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ANALYTIC HIERARCHY PROCESS FOR SUPPLIER SELECTION PROBLEM IN SUPPLY CHAIN MANAGEMENT: CASE STUDY OF A TEXTILE MANUFACTURER FIRM

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ABSTRACT

Supply Chain Management (SCM) offers some business solutions to companies in various sectors by increasing customer service while minimizing costs. Supply chains for suppliers, manufacturers, distribution centers, resellers, customers or any other members differs from each other depending on their business functions, goals, types of organizations etc. Thus, the definition of supply chain varies from one company to another. But in general, SCM can be defined as a *complex business relations network* that contains synchronized efforts among these business entities to plan, control, coordinate and distribute raw materials, parts, subassemblies and finished goods from suppliers to ultimate customers. It can be strongly claimed that, the most important objective of SCM is to ensure production and delivery of products at the right diversity, with the right amounts, at the right time and to the right locations. In order to achieve this aim, some strategic decisions have to be made such as finding number of plants (manufacturing facilities, distribution centers, cross-docks etc.) to be opened, defining location of these plants, *choosing suppliers* to use (called *Supplier Selection Problem*), determining transportation times and modes, and creating supply chain strategies. In this study, supplier selection problem in SCM is considered with the help of Analytic Hierarchy Process. A case study in a textile manufacturer is presented.
Keywords: Supply chain management, supplier selection, analytic hierarchy process.

TEDARİK ZİNCİRİ YÖNETİMİNDE TEDARİKÇİ SEÇİMİ PROBLEMİNE ANALİTİK HİYERARŞİ SÜRECİ YAKLAŞIMI: BİR TEKSTİL İMALATÇISI İŞLETME ÖRNEK OLAYI

ÖZET

Tedarik Zinciri Yönetimi (TZY) çeşitli sektörlerdeki işletmelere maliyetleri düşürürken müşteri hizmet seviyelerini yükselterek iş çözümleri sunmaktadır. Genel olarak TZY, tedarikçiler, imalatçılar, dağıtım merkezleri, perakendecilerden oluşan karmaşık iş ilişkileri ağındaki iş öğeleri arasındaki karşılıklı çabaların planlaması, kontrolü, koordine edilmesi, uyumlu hale getirilmesi olarak tanımlanabilir. TZY'nin en önemli amaçlarından biri üretim ve dağıtımın doğru çeşitlilikte, doğru miktarda, doğru zamanda ve doğru yerde gerçekleştirilmesinin sağlanmasıdır. Bu amaca ulaşmak için, açılacak tesislerin (fabrika, dağıtım merkezi vb.) belirlenmesi, tedarikçi seçimi gibi bazı stratejik kararların verilmesi gerekir. Bu çalışma da, Analitik Hiyerarşi Süreci yardımıyla, bir tekstil firmasında tedarikçi seçimi problemi ele alınmıştır.
Anahtar Sözcükler: Tedarik Zinciri Yönetimi, tedarikçi seçimi, analitik hiyerarşi süreci.

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1. INTRODUCTION

Supply Chain Management (SCM) has recently received a lot of interest due to the emergence of highly liberalized and globalized markets, increasing customer requirements, raising satisfaction levels, shrinking product life cycles, and fluctuating material costs (especially oil) depending on the economic and/or politic events all over the world [1].

The SCM problem may be considered at different levels depending on the planning horizon and the detail of information needed: strategic, tactical and operational. Design and optimization of supply chains is one of the strategic fields to be studied in the area of SCM [2- 3]. A supply chain is a network of business entities such as suppliers, plants, distribution centers and customer zones, which information and materials -raw materials, components and finished items-flow through. On the other hand, SCM is a management technique, which can reduce wastes through the business network and can increase the efficiency and profitability of all the members with a strong cooperation and high integration level between them [4].

SCM is referred to as an integrated system which synchronizes a series of inter-related business processes in order to: (1) acquire raw materials and parts; (2) transform these raw materials and parts into finished products; (3) add value to these products; (4) distribute and promote these products to either retailers or customers; (5) facilitate information exchange among various business entities (e.g. suppliers, manufacturers, distributors, third-party logistics providers, and retailers) [5].

It can be strongly claimed that the most important objective of SCM is to ensure production and delivery of products at the right diversity, with the right amounts, at the right time and to the right locations. In order to achieve this aim, some strategic decisions have to be made such as finding number of plants (manufacturing facilities, distribution centers, cross-docks etc.) to be opened; defining location of these plants; choosing suppliers to work with, determining transportation times and modes; creating supply chain strategies (Table 1).

