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OPTIMAL PLANT LOCATION SELECTION IN APPAREL COMPANY BY USING MULTI CRITERIA DECISION MAKING METHOD

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DECLERATION

I hereby declare that this master's thesis titled as **"Optimal Plant Location Selection in Apparel Company by Using Multi Criteria Decision Making Method"** has been written by myself in accordance with the academic rules and ethical conduct. I also declare that all materials benefited in this thesis consist of the mentioned resources in the reference list. I verify all these with my honour.

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ABSTRACT

Master's Thesis

Optimal Plant Location Selection in Apparel Company by Using Multi Criteria Decision Making Method

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Nowadays companies with wide range of variety of products and services are trying to withstand against the economic and social changes; since they are influenced by these changes intensively. Since the present markets in this complicated structure have to be shared by the companies jointly, strict and compelling competition occurs. In such an intensive environment of global competition, determination of plant location is important as a strategic decision to be effective in a long term. Plant location defined as the most suitable place for realization of basic functions as supply, production, storage, distribution and economic targets related with these, has direct influence on production, distribution and productivity of the facilities. Therefore, plant location determined by a facility should be determined as a region providing low costs and high profits, realizing targets of the facility at long term. Plant location appears as a decision required to consider and to analyze many factors such as raw material supply, marketing, transportation costs, communication, and substructure depending on the activity of facility. It is necessary that determined location should match the necessities of the facilities in a best way. Using scientific methods, this process poses importance of the business in the long term. In case where the multiple alternative and evaluation factor at the same time are used for the decision points, multi-criteria decision-making methods offer very useful results. Due to the high share of added-value and

export revenue generated in the production process, structural changes and technological developments in recent years taking place; textile and apparel sector continue to be the leading sectors of the country since the 1980s. However, since the sector have faced various threats, it is necessary to assess the best way of decisions to make among the opportunities in her hands.

This study gave place to theoretical knowledge regarding the choice of the plant location and also examined the multi-criteria decision-making techniques. Then, an application was made on the selection of plant location at Turkish apparel industry.

Keywords: Apparel Industry, Multi-Criteria Decision-Making, AHP, Plant Location Selection.

ÖZET

Yüksek Lisans Tezi

Hazir Giyim İşletmesinde Optimal Kuruluş Yeri Seçiminin Çok Kriterli Karar Verme Tekniği ile Belirlenmesi

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Sosyal Bilimler Enstitüsü

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İngilizce İşletme Yönetimi Programı

Günümüzde ürün ve hizmet çeşitliliği bakımından geniş bir yelpazeye sahip olan işletmeler meydana gelen ekonomik ve sosyal alandaki değişimlerden yoğun bir şekilde etkilendikleri için bu değişimler karşısında ayakta kalmaya çalışmaktadırlar. Varolan pazarlar bu komplike yapı içerisinde küreselleşmeyle birlikte firmalar tarafından ortak olarak paylaşılmak durumunda olduğundan, firmalar arası sıkı ve zorlu bir rekabet meydana gelmektedir. Küresel rekabetin yoğun olarak yaşandığı böyle bir ortamda kuruluş yerinin belirlenmesi uzun vadede etkili olacak oldukça önemli bir stratejik karar olarak önem taşımaktadır. Tedarik, üretim, depolama ve dağıtım gibi temel fonksiyonlarını ve bunlara bağlı ekonomik amaçlarını gerçekleştirebileceği en uygun yer olarak tanımlanan kuruluş yerinin işletmelerin üretim, dağıtım ve verimlilikleri üzerinde doğrudan bir etkisi bulunmaktadır. Bu sebeplerden dolayı bir işletmenin belirleyeceği kuruluş yeri uzun dönemde hedeflerini gerçekleştirebileceği, düşük maliyet ve yüksek kârı sağlayabilecek bir bölge olarak belirlenmelidir. Kuruluş yeri seçimi, işletmenin faaliyette bulunduğu sektöre göre hammadde temini, pazarlama, taşıma maliyetleri, ulaşım, haberleşme ve altyapı gibi birçok faktörün bir arada düşünülüp analiz edilerek ele alınması gereken bir karar olarak ortaya çıkmaktadır. Belirlenecek yerin işletmelerin ihtiyaçlarını en iyi şekilde karşılayacak niteliklere sahip olması gerektiğinden, bu işlemin bilimsel metotlar kullanılarak yapılması uzun vadede işletme açısından önem teşkil etmektedir. Aynı anda birden fazla alternatifin ve

değerlendirme faktörünün bulunduğu durumda karar noktalarını değerlendirmede ise çok kriterli karar verme metotları ise oldukça yararlı sonuçlar sunmaktadır. Tekstil ve Hazır Giyim sektörü ise son yıllarda gerçekleşen teknolojik gelişmeler ve yapısal değişiklikler, üretim sürecinde yaratılan katma değer ve ihracat gelirleri içinde yüksek payı nedeniyle 1980'lerden bu yana ülkemizin lokomotif sektörlerinden olmaya devam etmektedir. Ancak sektör çeşitli tehditlerle karşı karşıya kaldığından elinde bulundurduğu fırsatları vermesi gereken kararları en iyi biçimde değerlendirmesi gerekmektedir. Bu çalışma dahilinde kuruluş yeri seçimi ile ilgili teorik bilgilere yer verilmiş, çok kriterli karar verme teknikleri incelenip, Türk Hazır Giyim Sektöründeki kuruluş yeri seçimi üzerine bir uygulama yapılmıştır.

Anahtar Kelimeler: Hazır Giyim Sektörü, Çok Kriterli Karar Verme, AHS, Kuruluş Yeri Seçimi.

OPTIMAL PLANT LOCATION SELECTION IN APPAREL COMPANY BY USING MULTI CRITERIA DECION MAKING METHOD

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ABBREVIATIONS

AHP	Analytic Hierarchy Process
ANP	Analytic Network Process
CI	Consistency Index
CR	Consistency Ratio
DEA	Data Envelopment Analysis
EQ	Equation
ELECTRE	The Elimination and Choice Translating Reality
FAHP	Fuzzy Analytical Hierarchy Process
FMCDM	Fuzzy Multi Criteria Decision Making
GP	Goal Programming
ITKIB	İstanbul Tekstil ve Konfeksiyon İhracatci Birlikleri
MADM	Multi Attribute Decision Making
MCDM	Multi Criteria Decision Making
MODM	Multi Objective Decision Making
MAUT	Multi Attribute Utility Theory
PROMETHEE	Preference Ranking Organization Method for Enrichment Evaluations
RI	Random Index
TOPSIS	Technique for Order Preference by Similarity to Ideal Solution
TİM	Türkiye İhracatçılar Meclisi
USA	United States of America
VAD	Value Added Tax
VIKOR	VlseKriterijumska Optimizacija I Kompromisno Resenje
WTO	World Trade Organization

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INTRODUCTION

One of the most important decisions necessary to make from the required facts for sustaining the existence of plant during a long-term effectively is the selection of the geographical site to be founded. Since this decision has feature of being a strategic decision for the plant and plant is obliged to operate at the same region during this period, it has feature of being a decision taken by professional people and by using correct methods. The object of the study named “Optimal Plant Location Selection in Apparel Company by Using Multi Criteria Decision Making Method” is to apply numerical decision methods and to evaluate the acquired results for making decision on site selection of the plants. Making decision method used in the study was identified as one of the widespread used multi-criteria decision making methods, the Analytical Hierarchy Process (AHP).

