World Applied Sciences Journal 28 (12): 2254-2259, 2013
ISSN 1818-4952
© IDOSI Publications, 2013
DOI: 10.5829/idosi.wasj.2013.28.12.2074

A Mathematical Model to Select Suppliers Through Data Envelopment Analysis Integrated and Total Cost of Ownership Approaches (Case Study: Value Chain in Iran Automotive Industry)

[1]Akbar Rahimipoor and [2]Masomeh Tadriss Hasani

[1]Young Researchers Club, Sirjan Branch, Islamic Azad University, Sirjan, Iran
[2]Department of management, Rasht Branch, Islamic Azad University, Rasht, Iran

Abstract: Suppliers are critical members of an organization which could have lots of effects on performance of the organization. Due to various effects, a review on choosing methods of suppliers is necessary. Total cost of ownership is one of the modern methods apply for choosing and assessing suppliers. This approach provides required information related to the matter "assessing and choosing suppliers". This investigation seeks to select and evaluate automotive component suppliers using concept of Total Cost of Ownership. The present study uses Data Envelopment Analysis based on multiple criteria of Total Cost of Ownership concept and data related to automotive components manufacturing companies analyzed in 2010, by a strategic approach able to decrease Total Cost of Ownership for each company. In fact Data Envelopment Analysis introduces the most efficient suppliers with the least total cost and presents some strategies for other manufacturing companies of automotive components to reach efficiency.

Key words: Choosing supplier · Total Cost of Ownership · Data Envelopment Analysis · Supply chain Management

INTRODUCTION

Choosing a set of suppliers is a critical matter for organizations' success. During recent years, importance of choosing suppliers has been considered and emphasized a lot. Effective suppliers selection and evaluation is an important responsibility which shall be considered by purchases managers. Importance of choosing suppliers is due to its effectiveness on elements related to productions of organizations. Elements such as: price, design, production ability, quality and etc [1]. Lewis believes that no responsibility related to purchases is important like choosing a proper resource. Ingland and Liderz also have the same idea. They believe that choosing suppliers is the most important responsibility in purchasing. Later, Weber and *et al* mentioned that "in today's competitive environment availability to success in manufacturing with law cost and high quality without considering sellers' satisfaction is impossible". Therefore one of the most important purchase decisions is choosing and preserving a complete group of suppliers. Of course there is recently another concept called supply chain management has been provided and therefore researchers and jurists have more found that suppliers-selection management is a factor lead to increase in competition in all over the supply chain [2]. In supplier-selection decision making two issues should be considered: the first is that what criterion should be used and the second is what method should be exploited to compare suppliers. Weber and *et al* in 1991 pointed that as choosing suppliers is a complicated matter, various criterion could be considered for this choice. This issue is true about using different strategies for supplier-selection. In fact analyzing these two issues to select suppliers has been considered by many of universities' authorities and jurists in the matter of purchasing [2]. But the criterion that has much been under consideration during recent years is Total Cost of Ownership approach [3]. The present study seeks to investigate a proper supplier among automotive components manufacturing companies for parent company. Regarding that there are lots of methods to select and evaluate suppliers and as old methods of

Corresponding Author: Young Researchers Club, Sirjan Branch, Islamic Azad University, Sirjan, Iran.
Tel: +98-9197270728.

evaluation are not able to offer a complete and comprehensive evaluation of suppliers, this study has used Total Cost of Ownership approach to evaluate and select the best supplier. In addition to determine the most efficient supplier among component manufacturing company, statistical techniques of Data Envelopment Analysis was used. They are approaches which exploiting them lead to more efficiency and more usefulness in decision making to suppliers evaluation and selection.

DISCUSSION

Suppliers are a complementary part of supply chain process for an organization and as they are not included in organization, suppliers management requires a specialized skill in discussion. Suppliers should be selected properly because they can effect positively or harmfully on general performance of an organization. Various researches demonstrate that problems related to quality of production in organizations are due to imperfect raw material. Selecting competitive suppliers with precision minimizes harmful effects and in fact it increases positive effect on output quality of an organization. In other words, selecting a proper supplier is a crucial part included in organization [4]. It should be considered that traditional methods to select and evaluate suppliers, ignores a considerable amount of costs.