Table 1. Tasks of supply chain design

Tasks	Supply Chain Entities
Find number of __ to be opened.	Plants (manufacturing facilities), distribution centers, cross-docks etc.
Define location of __	Plants, distribution centers, customers.
Find time of __	Supply chain lead time that consists of supplier delivery times, cycle times in plants and transit times spent between stages and refers the time interval from supply time of raw materials to delivery of finished goods to last customers.
Determine quantity of __	Materials/items to be supplied. Products to be produced. Capacities of plants and distribution centers (DCs). Demands of customers.
***Select* __**	**Suppliers.** **Distribution channels/options.**
Create strategy related to __	Distribution management. Outsourcing/third party logistics. Inventory management. Information technologies.

A number of attempts have been made to model and optimize supply chain systems. In their pioneering paper, Cohen and Lee [6] developed a deterministic, mixed integer, non-linear mathematical programming model. Pyke and Cohen [7] present a stochastic mathematical programming model for a tree-stage supply chain consisting of one manufacturing plant, one warehouse and one retailer. Petrovic et al. [8] consider a serial supply chain including inventories and production facilities between them in fuzzy environment.

Ganeshan et al. [9] examine the sensitivity of supply chain performance to three inventory planning parameters: *i*) the forecast error, *ii*) the mode of communication between echelons, and *iii*) the planning frequency, by developing a simulation model based on a case study. Syarif et al. [10] propose a minimum spanning tree based on genetic algorithm approach for a multi-stage supply chain problem formulated by 0-1 mixed integer linear programming model. Yan et al. [11] propose a mixed-integer programming model for supply chain design with consideration of bills of materials. They use logical constraints to represent bills of materials and the associated relationships among the main entities of a supply chain such as suppliers, producers and distribution centers. Sundarraj and Talluri [12] present a multi-period integer-programming model to assist decision makers in the procurement of component based enterprise information technologies. Jayaraman and Ross [13] consider a mixed integer linear programming model to determine locations (for distribution centers and cross-docks) and distribution strategies in supply chain management. They propose a simulated annealing approach for the model, which is characterized by multiple product families, a central manufacturing plant site, multiple distribution center and cross-docking sites, retail outlets, and evaluate the computational performance of the proposed approach under a variety of problem scenarios. Deshpande et al. [14] model a supply chain using a multi agent framework. They propose a real-time scheduler for the task assignment that can schedule new orders with soft real-time deadlines. The scheduler is based on an algorithm using the fuzzy set approach for the real time operation in a supply chain. Erol and Ferrell [15] develop a model that simultaneously assists an industrial distributor in making two decisions: assigning suppliers to warehouses and assigning warehouses to customers. Their model uses a multi objective optimization-modeling framework and allows information on the distributors simultaneously to satisfy several conflicting objectives like minimizing cost and maximizing customer satisfaction. Guillen et al., [16] formulate the *supply chain design problem* as a multi objective stochastic Mixed Integer Linear Programming (MILP) model, which is solved by using the standard ε-constraint method, and branch and bound techniques. This formulation does not only take supply chain profit over the time horizon and customer satisfaction level into account, but it also considers uncertainty by means of the concept of financial risk associated with different design options, resulting in a set of Pareto optimal solutions.

Based on the above comments, in this study, supplier selection problem as a design task in SCM is considered with the help of Analytic Hierarchy Process (AHP). Because, the problem is based on making comparisons and AHP technique has been applied extensively for this type of problems (resource allocation, facility location, portfolio selection etc.). Initially, a case study in a textile manufacturer is presented. In the second section, the AHP is summarized. In the third section the case study is introduced. Finally, in the fourth section, concluding remarks are given.

2. METHODOLOGY: ANALYTIC HIERARCHY PROCESS (AHP)

In this study, Analytic Hierarchy Process (AHP), which is proposed by Saaty [17] and a powerful tool that, provides decision maker (DM) to recognize decision mechanism himself and therefore to make the best alternatives easy to choose, is used to select suppliers.

Using Saaty's pairwise comparison scale (Table 2), we can determine the relative weights of the set of objectives in respect to each other and express them in a pairwise comparison matrix.

Saaty [17] simulated random pairwise comparisons for different size matrices, calculated the consistency indices, and arrived at an average consistency index for random judgments for each size matrix. Table 3 gives information on compatibility and consistency for different size judgment matrices.