Today, in addition to analysis methods used in the past, more sensitive important results can be obtained with numeric methods and models regarding to improved applicability. All in all, plant location selection aiming to select among the existing decision points enters the application field of numerical decision methods as it is a kind of decision problem.

For selection of plant location as one of the most strategic decision, more than one factor is considered. These factors show change from sector to sector and their numbers change. Without distinguishing the other ones, selection factors to be used in this study are the common factors that many sectors consider in priority.

In this study, plant location selection is discussed in four sections. The first section is mainly on identification of plant location, factors having effect on selection process and also current situation of the textile and the clothing sector. Second section identifies decision making, multi criteria decision making process, most commonly used methods and literature survey relevant to this matter. AHP as one of the multi criteria decision making method, its prosess steps are explained in the third section. This technique is illustrated with a simple example. In the final section, plant location problem is discussed by taking neccesaary data from an apparel firm that plans to open a new facility.

CHAPTER ONE

PLANT LOCATION SELECTION & OVERVIEW OF TEXTILE AND APPAREL SECTOR

1.1. DEFINITION OF PLANT LOCATION

There are more than one definition proposed for concept of plant location carrying importance regarding the existence and future of the plant, however in this section the mostly encountered identifications are included.

Facility location is plainly a geographical site that plants sustain their production activities.

In a wider sense, facility location for an industry is the most convenient site that plants sustain the main functions such as supply, production, storage and distribution and their economic aims in connection with them (Demircioğlu, 2010).

It is a life space carrying all features in its structure required for business field with activities necessary for living and developing by considering the highest profit with minimum cost. Another definition is that it is a place which provides technical and economic conditions required for production activities in a most convenient way with respect to other places and consequently making the investor successful (Demirdöğen, 1988).

1.2. IMPORTANCE OF FACILITY LOCATION

Place selected as facility location of a plant shall be a place providing maximum profit and minimum cost that aims shall be realized for a long term. Misplacement of the foundation of the plant shall increase the costs for solving many problems such as raw material supply, marketing, handling, transportation, communication and substructure, thus cause an increase for unit costs (Eleren, 2007: 280).

For this reason, selection of facility location is a decision needing attention that requires analysis of many factors. Since the selected place should have feature of supplying the needs of plants in a best way, these needs should be identified objectively and exactly, features determining the effects on plant activities should be evaluated, support should be taken from specialist person and institution which their knowledge and experience are used, decisions should be made by considering long-term, changes during time should be considered when the actual position is evaluated (Çınar, 2010: 37).

All-in-all, stated concept defined as "site where plant has activities”, may become inconvenient place under changing conditions due to changing inner and outer factors during time although it is a suitable place under the present conditions. This situation may bring together various depressions under existing competition environment. When the factory faces such case, it should move to another place where it shall be adapted to work more efficiently before it is late. Although such necessities it is very difficult to move the system completely to another place especially costwise. Besides the cost factor, adaptation to a new environment, leaving some habits of the plant, providing the adaptation of staff at the new place also brings together some social problems. For such case plant owner should take necessary measures.

Facility location selection is basically realizes in three steps. At the first step in order to compare the sites to be selected and to place the main objects of the plant, it is necessary to define some criteria and to prioritize them. These factors considered as proximity to market, labor possibilities, proximity to raw material sources have different order of priority for each plant type. Therefore, importance order of these factors may change for a plant. At the second step criteria are listed having effect on facility location selection and an area where plant shall sustain their activities by evaluating such criteria. Before making decision on alternative locations to be selected in the region, thinking on a large scale shall cause gaining time and preventing the cost losses. For the last step, suitable place and land is selected for the decided region. During this step, factors determined for site selection shall be increased and it is entered into a more detailed decision process. After determination of the suitable areas in the region, areas are compared either by traditional methods or continuous numerical methods and the most suitable site is selected (Demircioğlu, 2010).

1.3. OPTIMAL PLANT LOCATION

Plant location selection for the firms needs to be dependent on a sound basis since it is a long-term planning. A wrong decision puts the plant into the difficult positions and causes big damages since it cannot be changed for a short and medium term (İlarslan, 2001).

Optimal facility location gives opportunity to realize the best foundation and operation objectives; at the same time it is a place providing profit, saving and efficient operation. For this reason plant managers try hard for selection of facility location in order to realize their activities in most convenient conditions.

For selection of optimal location, it is necessary that factors like productivity, economy, profitability, efficiency and optimality should be taken into consideration concomitantly.

Productivity is the increase at the plant on the production of goods and services using certain inputs of a period by the comparison of the last period.

Economy; shows the situation which the goods and services produced by certain inputs per unit cost is minimum.

Profitability; expresses the productivity of capital used at a certain period and shows the increase of the capital.

Efficiency defines the accessibility degree of the plant to predefined goals and objectives. Efficiency closely related with effect and productivity of plant activities.

Optimality; is the result of the mixtures of productivity, economy, profitability and efficiency and decision made by considering these factors are optimal decisions (Tekin, 2005: 48).

1.4. FACTORS AFFECTING PLANT LOCATION SELECTION

Plant location selection term in literature is first defined by German economist Alfred Weber. Weber defined plant location factor as “the advantage obtained as a result of an occurrence to any place of an economic activity at one point or at some specific points” (Weber, 1929).

There are many factors affecting the plant location selection of companies. It is known that plant location factors are not static and that they are not same for each work branches. Since these factors show changes according to different jobs, the most important thing is to distinguish the most important factors at this point for a company. Since selection by considering all factors together makes the problem very complex, the factors should be listed according to their importance levels. Factors affecting plant location selection decision are both very complex and both correlated with each other closely. Everything which provides superiority to production activity (especially providing cost superiority) at a certain site may be qualified as plant location factor. Plant location factors are generally considered with four main sections. These are listed as economic, natural, social and psychological, physiologic and politic factors respectively. Economic factors are the factors affected by decisions of plant management and generally inside the auditing area of the plant. Economic results of them, in other words their effects on cost and profitability are distinct and precise. In spite of this, natural factors as climate and condition of the land may affect plant location selection. Land structure, altitude, temperature differences, presence of earthquake belt, degree of humidity, even wind conditions, are among the effective points during decision making step. Social factors, performing duties of workers under the framework of desired life style which shall be useful, are very important with respect to themselves and the company. Moreover, resistance of the society with reasons like noise, pollution of air and water may affect location selection of plant. Considering this situation, state and municipalities enact limiting laws and directives related with location selection of plant. For selection of location obligation of respecting law and directive should be taken into consideration. Psychological, physiologic and political factors making the last step are related with the individual position of investor and policies of people taking part at state management.