When all of these costs come into consideration, it has much influence on total cost concluding from producing process related to suppliers. These additional costs are ignored most of the time due to lots of reasons but the major reason is limitations related to evaluation system in traditional performance [5]. In fact it could be said that these evaluation methods are just based on price or firstly is based on price or quality evaluation which were applied absolutely or compatible with matrix models [6]. In this time, management is fronted by lack of worthy information to evaluate and select suppliers' performance. Therefore necessity of applying modern approaches in selection and evaluation process would be appeared. In an article written by Weber and *et al*, several professional and new methods are presented to evaluate suppliers [7]. This study uses criteria of total cost of ownership to evaluate performance of those automotive component manufacturing companies considered as parent companies to supply components. The study seeks to investigate the most proper supplier among component manufacturing companies based on total cost of ownership concept for parent companies until reminds managers to investigate a new method to be able to evaluate and select their supplier because traditional methods to evaluate suppliers' performance are not able to carefully and properly evaluate suppliers. Concept of total cost of ownership has assisted managers to better understanding and costs managing related to supplier selection and therefore useful information would be accessed for development and discussion [8]. In this research, total cost of ownership is applied as an objective analysis toward some of costs related to purchase and envelopment analysis is exploited as an approach toward determining the most efficient supplier.

Review on Literatures: Importance of a proper framework to determine supplier in an organization is obvious when reviewing previous researches [6]. Total cost of ownership model is a tool for systematic computation for all costs related to decision making about investment on Stain Technique Information Technology which was introduced in 1987 by Gartner for the first time. He recommended to his customers to consider all depended cost to purchase after required computations and then decide [9].

There have been lots of researches about total cost of ownership which present a wide range of application of this technique. Some of these researches are as follow:

- In 2004 Ziger Digerio and *et al* dealt with study in application of total cost of ownership to serve Alcatel airlines selecting. This study presents a mathematical programming model to select suppliers in multi-service sections and simultaneously to determine market share for selected suppliers [10].
- In 2005 Soyoung sohn and *et al*. represented an article topic on Total Cost of Ownership Model, A Model for customer centered. The proposed model in this research is for using total cost of ownership model which not only considered primitive costs but operation's costs and costs of lost opportunity including from mal-management of customer when it has passed more than one decade of the good's life [11].
- In 2006 Sebastian Morsinkof and *et al*. dealt with influences of data related to total cost of ownership in level of decision making for purchase. This research mentioned that how data obtained from total cost of ownership do influence on decision making and decrease its complication [12].
- In 2007 Hung Sik Kim and *et al* used total cost of ownership as a model to apply Logistic system of rural radio frequency. This article proposed total cost of ownership model for procurement system of Radio Frequency Identification software [5].

- In 2007 Jahani Hilala *et al*. represented an article with topic "selecting production line in compare with Methodology of Total Cost of Ownership". This article aims to represent methodology of total cost of ownership for assembling system and analyzing profit or lost. In addition it shows advantages of this technique to decide about system selecting.
- In 2009 Matthias Weber and *et al*. dealt with survey in decrease in structure of total cost of ownership to produce Medical appliances. In this article total cost of ownership methods are described as one of the approaches for costing based on activity throughout value chain to evaluate and analyze international costs for outsourcing activities [13].
- In 2006 Keivan Dadras, represented an article with topic "Supplier-selection process, Comparing Total Cost of Ownership and Analytical Hierarchy Process". Methods of supplier-selection are introduced in this article and finally Total Cost of Ownership and Analytical Hierarchy Process are compared [14].
- In 2006 Reza Mohammadi wrote an article with topic "Data Envelopment Analysis for supplier-selection based on concept of Total Cost of Ownership" which we dealt with in the part "Data Envelopment Analysis" [8].
- In 2007 Ramantan and *et al*. conducted a study with topic "Supplier-selection, an integrated approach of Data Envelopment Analysis and Analytical Hierarchy Process based on concept of Total Cost of Ownership. This study seeks a way to integrate Total Cost of Ownership and Analytical Hierarchy Process to select proper suppliers for a company [4].