Table 2. Pairwise comparison scale used in AHP [17]

Importance/ Preference Level	Verbal Definition	Explanation
1	*Equal* importance of both elements	Two elements contribute equally
3	*Moderate* importance of one element over another	DM favors one element over another
5	*Strong* importance of one element over another	DM favors one element strongly
7	*Very strong* importance of one element over another	An element is very strongly dominant
9	*Extreme* importance of one element over another	An element is extremely dominant
2, 4, 6, 8	Intermediate values	Used to compromise between two judgments

Table 3. Relationship between consistency and compatibility for a different number of elements [17]

Dimension of Matrix	3	4	5	6	7	8	9	10
C.R.=C.I./R.I.	0.05	0.08	0.10	0.10	0.10	0.10	0.10	0.10
Dimension of Matrix	11	12	13	14	15	16	17	18
C.R.=C.I./R.I.	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10

Consistency Ratio (CR = CI/RI) is the ratio of the consistency index to the average consistency index for random comparisons for a matrix of the same size. Inconsistency ratio of about 10% or less is usually accepted.

3. CASE STUDY OF A TEXTILE MANUFACTURER FIRM

The textile manufacturer firm that studied with, is a part of a holding company's constitution, and started functioning at Konya 2. Organized Industry District in December 2002. It was founded on a 28000 meter square field, where a 5000 meter square building set on. Activity subject is on garment. Company's products such as Sweat with Zipper, T-Shirt, and Sweat with Hood and Athlete with Hood are for both men and women. It ships to various countries in Europe. Average annual production is 2.500.000 items per year. It employs 308 people and has also a machine park, which includes 132 machines. 62 of these machines are regular, 34 of them are pattern sewing machines and 36 of them are overlockers. The firm worked with 3 bands when it was founded. Later on, the number of the band increased up to 6. All of the products of the company are exported. Many of its products are sold to European countries; Australia; United States and Canada. It has well-known customers like Adidas, Zara, Quelle, Next, Cecil, Benetton, Carnet De Vol and Topman.

The firm obtains the yarn for manufacturing from six different suppliers that are: SX, AX, CX, BX, RX and TX Tekstil. The firm's purpose is reducing the number of suppliers by eliminating some of them in order to increase efficiency in the supply chain. The textile firm proposes seven criteria during the elimination of the suppliers:

1. **Quality:** For the yarn, the company seeks the satisfaction of two requirements. First one is *"color quality"*, which requires the dye would not release off the yarn easily. The second requirement is *"strength"*, which seeks that the yarn would not fall apart easily if stretched. In the garment industry, meeting these criteria is vital for yarn quality. Because of being basic raw material/input, high-class yarn composes basic of high-class productions.

2. **Supply Performance:** This refers to the replenishment level of the yarn by the suppliers to the manufacturer. As well as to avoid delays in the manufacturing plans of the firm, it is also important to give confidence to the suppliers that the purchase of their product will be on a constant satisfactory level.
3. **Cost:** Cost is a major factor in determining the supplier. The quality of the yarns should be the same, the supplier that offered the lower price will have a stronger likeliness of getting chosen by the manufacturer.
4. **Compromise ability:** This refers to the agreeability level between the supplier and the manufacturer on the timing and the cost of the yarn. A short-term relation with a supplier is not desired because the manufacturer wants to receive standard quality material. In the past, the firm experienced that non-standard material processes ended up with inconsistent product quality. In addition, continuity on relations facilitates collective activities and makes a synergy.
5. **Technology:** The technology or automation levels of suppliers' are explicitly relevant to the quality of their products. Those suppliers that use more advanced technologies in their manufacturing processes have been observed to have higher quality products in the field. Therefore, the technology used by the suppliers is also to be considered by the textile manufacturer firm.
6. **Color procurement:** It means appropriating of accurate yarn tone from suppliers. For the company, this criterion has greater importance than the other criteria. The color tone to capture has very narrow tolerance intervals. Not meeting customers' color code requirement may cost loss of business with the current customers permanently.
7. **Distance:** If production planning and inventory control is not well managed, this criterion gets more important. But when the planning & control is reliable and suitable, it takes part behind of cost and quality. Because, planning has great importance in supply chain management. Basing on the affordable amount of security-stock levels, taking lead-time into account before yarn stock runs out can provide help for the right decision.