Many potential criteria should be considered in selecting a particular plant location. Whatever the variability of plant location factors may be, majority of them are in the context of allowance for cost expenses. Since increasing the number of factor makes the decision process difficult, it is necessary to use the most important ones. Factors affecting the facility location selection process and frequently taken into consideration are listed in the table below according to the results of the studies have been done so far (Eleren, 2007: 408; Chu, 2002: 859; Ertuğrul, 2008: 784 and MacCarthy, 2001: 7).

Tablo 1: Significant Factors for Facility Location Selection

• Proximity to the market	• Human resource
• Proximity to raw material	• Investment cost
• Transport facilities	• Land size
• Incentives	• Climate
• Labor	• Quality of life
• Infrastructure	• Community considerations
• Land cost	• Ground features
• Subjective factors	• Security
• Communication possibility	• Political condition
• Subsidiary industry	• Cultural condition
• Energy cost	• Competitors

1.5. CLASSIFICATION OF PLANTS REGARDING TO PLANT LOCATION

Facilities may be collected at three main groups regarding the plant location (Güner, 2012: 3).

Plants Oriented to Raw Material Source

They are the plants founded at raw material source or proximity of raw material source aiming to lower transportation costs to minimum level due to bulky materials used. Iron-steel, coal and cement plants may be given as examples.

Plants Oriented to Market or Consumers

They produce products which their volumes and weights increase during manufacturing and they are founded in the proximity of markets in order to have savings from transportation costs. Macaroni and detergent plants may be given as examples.

Plants with Different Location

Weaving and garment plants included at this group do not show any difference related with proximity to raw material source or to markets. An apparel firm may be placed to a region supplying fabric and in proximity of consumption region.

1.6. DEFINITION AND SCOPE OF TEXTILE AND APPAREL SECTOR

Textile and apparel sector is an industrial branch playing important role in the economic development process of countries and one of the first sectors that industrial process was started. Textile and apparel sector includes processes that turns fibers and yarns to used articles. According to this definition, sector includes preparation of fiber, yarn, weaving, knitting, paint, print, finishing, cutting, sewing production processes. Process from fiber to yarn and manufactured fabric is evaluated as textile and from fabric to dress is evaluated as apparel sector. Textile and apparel sector can be explained simply as Figure 1.

Figure 1: Basic Manufacturing Steps of Textile and Apparel Sector

Source: Firat Kalkınma Ajansı, 2011.

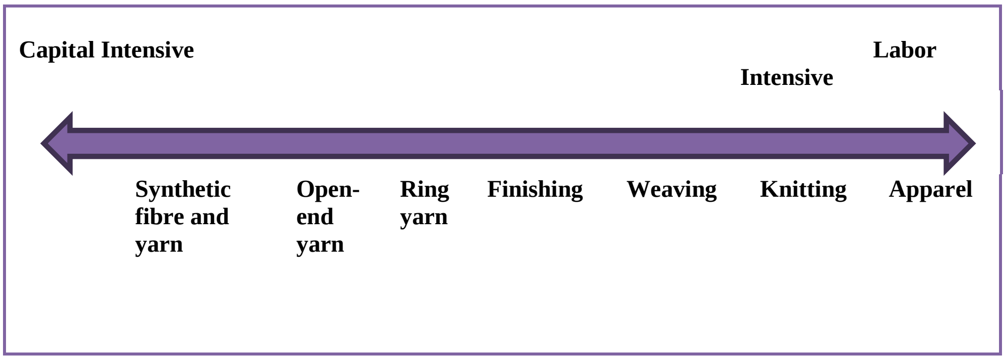
Textile sector is defined as light industry regarding to the raw materials used and process features. Production steps at textile sector were observed as labor intensive industry branch with reasons of variability of its machines and low production speed. However as a result of some recent structural changes observed in the industry, it has become capital intensive sector.

Apparel sector is expressed as labor intensive due to it has weight on labor power. While apparel sector in developed countries has taken position of technology intensive, in developing countries since it protects its labor intensive feature, it grows regarding labor power. This sector has assumed an important role in the economic development of developing countries for a long time (Arslan, 2008: 24).

As the share of developed countries in manufacturing industry of textile and apparel sector decreases, it is observed that production and trade shares in developing countries increase (Arslan, 2008: 25).

These production steps show great differences among themselves with respect to their existences as labor intensive or capital intensive. While chemical fiber and yarn drawing is placed in the most capital intensive petrochemical industry of the world; yarn, weaving, knitting and textile finishing plants form the fourth capital intensive sector. Apparel is still labor intensive industry sector. Sub-sectors of textile are listed from capital intensive to labor intensive as follows.

Figure 2: Capital and Labor Intensity in Textile and Clothing Sector



Source: http://www.fka.org.tr/SayfaDownload/BiNGoL_iLi_TEKSTiL_VE_KONFEKSiYON_SEKToRu.pdf (10.04.2015).

Textile and apparel sector has close cooperation technically with many sectors. Textile machinery from machine industry and chemistry industry uses synthetic fiber and dyes as input and developments lived in the sector concern these industries closely (Halkbank Kurumsal Sosyal Sorumluluk Projesi, 2010: 15).

1.7. GENERAL POSITION OF TEXTILE AND APPAREL SECTOR IN THE WORLD

Textile and apparel industry are the important sectors because of its work opportunities provided in developing countries, their high share of value created in production and export income (Kanoğlu and Öngüt, 2003: 62).

Although labor intensive, due to apparel is a business area formed by small capital by new investors and it is basic product consumed in all countries, textile and apparel production has important place since the industrial revolution (Güleryüz, 2011: 8). Researches have definitely showed that apparel trade shifts from developed countries to developing countries. Developed countries mostly have consumer position. While design develops in the field of fashion and creates products with high value-added, developing countries have producer position, because they have low labor costs. Depending on the rise of production costs and burdens occurred at employment, it is known that Japan has shifted apparel production to Asian countries. Therefore textile and clothing production has increased in Asian countries such as Hong Kong, South Kore and Taiwan (Güleryüz, 2011: 85). The most important event affecting world textile and apparel trade was the entry of China to WTO as 143th member in 2001. With this membership China was subjected to Textile and Clothing Agreement and has increased textile and apparel export after the removal of quotas from 2005. Removal of quotas has increased the importance of the subject of price on buying decisions of consumers in great nations USA, Germany and Japan. In the new age, providing service has gained importance together with product supply (İzmir Atatürk Organize Sanayi Bölgesi, Proje ve İş Geliştirme Birimi, 2012: 6).