Theoretical Framework: Total cost of ownership technique is a purchase tool and a philosophy which seeks an understanding of real costs of a good or representing a definite service from a special supplier. While there are lots of authorities to use this approach, especially in USA companies, but compatibility with this concept is going slowly. This approach is a complicated process which requires purchase by companies to determine more important and considerable costs during process of reaching, maintenance, usage and consequence production of a good or service [2]. It could be say that model of total cost reflexes the final statues which not only includes costs of purchase or investment but it considers all future applied aspects and maintaining tools, devices or system and lead to decrease in probable costs which creates in investment or purchase. This model is very useful in accurate economical evaluation of structures of systems like Logistic which requires high initial investment [8]. But to become more applied, proper tools should be used for evaluation through this approach, tools such as Data Envelopment Analysis. Data envelopment analysis has various models and this variety is increasing but all of them are based on some main models called CCR_BCC and BCC_CCR and BCC and CCR which are designed by originators of this branch of science [15]. Figure 1 represents a simple model of data envelopment analysis for supplier-selection which has represented in 2006 by Reza Mohammadi and it is the major resource for the present research.

As it is shown in the figure above, input variables which are parts of total cost of ownership model criteria, divides into 5 main categories:

- Production cost including: Raw materials, human power, dissipation of machinery, storehouse cost.
- Cost of quality including: Inspection costs, rework, wastes, ranking, sales returns, delay in delivery.
- Cost of technology including: Designing cost and engineering cost.
- After sale services cost including: Guaranty cost and costs related to customers' complaint.
- Price which includes Cost of goods sold [8].

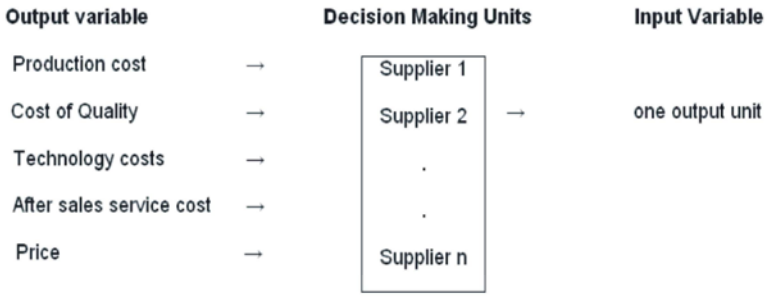

Fig. 1: *A simple model of data envelopment analysis for supplier-selection [8]*

Table 1: Cost of each section and total cost of each unit of suppliers (numbers are based on 1000 Rial)

Supplier	Production Cost	After Sale Service Cost	Price	Total Cost
1	411	511	628	1550
2	445	517	530	1429
3	541	511	578	1630
4	531	511	640	1682
5	311	513	551	1375
6	255	515	588	1358
7	445	517	560	1522
8	243	516	696	1455
9	269	523	628	1420
10	203	531	568	1302
11	439	525	608	1572
12	259	511	530	1302

Therefore, regarding to this categorization, Table 1 shows aspects of direct and indirect costs included during the process of production of 12 suppliers of automotive components. These costs are divided into 4 main categories including: production cost, quality cost, after sales service cost and price.

Questions: This research aims to responses following main question:

Which supplier of automotive components manufacturing company is able to provide required components of parent company using concept of total cost of ownership?

Also the following questions are as secondary questions:

- Which are efficient suppliers by virtue of selected supplier through total cost of ownership approach?
- Is there any relation between efficiency of other suppliers and the most efficient supplier?
- How could change an inefficient supplier to an efficient one?

Research Methodology: The present research method is applied in terms of purpose and it is descriptive in terms of data collection. This study has dealt with statues of input variables in 12 automotive component suppliers. Data collection in the primitive levels has obtained from libraries and in the next levels it was done by field research. Seeking for requested data related to this research, the researcher could manage documents and financial statements by referring to components manufacturing companies. In the next stage, obtained data analyzed by non-parametric statistical techniques of data envelopment analysis to select the most efficient supplier of automotive components for parent company.