The decision structure, which captures the explained criterions above, about the supplier selection problem of the textile firm, is given in the Figure 1 below.

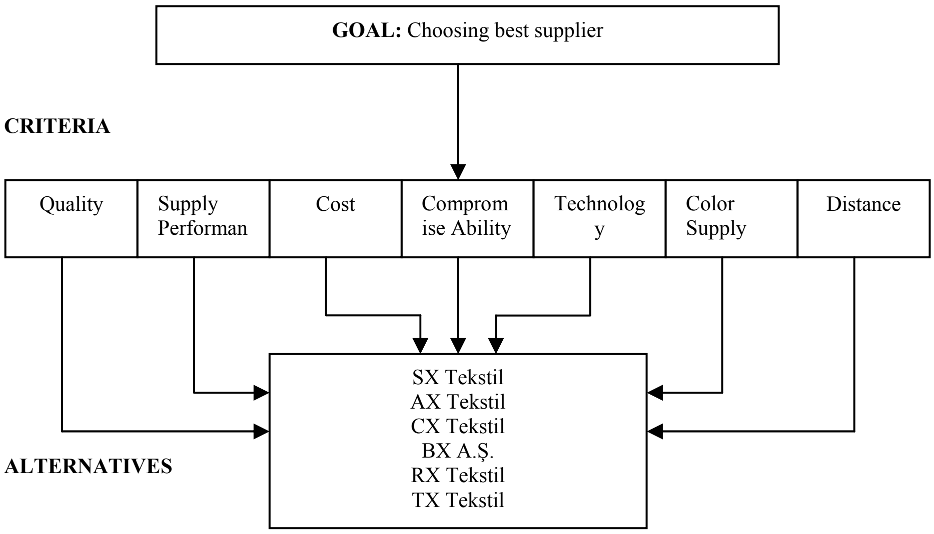

Figure 1. Hierarchy model

The matrix of pairwise comparisons of the criteria given by the textile manufacturer firm in the case study is shown in Table 4. The judgments are entered using the Pairwise Comparison Scale (Table 2), first verbally as indicated in the scale and then by associating the corresponding number.

Table 4. Pairwise comparison matrix with respect to the goal

GOAL	Quality	Perform	Cost	Compro.	Technol.	Color	Distanc e
Quality	1	4	1/3	3	4	1/3	5
Performance		1	1/6	1/3	1/3	1/7	2
Cost			1	4	5	1/2	7
Compromise				1	2	1/5	5
Technology					1	1/7	4
Color						1	9
Distance							1

Using Pairwise Comparison Matrix, as displayed in the Table 4 above, Inconsistency Index is found as 0.05<0.10 in ***Expert Choice*** software. Decision maker's evaluation is consistent. The weight values or the priorities derived from the judgments are following (Table 5):

Table 5. Priority values of criteria

Quality	Supply Performance	Cost	Comparison Ability	Technology	Color Supply	Distance
0.155	0.037	0.266	0.086	0.062	0.368	0.025

We now move to the pairwise comparisons of the alternatives/suppliers, comparing them pairwise with respect to how much more important one is than the other with respect to the criterion which is showed with shaded cell on the North West corner on the top of the Tables 6-12. Thus, there are seven 6x6 matrices of judgments since there are seven criteria, and six suppliers to be pairwise compared for each criterion (Tables 6-12).

Table 6. Pairwise comparison matrix with respect to the quality criterion

Quality	SX	AX	CX	BX	RX	TX
SX	1	4	5	3	2	1
AX		1	2	3	1/4	1/3
CX			1	½	1/4	1/5
BX				1	1/2	1/3
RX					1	1/2
TX						1

Here, the question asked to the manufacturer is "Of the two suppliers being compared, which is considered better with respect to performance criterion?" The answer is presented in Table 7.

Table 7. Pairwise comparison matrix with respect to the performance criterion

Performance	SX	AX	CX	BX	RX	TX
SX	1	1	3	4	2	2
AX		1	3	4	1/2	1/2
CX			1	1/3	1/4	1/3
BX				1	1/2	1/2
RX					1	1/2
TX						1

The manufacturer judgment which shows the relative "importance" of the suppliers with respect to the cost criterion is given below (Table 8).