1.8. PAST AND PRESENT SITUATION OF TEXTILE AND APPAREL SECTOR IN TURKEY

Foundations of textile and apparel sector in Turkey were laid in the Ottoman Empire Period. Small scale enterprises made weaving productions in Denizli and Tokat and silk productions in Bursa. In 1915, 18 of 22 leading public enterprises, 10 of 28 joint-stock companies, 45 of 214 private sector companies and totally 73 of 264 industrial companies had business in this industry (Halkbank Kurumsal Sosyal Sorumluluk Projesi, 2010: 8).

After foundation of Republic, all textile and apparel factories and workshops were collected together under the roof of Sumerbank by the establishment of this institution. Sumerbank has leaded the private sector by the investments and personnel raised. It was provided that the accumulation of Sumerbank was transferred to private sector with time. Private sector investments started in the fifties has developed by time and productivity role of the state has decreased during these years. Private sector shares were 28 % in 1952, 62 % in 1962 and more than 90 % in 1990 (Güleryüz, 2011: 4). Together with foreign expansion and export promotion policies based on free market economy applied after 1980, especially after the second half of eighties; textile and apparel export has been increased in great proportion and has become the most important item of export. In the beginning of nineties, the share of the sector in total export has reached up to 40 % and its importance in employment has increased. Textile and clothing industry at the period of 1980-2000 has become the biggest exporting manufacturing industry of nation with 20,5 % expansion annually (Eraslan *et al.*, 2008). However with the entry of China to global textile and apparel markets, Turkish textile and apparel industry has faced with decline of export from 2000. In spite of this, in 2005 Turkey was raised to the position of 4th biggest apparel supplier and 11th biggest textile supplier of the world (İzmir Atatürk Organize Sanayi Bölgesi, Proje ve İş Geliştirme Birimi, 2012: 6)

According to 2010 data of WTO; it is the 8th textile exporter and 5th apparel exporter of the world. When looked to the world listing, it is the 7th biggest production center of cotton which is the most important raw material of textile and apparel sector (İzmir Atatürk Organize Sanayi Bölgesi, Proje ve İş Geliştirme Birimi, 2012: 6). When textile and apparel sector is evaluated together, it is the first sector of Turkey regarding gross domestic product, share among manufacturing industry and industrial production, export, net foreign currency input provided to economy, employment, investment, foreign expansion and macro economic indicators.

Macroeconomic data of the year of 2014 at sectoral basis are examined, the biggest sector which exports most was the automotive sector with 22,2 million dollars followed by apparel sector with 18,7 million dollars (Türkiye İhracatçılar Meclisi (TİM), 2015).

In the context of nations EU had important percentage in apparel export with 44,7 % in 2014. During this term Middle East having second place had increased its share to 19,3 % (İstanbul Tekstil Ve Konfeksiyon İhracatçi Birlikleri (İTKİB), 2015: 103).

Now Turkey has entered maturity stage generally in this sector because of the developments lived. The future of this sector shall be affected by managing the transition period and providing adaptation in the best manner.

1.9. IMPORTANCE OF PLANT LOCATION SELECTION FOR APPAREL SECTOR

Apparel sector as accepted as the locomotive of domestic trade of Turkey also is in the position of making optimal decisions most efficiently and carrying its development over in order to use competition advantages in regional and global sense. Although textile industry meets with crises in our country and in the world from time to time, it is worthwhile by the investors because of its attractability.

As for other enterprises, in textile and apparel sector selection of facility location is also important for the future of the plants. Misplacement of the plant to inconvenient region causes high costs of transportation afterwards and leaves the economic life with difficult situations. Therefore in the situation having more than one alternative shall provide advantage by evaluating with using scientific methods.

It is possible to group the cost elements used in selection of facility location as follows:

- ✓ Cost of getting land, building, wages, energy, raw material and machine sources,
- ✓ Cost related with labor, technologic sources,
- ✓ Cost related with handling, transportation of product and access of product to the consumer.

Each of these cost elements has sensitive features that may be affected from the selection of facility location. A wrong decision made about location selection shall bring an important burden to the plant (Kişioğlu, 2004).

CHAPTER TWO
DECISION MAKING PROSESS AND MULTI CRITERIA DECISION MAKING

2.1. DECISION MAKING

Plants are required to make decisions in many cases in order to solve problems encountered for survival and sustaining their lives. For decision making more than one definition are available. More generally if there are more than one alternatives, it is defined as to select one among the alternatives. Another definition is selection of one among the behaviors according to optimization criteria (Saat, 2000).

Existence of more than one alternatives among decision problems and criteria for evaluation to be considered make the situations more complex like having different features of each alternatives and variability of the advantages provided to decision maker and existence of risks for wrong decision (Güner, 2005: 28).

Rapid changes lived today have increased ambiguity inside plants and globalization and have brought decision making to a difficult and strategic position. Management people should have and develop this capability. As collecting only the necessary data correctly and punctually is not sufficient; these data must be analyzed by using suitable decision techniques with the help of scientific methods. Organizations eliminate these denials of changing technology and globalization in this way and provide competitive advantage (Doğan, 2004: 4).

Generally decision making process is formed by three steps. It is required to make different analyses like Pareto in behalf of determining which one should be considered prior among the problems encountered. The first step is formed by specifying the problem in detail, determining the objectives, decision variables, owned resources and required parameters for the solution of problem by the decision maker. The second step is placing the alternatives that may be suitable in the light of these data. The final step is to look for whether the decision fits to the desired conclusion (Güner, 2005: 29).

2.2. BASIC CONCEPTS IN DECISION MAKING

Although multi-criteria decision making methods contain many diversity, concepts used commonly for modelling of decision making problems were determined as stated below (Zeleny and Cochrane, 1973).

Criteria: It is the measurement of basis and activity for making evaluation. Criterion appears inside the problem structure as a form of features and objectives. Criteria may be defined as measurements, rules and standards guiding the decisions.

Targets: Targets may be defined exactly as the needs and demands of decision maker. It represents the special value or priority of feature of one of the qualities or purposes. Targets may also be expressed as desired level of the success.

Qualities: It has the same meaning as performance parameters, element, factor and features. Quality expresses level of purpose as a value.

Purposes: After determining the qualities they are measured and defined. Decision maker decides on qualities which maximization or minimization should be done according to his own desires and needs.

Priorities and Weights: Weights are the listing of targets numerically and hierarchically depending on the importance of targets. Priorities are listing of targets numerically and hierarchically. Numeric weights are named as cardinal weights; hierarchic weights are named as ordinal weights.

2.3. MULTI-CRITERIA DECISION MAKING

As a definition, Multi-Criteria Decision Making (MCDM) is analyzing a situation if there are contradictory criteria with each other during decision making process. It was developed by considering the data coming from various and different sources are not evaluated effective and productive (Arikan, 2013: 87).