Modeling and Data Analysis: In this research, envelopment model of BCC (input oriented), holding several inputs and one out has been used. This envelopment model determines the amount of suppliers' efficiency so that while decreasing input multi variables, an especial output unit creates. When an especial output unit creates, all suppliers locate in an optimized level. Equation 1 represent general figure of input envelopment BCC model with several inputs and one output. In this model number of considered units is based on an experimental relation in related to number of units under evaluation and number of inputs and outputs should be three times more than total number of outputs and inputs [16]. As we have 3inputs in this research, therefore number of units under consideration should be at last 9 units.

Equation 1

$$Miny_0 = \theta$$

$$st:$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{r0} \qquad (R=1,2,\ldots\ \ldots\ \ldots S)$$

$$\theta x_{i0} - \sum_{j=1}^{n} \lambda_j x_{ij} \geq 0 \qquad (i=1,2,\ldots\ \ldots\ \ldots m)$$

$$\sum_{j=1}^{n} \lambda_j = 1 \qquad (j=1,2,\ldots\ \ldots\ \ldots n)$$

$$\lambda_j \geq 0$$

In this equation, θ shows ratio of decrease in inputs under consideration, to develop efficiency, x shows inputs, y is outputs and λ shows corresponding variable with other limitations.

As it has shown in Table 1, columns 2, 3, 4 and 5 show status of input variables in 12 automotive component manufacturing companies. Total cost for each supplier which in fact is total of the four mentioned columns, has shown in column 6. Among the 12 companies, suppliers Nos. 10 and 12, have the least total cost. Of course such a conclusion will not obtain if each unit is surveyed separately. For example cost of after sales service of supplier No. 10,is more than other suppliers. But regarding to the total cost of ownership, suppliers Nos. 10 and 12 are the most efficient suppliers of required components for parent company.

Table 2: Results of input envelopment model

Supplier	Production Cost	After Sale Service Cost	Price
2	186	---	---
4	120	12	---
6	---	---	9.318
7	37.393	---	----
9	---	---	82.806
2	186	---	---

Table 3: Amount of the original restrictions ininefficient units to reach the border of efficie

Supplier	1	2	3	4	5	6	7	8	9	10	11	12
Technicalefficiency	100	100*	100	100*	99.9	99.8	99	100	98.1	100	97.4	100

Table 4: Changes on each unit to reach to efficiency

Supplier	Production Cost	After Sale Service Cost	Price	Total Cost
1	---	---	---	1
2	445to 259	517 to513	---	1
3	---	---	---	1
4	531to411	---	640 to 628	1
5	to310.687 311	513 to512.485	551 to550.446	1
6	254.434to225	515to513.856	588to577.376	1
7	445to403.284	517to511.977	560to554.559	1
8	---	---	---	1
9	269to263.824	523to512.937	628to533.11	1
10	---	---	---	1
11	439to427.607	511.376to525	608to592.222	1
12	---	---	---	1

Table 5: Source unit of each company and ratio between them

Supplier	Source Unit No.	Ratio	Source Unit No.	Ratio	Source Unit No.	Ratio
1	1	1				
2	12	1				
3	3	1				
4	1	1				
5	1	0.161	3	0.096	12	0.742
6	8	0.285	12	0.715		
7	3	0.512	12	0.488		
8	8	1				
9	1	0.032	12	0.968		
10	10	1				
11	1	0.465	3	0.347	12	0.188
12	12	1				

CONCLUSION

Table 2 represents conclusions of input envelopment model. As it has shown in this table, automotive component manufacturing companies Nos. 1,3, 8 are the most efficient supplier considering data envelopment analysis technique like company Nos. 10 and 12 which had the least amount in total cost model. May be other suppliers have efficiency by Farrell scale but they do not have efficiency by data envelopment analysis. It means that efficiency is small in some cost and it does not exist in total cost. For example suppliers Nos. 5, 6, 7, 9, 11 have efficiency less than 1 by Farrell scale but suppliers Nos. 2 and 4 have efficiency qual to 1 by Farrell scale but they have very small efficiency by data envelopment analysis. In fact these two suppliers have efficiency in the units after sale services cost and price, but as they face with limiter issues in other units, they have small efficiency by envelopment analysis. Table 3 shows the amount of the original restrictions that other inefficient companies are faced. In fact, this table represents The fundamental changes in the structure of the relevant costs in the inefficient companie so they can y placed on the border of efficiency.