Table 8. Pairwise comparison matrix with respect to the cost criterion

Cost	SX	AX	CX	BX	RX	TX
SX	1	6	8	5	7	4
AX		1	3	1	3	3
CX			1	1/3	2	2
BX				1	2	3
RX					1	1/2
TX						1

Table 9 reflects the manufacturer judgment about the relative "importance" of the suppliers with respect to the compromise abilities of suppliers.

Table 9. Pairwise comparison matrix with respect to the compromise ability

Compromise	SX	AX	CX	BX	RX	TX
SX	1	5	9	7	7	7
AX		1	5	6	7	6
CX			1	4	2	3
BX				1	3	2
RX					1	2
TX						1

Table 10 reflects the manufacturer judgment about the relative "importance" of the suppliers with respect to the technology criterion.

Table 10. Pairwise comparison matrix with respect to the technology criterion

Technology	SX	AX	CX	BX	RX	TX
SX	1	2	3	5	1/3	1/5
AX		1	2	4	1/4	1/5
CX			1	½	1/6	1/8
BX				1	1/4	1/5
RX					1	1/2
TX						1

Table 11 reflects the manufacturer judgment about the relative "importance" of the suppliers with respect to the color criterion.

Table 11. Pairwise comparison matrix with respect to the color procurement

Color	SX	AX	CX	BX	RX	TX
SX	1	1/3	2	5	1/2	1/2
AX		1	4	6	2	2
CX			1	3	1/4	1/5
BX				1	1/5	1/6
RX					1	2
TX						1

Table 12 reflects the manufacturer judgment about the relative "importance" of the suppliers with respect to the distance criterion.

Table 12. Pairwise comparison matrix with respect to the distance criterion

Distance	SX	AX	CX	BX	RX	TX
SX	1	1	1/2	1/8	1/2	1
AX		1	1/2	1/8	1/2	1
CX			1	1/5	1	2
BX				1	7	8
RX					1	2
TX						1

The priorities derived from the manufacturer judgments about criteria are evaluated by AHP. The relative importance of the suppliers with respect to each criterion and inconsistency ratios of the judgments are laid out in a matrix (Table 13) below.

Table 13. Supplier-criteria matrices' results

Firm/Criteria	Quality	Perfom.	Cost	Comp.	Tech.	Color	Distance
SX	0.294	0.274	0.520	0.525	0.136	0.122	0.063
AX	0.103	0.181	0.148	0.223	0.093	0.331	0.063
CX	0.048	0.055	0.073	0.108	0.040	0.067	0.100
BX	0.079	0.088	0.143	0.066	0.052	0.035	0.573
RX	0.198	0.183	0.049	0.040	0.265	0.240	0.115
TX	0.278	0.220	0.067	0.039	0.416	0.205	0.087
Inconsistency	0.05	0.08	0.06	0.09	0.06	0.04	0.06

Following AHP procedure, priority values for the suppliers are calculated as follows:

Table 14. Priority values of suppliers

SX	AX	TX	RX	BX	CX
0,294081	**0,21**0357	**0,17**5813	**0,16**156	**0,08**9644	**0,06**7817

As the result of implementation of AHP method, SX İplik, which carries on business as yarn factory in the holding company's constitution has the best performance among the six supplier firms. Although AX İplik is not a holding company and has no capital partnership, it also presented a good overall performance.

4. CONCLUSIONS

Due to the unpredictability of customer demand, great advancements in technology and communication channels (i.e. broadband Internet links), businesses jump over the local boundaries. In this environment, organizations face sophisticated customers that demand different specifications on products, lower costs, higher quality and faster response [18]. In the goal of taking cost and service quality/level into account, SCM would provide production and delivery of products at the right diversity, with the right amounts, at the right time and to the right locations while minimizing costs over the chain layout. So, to reach the "optimal layout", SCM makes some strategic decisions such as finding the number of plants (manufacturing facilities, distribution centers, cross-docks etc.) to be opened; defining location of these plants; choosing suppliers to use determining transportation times and modes; creating supply chain strategies.

In this study, a supplier selection problem in SCM is analyzed with the help of Analytic Hierarchy Process. A case study at a textile manufacturer firm is presented. After application of the explained model, the supplier with the optimal benefits to the company has been selected among six of them. This selection supports the approach of *vertical integration* of value chain activities. In this approach, the buyer firm owns its upstream suppliers (raw material suppliers, intermediate manufacturers etc.) and its downstream buyers (distributers). In our case, the integration type is backward integration and the textile manufacturer firm expands through upstream. The Analytic Hierarchy Process method supports the firm's vertical integration strategy.

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