Since using traditonal methods does not provide realistic solution, MCDM methods have found a place in many studies today. Although MCDM is a sub level of operations research and management science it contains methods for evaluation of more than one decision criteria and preferring among alternatives, grouping and listing of alternatives (Demirer, 2012: 11). MCDM problems are listed in two categories; Multi Objective Decision Making (MODM) and Multi Attribute Decision Making (MADM). MODM methods are used for problems among limitless alternatives defined by mathematical limits. MADM methods are used for choosing one alternative among determined precise alternatives (Tabucanon, 1988).

There are also many such type problems in daily life. When the literature is reviewed, MCDM studies have many applications on fields such as economy, financing, marketing, transportation and human resource management.

2.4. MULTI-CRITERIA DECISION MAKING METHODS

MCDM methods have created more clear, rational and efficient decision processes and helped development of making decisions with high quality. These methods are powerful methods used widely for solving complex problems containing contradictory criteria, different point of views and perspectives and high rate of uncertainty and inaccuracy. Literature search has shown that these methods are used often. In this section, there is information on most frequently used decision making techniques and methods which shall be stated are listed as below.

- ✓ Technique for Order Preference by Similarity to Ideal Solution **(**TOPSIS)
- ✓ Analytic Network Process (ANP)
- ✓ The Elimination and Choice Translating Reality (ELECTRE)
- ✓ Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE)
- ✓ Goal Programming (GP)
- ✓ Multi Attribute Utility Theory (MAUT)
- ✓ Data Envelopment Analysis (DEA)

2.4.1. Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)

2.4.1.1. Introduction

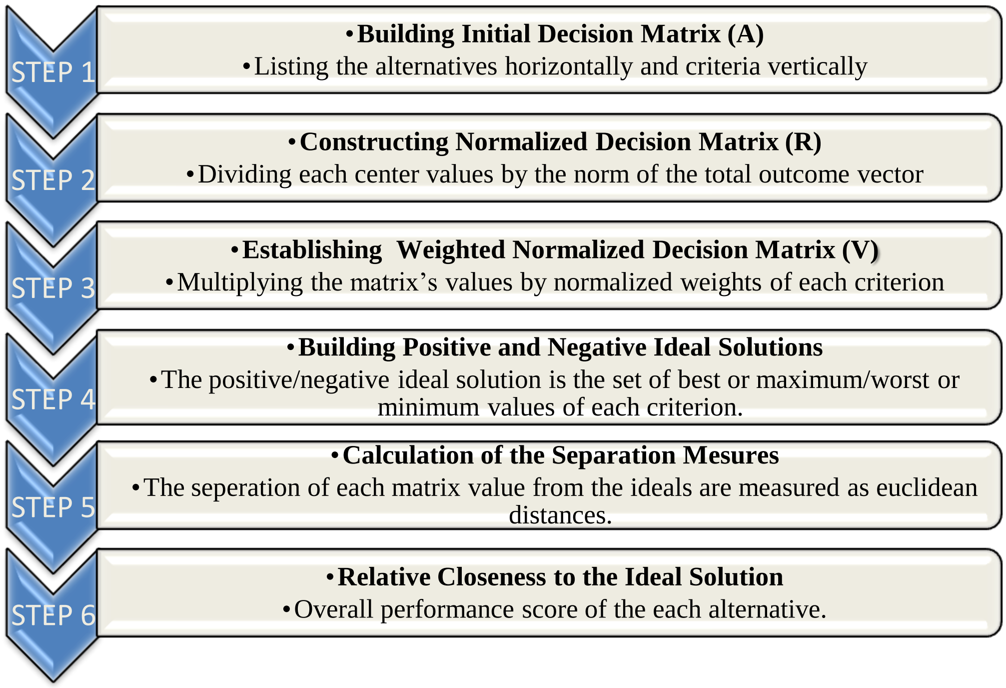
TOPSIS is one of the MCDM techniques and presented in Chen and Hwang (Hwang and Yoon, 1981), with reference to Hwang and Yoon (Shih *et al.*, 2007). The basic principle of the method is that the chosen alternative is expected to have the shortest Euclidean distance from the positive ideal solution and contrarily have the farthest distance from the negative ideal solution. The ideal solution is hypothetical solution that corresponds to maximum attribute of all attribute values in database where comprising the satisfying solution. Accordingly, the negative ideal solution is hypothetical solution for which all attribute values correspond to minimum attribute values in database. Thereby the solutions which are the closest solution to the hypothetically best and farthest from the hypothetically worst are given in TOPSIS method.

TOPSIS method has several advantages; one of which is the application convenience and simplicity when identifying the suitable alternative quickly. Additionally, it performs similar to various methods that use additive weights and performs better than other methods in most cases. When it compared with the other methods solution process is shorter than others.

2.4.1.2. Application Steps of TOPSIS Method

TOPSIS procedure is basically composed of six steps (Shih *et al*., 2007). First of all criteria and their weights are determined and after normalization process distance from the negative and positive ideal solutions are calculated. Then finally alternatives are ranked according to the values of the relative closeness to the ideal solution. All steps of the method are shown in Figure 3.

Figure 3: Visualizing the steps of TOPSIS method



Step 1. Construct Initial Decision Matrix (A)

Alternative *i*, *i=1,2,...,m* horizontally and criteria *j*, *j=1,2,...,n* vertically are placed in the decision matrix. It is created by the decision makers and shown in the Eq. (1)

$$A_{ij} = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ a_{m1} & a_{m2} & \dots & a_{mn} \end{bmatrix} \tag{1}$$

M expresses the numbers of decision points and n shows the numbers of evaluation factors.

Step 2. Construct Normalized Decision Matrix (R)

There are some other techniques to perform normalization process. Vector normalization is a method frequently used. Vector normalization for the normalized decision matrix is given in the Eq. (2)

$$r_{ij} = \frac{a_{ij}}{\sqrt{\sum_{k=1}^{m} a_{kj}^2}} \tag{2}$$

R matrix is expressed as Eq. (3)

$$R_{ij} = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix} \tag{3}$$

Step 3. Construct Weighted Normalized Decision Matrix (V)

Primarily weight values (w_i) related to the evaluation criteria are determined $(\sum_{i=1}^{n} w_i = 1)$. To construct the weighted normalized decision matrix, the normalized decision matrix is multiplied by its associated weights. The structure of matrix *Y* is given in Eq. (4)

$$V_{ij} = \begin{bmatrix} w_1 r_{11} & w_2 r_{12} & \cdots & w_n r_{1n} \\ w_1 r_{21} & w_2 r_{22} & \cdots & w_n r_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ w_1 r_{m1} & w_2 r_{m2} & \cdots & w_n r_{mn} \end{bmatrix} \tag{4}$$

Step 4. Determine the Positive Ideal (A^*) and Negative Ideal (A^-) Solution

The largest value of the column for the ideal solution set is selected. Finding positive ideal solution set is shown in Eq. (5).

$$A^* = \left\{ (\max_i v_{ij} \middle| j \in J), (\min_i v_{ij} \middle| j \in J^{'} \right\} \tag{5}$$

Sets which will be calculated by using Eq. (5) is shown in Eq. (6)

$$A^* = \left\{ v_1^*, v_2^*, ..., v_n^* \right\} \tag{6}$$

For the negatif ideal solution set, the smallest values of the column are found. Negative ideal solution set is given in Eq. (7)

$$A^- = \left\{ (\min_i v_{ij} \middle| j \in J), (\max_i v_{ij} \middle| j \in J^{'} \right\} \tag{7}$$

Sets to be calculated with the help of the Eq. (7) is shown in Eq. (8)

$$A^- = \left\{ v_1^-, v_2^-, ..., v_n^- \right\} \tag{8}$$

J is associated with the benefit (maximization) and *J'* is associated with cost (minimization) value in both formulas.

