determined by pairwise comparison subjectively. But in DEA method, the weights are

obtained by the solution of the mathematical model without any subjective effect. The second reason of the difference is, the efficiency score in DEA is calculated with the relationship between inputs and outputs. Therefore in AHP the performance level is obtained by the mixed calculation of the pairwise comparison results for the criteria and the observed performance values.

DEA has important advantages on AHP:

- a.** Objectivity: The results of the DEA obtained by the solution of the mathematical model without any subjectivity.
- b.** Benchmarking: DEA presents the reference suppliers for inefficient suppliers.
- c.** Determining improvement targets: Based on the efficient suppliers DEA gives the improvement targets for inefficient suppliers.
- d.** Negotiation tools: DEA supplies negotiation tools and values for each performance criteria.

Conclusion

Increasing competition among the corporations in the global market is today leaving the stage to the competition among the network of corporations. Leading this competition requires increasing productivity, minimizing costs and customer response times. An efficient supply-chain and performance-based supply-chain management as well as other within-corporation processes are vital to reach these objectives. Suppliers are one of the most important chains of the supply-chain. The quality of products, total costs and customer satisfaction under these circumstances are directly affected by the supplier performance. Hence, supplier evaluation has a strategic importance for the corporations. The results reached by using the right performance criteria and evaluation method would produce robust solutions towards improving the performance of suppliers.

The first aim of this study is to develop suitable supplier performance criteria and criteria weights based on the performance criteria determined for the retail industry in the literature. The evaluation of supplier performances by DEA and AHP and make a comparison between them is the second aim of this study.

The performance criteria used for supplier evaluation are, markup, delivery and selling history. The best t supplier based on AHP methodology is S_1 . S_1 and S_5 are the best suppliers based on the DEA method.

The objectivity, benchmarking, determining improvement targets and negotiation tools proprieties make DEA better supplier performance evaluation methodology than AHP. The rankings obtained by the two methodologies are highly consistent based on the Spearman's rank correlation coefficient.

Two multiple-criteria supplier performance evaluation methodologies and their comparison presented in this study. The integration of the these two methodology is left as a subject for future research.

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