Table 4 shows the amount of changes which should be included in suppliers. For example supplier No. 5 should decrease its production cost from 311 to 310.687,its after sale services cost from 513 to 512.458, its price from 551 to 550.446, to reach efficiency so that locate on efficiency boundary. Table 5 represent efficiency resource unit.

In fact this table shows efficiency units which other suppliers are evaluated according them.

For example supplier No. 2 is evaluated according to supplier No. 12. because it has closer cost to this unit. Ration of this unit to efficiency unit is 1. Supplier No. 6 evaluates according to suppliers No. 8 and 12. The reason is that in some of the costs it is closer to efficiency unit 8 and in some of the cost it is closer to efficiency unit 12 and therefore ratio of this supplier to efficiency unit 8 is 0.2854 and to efficiency unit 12 is 0.715 and totally this ratio will be 1.

CONCLUSION AND SUGGESTIONS

Modern methods to evaluate suppliers' performance, provides good information for managers. Using this approaches help to costs management. Managers could decrease total cost including from production process by managing costs which are more important during the process and select suppliers who is more compatible with their criteria. To select these criteria lots of approaches could be used.Modern approaches such as: costing in terms of purpose, Kaizen costing technique, Costing based on activity, Balanced Score Card model and lots of other techniques which are using increasingly. The use of such techniques are the trail along with new assessment for example DEA, Not only can help to, the correct diagnosis and evaluation of the performance of managers in their comanies, But cases of misleading the goals of heavily illustrated and remembered managers to achieve efficiency, research of the perfect solutions to reduce some of the costs and pay attation to the management of the cost of their companies.

REFERENCES

1. Narasimhan, Ram, Talluri, srinivas, Mendez David, 2001. Supplier evaluation and rationalization via data envelopment analysis:an empirical examination. The Journal of Supply Chain Management.
2. Lee, Eonkyung, Ha, Sungdo and Kim Shenungkown, 2001. Supplier selection and management system considering relationship in supply chain management.ieee transactions on Engineering Management, 48(3).
3. Zhang, zhiming.,jiasu, lening cao., kinman, tokengpong.,(2007). Evoulution of selection criteria and methods.European journal of Operational.
4. Ramanathan Ramakrishnan, 2007. Supplier selection problem: integrating DEA with approaches of total cost of ownership and AHP.supply chain Management Journal, 12(4): 258-261.
5. Kim Sik, Sohn, Hong, Young, so., 2007. Cost of ownership model for the RFID logistics system applicable to u-city, Department of Information and Industrial Engineering.
6. Ellram M. Lisa, 1995. Total cost of ownership:an analysis approach to purchasing. International Journal of Physical Distribution and Lagistics Management, 25(8).
7. Weber, A. Charles, Current, R. John and C. Bentom, 1991. Vender selection criteria and methods. European journal of Operational Research.
8. Mohammady Garfamy Reza, 2006. A data envelopment analysis approach based on total cost of ownership for supplier selection. Journal of enterprise Information Management, 19(6): 662-678.
9. Rust Bill and Stegman Eric, 2003. Why total cost of ownership (TCO) matters.
10. Degraeve Zegar, Labor Eva and Roodhooft Fillip, 2004. Total cost of ownership purchasing of a service:the case of airline selection at alcatel bell.
11. Sohn Soyoung, Lee, Ji so, 2005. Cost of ownership model for CRM system. department of computer science and industrial systems engineering.
12. Morssinkhof, Sebastiaan., wouters, marc, warlop, Luk., 2006. Effects of providing total cost of ownership information on attribute weights in purchasing decisions.
13. Weber, Matthias, Hiete, Michael, Lauer, Lars and Rentz Otto, 2009. Low cost country sourcing and its eeffects on the total cost of ownership structure for medical devices manufacturer.
14. Dadrasy Kaivan, 2006. The issue of choice of supplier comparison method of total cost of ownership and the process of hierarchical analysis., Ravesh Magazine., 15(102): 34-39.
15. Mehregan Mohammadreza, 2008. Quantity models in the evoulution of organizations., Tehran second edition, Publishing Management College.
16. Azar Adel and Motameny Aliraza, 2003. Measuring productivity in manufacturing companies by data envelopment analysis models., danesh var rafter magazine., Shahed University, pp: 44.