Step 5. Calculation of the Separation Measure to the Ideal and Negative Ideal Solution

Euclidian distance is used to determine the separation of each alternative from the ideal solution and negative ideal solution. The calculation of separation from the ideal solution (Si^*) is given in Eq. (9).

$$S_i^* = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^*)^2} \tag{9}$$

Similarly, the calculation of separation from the negative ideal solution (Si^-) is given in Eq. (10).

$$S_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2} \tag{10}$$

Step 6. Calculation of the Relative Closeness to the Ideal Solution

The relative closeness to the ideal solution ($Ci*$) which is found by using the distance measures is calculated in previous step. Calculation of the relative closeness to the ideal solution is presented in Eq. (11).

$$C_i^* = \frac{S_i^-}{S_i^- + S_i^*} \tag{11}$$

The value of C_i^* is between $0 \le C_i^* \le 1$ and C_i^* = 1 shows the absolute closeness of the corresponding alternative to the ideal solution, in the same sense C_i^* = 0 shows the absolute closeness of the corresponding alternative to the negative ideal solution.

2.4.2. Analytic Network Process (ANP)

ANP on the basis of analytic hierarchy process is one of the most popular multi criteria decision making method formulating and analyzing decisions and it was developed by Saaty (Zaim, *et al.*, 2014).

ANP enables interrelationships among the decision levels and attributes to be taken into consideration in a more general form. ANP uses ratio scale measurements based on pairwise comparisons. However, it does not impose a strict hierarchical structure as in AHP, and models a decision problem using a systems-with-feedback approach. In ANP, the relative importance values are determined similar to AHP using pairwise comparisons with a scale of 1–9, where a score of 1 indicates equal importance between the two elements and 9 represents the extreme importance of one element compared to the other one (Karsak *et al*., 2003).

The first step of the ANP is the construction of the network, next step is the calculation of the priorities of the elements. In order to construct the structure of the problem, all of the interactions among the elements should be considered. When the elements of a component *Y* depend on another component *X*, it represent this relation with an arrow from component *X* to*Y* (Ethem, and Alptekin, 2007). All of these relations are evaluated by pairwise comparisons and a supermatrix, which is a matrix of influence among the elements, is obtained by these priority vectors. The supermatrix is raised to limiting powers to calculate the overall priorities, and thus the cumulative influence of each element on every other element with which it interacts is obtained. The supermatrix representation of a hierarchy with three levels is as follows (Eq. 12) (Saaty and Vargas, 1998).

$$W= \begin{array}{l} \\ \text{Goal (G)} \\ \text{Criteria (C)} \\ \text{Alternatives (A)} \end{array} \begin{array}{c} \begin{array}{ccc} \text{G} & \text{C} & \text{A} \end{array} \\ \begin{bmatrix} 0 & 0 & 0 \\ w_{21} & 0 & 0 \\ 0 & w_{32} & 1 \end{bmatrix} \end{array} \tag{12}$$

2.4.3. The Elimination and Choice Translating Reality (ELECTRE)

ELECTRE method was first developed by Bernard Roy and his friends in France in the mid 1960’s.

Basic principle of ELECTRE method is to be interested in priority relations by using paired comparison of separated alternatives according to each criterion. Priority relation of *Ai* and *Aj* alternatives is shown as $Ai \rightarrow Aj$ numerically if alternative *i* is not dominant to alternatif *j* and later decision maker may still undertakes the risk of alternative *Ai* which is better than alternative *Aj*.

Roy has developed ELECTRE method in order to remove failure to reach a conclusion by obtaining weak empty models from a value function with spending less effort. Method based on establishing dominance among alternatives uses concordance index and discordance indexes for measuring them as basis. These indexes are numerical values showing which alternative is more dominant (Çakın, 2013). ELECTRE methods are developed by time, in literature ELECTRE I, II, III ve IV methods are included.

Tablo 2: ELECTRE Methods

Method	Method Developer	Date	Types of Problem
ELECTRE I	B. Roy	1968	Selection
ELECTRE II	B. Roy, P. Bertier	1971	Ranking
ELECTRE III	B. Roy	1978	Ranking
ELECTRE IV	B. Roy, J. C. Hugonnard	1982	Ranking
ELECTRE IS	B. Roy, J.M. Skalka	1985	Selection
ELECTRE TRI	B. Roy, D. Bouyssou, W. Yu	1991-1992	Assignment

Source: Yürekli, 2008.

Application areas are listed as management problems, accounting and financing database selection, capital investment, production planning, marketing, application evaluation, plant location selection, computer and information selection, and market selection. Advantages of this method are that unlike other methods there is no need detailed data for solution and more appropriate results are obtained when comparing some criteria. Disadvantage of the method is that it is not appropriate for problems with many alternatives (Can, 2012: 76).

2.4.4. Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE)

PROMETHEE was developed for priority determination method with multi-criteria in 1982 by Jean-Pierre Brans. PROMETHEE method was developed because of difficulties available in literature during application step of prioritization in the methods and has been used in the studies until today. PROMETHEE method is known as one of the most efficient methods in solution of multi-criteria problems (Koçdağ, 2013).

PROMETHEE method is based on paired comparison according to evaluation factors of decision points. Basic difference from other decision making methods is its importance weights showing relation level among evaluation factors as well as considering the inner relation of each evaluation factor. PROMETHEE method is developed by time. At first, PROMETHEE II was developed in 1985 and now PROMETHEE VI method has been used. It is observed that PROMETHEE method is mostly used in environment control, business and financing management, logistics, chemistry in the literature scanning (Figueira *et al*., 2005).

2.4.5. Goal Programming (GP)

GP as special extension of linear programming is an approach used in decision making and different optimization problems. It was recommended first time by Charnes, Cooper ve Ferguson in 1950. This technique was expanded by Ijiri in the middle of sixties, Ignazzio and Lee did many applications by defining it with details in the seventies (Davis and McKeown, 1985). GP is an important technique for solution of multi objective decision problems in order to provide decision makers a satisfactory solution set. Goal programming as special extension of linear programming realizes minimization of deviations among targets instead of direct maximization or minimization of target criterion as linear programming. The most important characteristic of goal programming is its ability to solve contradictory goals with each other according to priority listing or relative weighting (Umarusman, 2007: 25). Basically there are two solution methods related with linear goal programming as graphical method and simplex method. The steps needed to structure a GP model are threefold (Rifai, 1996).

2.4.6. Multi Attribute Utility Theory (MAUT)

MAUT was developed by Keeney and Raiffa in 1976 and it is an evaluation scheme which is very popular by decision makers for evaluating their judgments (Kahraman and Kaya, 2012: 812).

MAUT analysis of alternatives explicitly identifies the measures that are used to evaluate the alternatives, and helps to identify those alternatives that perform well on a majority of these measures, with a special emphasis on the measures that are considered to be relatively more important (Butler *et al*., 2001).

For application of the method, a numeric score (value), "*V*" is assigned for each alternative. If *V(a)* value is greater than *V(b)*, alternative a, is preferred to alternative b.

$$V(a) = \sum_{i=1}^{n} w_i v_i \tag{13}$$

v_{ia} is the value function of alternatif *a* under criteria *i*. *W* shows the weight of criterion *i* under the total score. Total value score for each alternative is calculated and alternative with highest score is selected (Kul, 2012: 34).

2.4.7. Data Envelopmet Analysis (DEA)

DEA, a technique based on linear programming, may be defined as a method used to assess relative activities of responsible decision points with producing output or outputs by using similar inputs. In cases with many inputs and outputs, its ability to make assessment is one of the features separating it from other methods (Özdil, 2014: 13). Another superiority of DEA is the information given on the comparison of analyzed process with other process units, the sensitivity analysis, what responds it gives against different scenarios, potential opportunities and weak points (Özgür, 2011: 11)

2.5. LITERATURE REVIEW

There are many studies using multi-criteria decision making methods in literature for selection of optimal facility location. In this section, studies related with the subject were examined and summarized as follows.

It is tried to determine the optimal location among three location alternatives for a textile company to be established in Uşak. Company location criteria have been evaluated by the ELECTRE method using in determining optimal location choice (Akyüz and Soba, 2013).

A facility location selection problem is considered by using fuzzy TOPSIS method and a decision support model is provided in order to help a bank selecting the most appropriate city for opening a branch among six alternatives in the South Eastern of Turkey (Çınar, 2010). The analytic hierarchy process and goal programming are combined for global facility location-allocation problem (Badri, 1999).

In another study, fuzzy analytic hierarchy process (AHP) and the fuzzy technique for order preference by similarity to ideal solution (TOPSIS) methods are compared for the selection of location of a textile company in Turkey. The similarities and differences of two methods are also discussed (Ertuğrul and Karakaşoğlu, 2008).

A new TOPSIS approach for selecting plant location under linguistic environments is applied, where the ratings of various alternative locations under various criteria, and the weights of various criteria are assessed in linguistic terms represented by fuzzy numbers for selection of plant location which plays a very important role in minimizing cost and maximizing the use of resources for many companies (Yong, 2006). A case study is about locating some warehouses as distribution centers (DCs) in a real-world military logistics system. In order to find the least number of DCs and locating them in the best possible locations MODM techniques are used and the locations of DCs are determined (Farahani and Asgari, 2007). The integration of intuitionistic fuzzy preference relation aiming to obtain weights of criteria and intuitionistic fuzzy TOPSIS method aiming to rank alternatives for dealing with imprecise information on selecting the most desirable facility location (Boran, 2011).

In order to solve plant location selection problem a new integrated methodology is structured. Analytic hierarchical process (AHP) and VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR), are combined in order to make the best use of information available. Additionally the Delphi method is utilized to select the most influential criteria by a few experts. The aim of using the AHP is to give the weights of the selected criteria. Finally, the VIKOR method is taken into account to rank potential alternatives (Tavakkoli et al., 2011).

21 criteria for international tourist hotel location acquired from literature review and practical investigations and the methods of fuzzy set theory, linguistic value, hierarchical structure analysis, and fuzzy analytic hierarchy process are used to consolidate decision-makers' assessments about criteria weightings. Then finally the international tourist hotel location selection in Taiwan is conducted to demonstrate the computational process and effectiveness of FMCDM proposed (Chou et al., 2008).

Another study proposed a hybrid method of multi criteria decision making (MCDM) that make it possible to select the optimal location that satisfies the decision maker. With the aid of fuzzy AHP, proposed model considers objective, critical, and subjective factors as the three main common factors in location analysis (Tabari, 2008). A simple, systematic and logical scientific approach is structured to evaluate power substation location through integrating Fuzzy Analytical Hierarchy Process (FAHP) with PROMETHEE. To accredit the proposed model, it is implemented in a power substation location selection problem in Bangladesh (Kabir and Sumi, 2014).

Choosing plant location by Fuzzy TOPSIS technique is performed for the tanning industry which is one of the basic dynamics of the economy (Eleren, 2007). An exemplary model is developed for choosing the place of incorporation in textile industry. The model is performed with the help of analytical hierarchy process and fuzzy analytical hierarchy process and then effects to the results are presented. As a result of application Istanbul has designated as the first province with possibility of labor, proximity to the market and raw material, transportation and sub-industry (Alp and Gündoğdu, 2012).

CHAPTER THREE

MATHEMATICAL METHOD USED IN THE DECISION PROCESS

3.1. ANALYTIC HIERARCHY PROCESS (AHP)

In this part of the study prosess steps of AHP one of the MCDM method used in the decision making problems are explained comprehensively. Later, this method is also discussed with an example.

3.1.1. Definition of Analytic Hierarchy Process

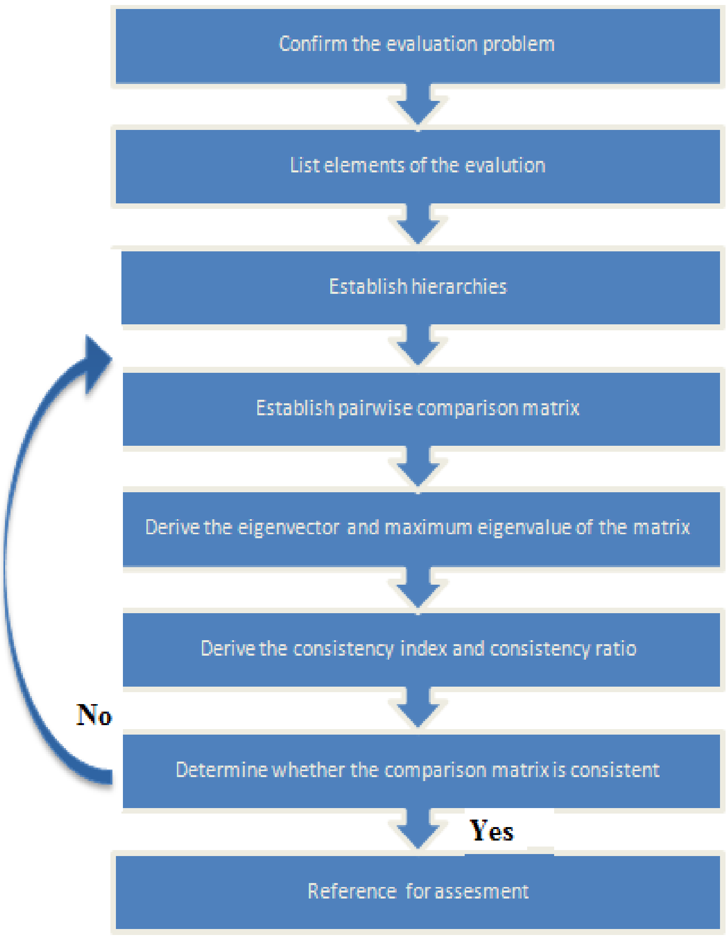
AHP was first developed by Saaty (Saaty, 1988) and is often referred to as the Saaty method. This multiple criteria decision-making tool is very popular and widely used in the domain of decision making.

It is observed that AHP is being predominantly used in the theme area of selection and evaluation. As far as the area of application is concerned, most of the times AHP has been used in engineering, personal and social categories. This should help researcher judge the applicability of AHP in their area of interest (Vaidya and Kumar, 2006). This method divides a complicated system under study into a hierarchical system of elements. Pair-wise comparisons are made of the elements of each hierarchy by mean of a ratio scale. Then, comparisons are quantified to establish a comparison matrix, and the eigenvector of the matrix is derived, which signifies the comparative weight amongst various elements of a certain hierarchy. Finally, the eigenvalue is used to assess the strength of the consistency ratio of the comparative matrix and determine whether to accept the information (Lin and Yang, 1996).

3.1.2. The Implementation Steps of the AHP

Developed by Thomas L. Saaty in 1971, AHP is formed by many discrete concepts and techniques. They may be listed as hierarchic configuration of complexity, pairwise comparison, use of eigen vector in derivation of weights and measurement of consistency. Although use of each of these techniques alone is advantageous, Thomas L. Saaty created a process giving powerful results by combining these concepts and techniques (Aksoy, 2013). The decision process flowchart of AHP is shown in Figure 4.

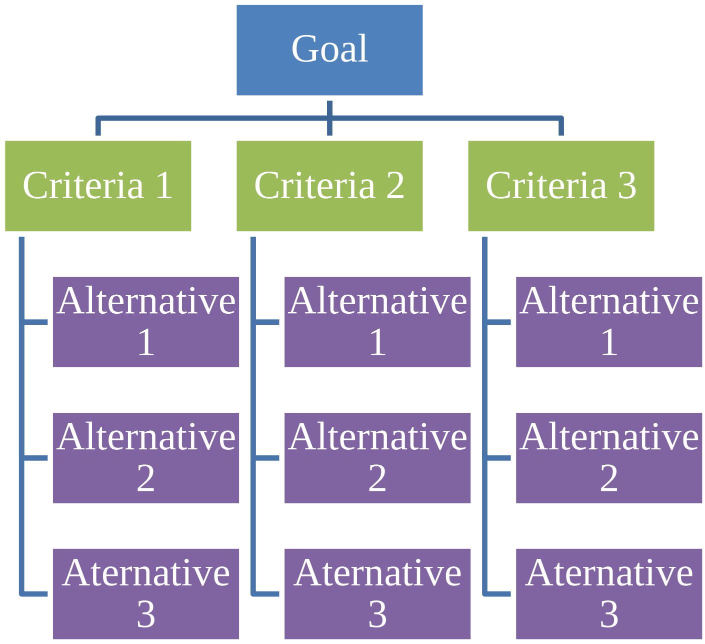
Figure 4: Flowchart of the Decision Process of AHP



3.1.3. Definition of Problem and Creating of Hierarchic Structure

Decision making problem is defined for the first step, purpose is identified, decision points and factors affecting these decision points are determined. Then in order to facilitate the process, a hierarchic structure is created. Separation process of sub-headings in this hierarchy is shown by structure similar to tree. This used tree structure helps to simplify the problem (Aksoy, 2013). In the hierarchy model, first level represents target, the second level represents criteria and third level represents options. General hierarchical structure of AHP model can be seen in Figure 5.

Figure 5: Simple AHP Hierarchy



3.1.4. Creation of Pairwise Comparison Matrix

After purpose and criteria are determined, in order to determine importance degrees of criteria among themselves, *(nxn)* pairwise comparison matrix as shown in Eq.14 is created (Saaty, 1988).

In order to get criterion matrix and alternative matrix pairwise comparison is performed by the decision maker.

$$A = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{bmatrix} \tag{14}$$

Comparison of factors are done one to one and mutually according to importance values they own. At one to one comparison of factors, importance scale in Table 3 created by Saaty.

Tablo 3: Scale of Relative Importances

Intensity of importance	Definition
1	Equally important or preferred
3	Slightly more important of preferred
5	Strongly more important or preferred
7	Very strongly more important or preferred
9	Extremely more important or preferred
2,4,6,8	Intermediate values to reflect compromise
Reciprocals	Used to reflect dominance of the second alternative as compared with the first

Source: Bruce *et al*., 1989.

Components on the diagonal of comparison matrix, in other words when $i = j$ it takes the value of 1, because in this case concerned factor is compared by itself.

For example, if the first factor is considered more important than third factor by the comparator, in this case the first row and third column of comparison matrix shall take the value of 3 (i: 1 j:3). Otherwise in case of comparison of first factor with the third factor, if the most important option is the third factor, first row and third column component of comparison matrix shall take the value of 1/3. Values of 2, 4, 6, and 8 in Table 2 are intermediate values. For example when decision maker is hesitant in comparison, between values 5 and 7, it may be used value 6.

3.1.5. Obtaining Percent Importance Distribution of Factors

Comparison matrix shows importance levels of factors relative to each other within certain logic. However in order to determine the weights of these factors in whole, in other words percent importance distributions, column vectors of comparison matrix is used and B column vector is formed with n units and n components. In Eq. 15 below, this vector is shown:

$$B_i = \begin{bmatrix} b_{11} \\ b_{21} \\ . \\ . \\ . \\ b_{n1} \end{bmatrix} \tag{15}$$

For calculation of B column vectors, Eq. 16 is used.

$$b_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \tag{16}$$

If steps explained above are repeated in other evaluation factors, B column vector is acquired. When n units of B column vector are brought together in matrix format, C matrix shown below shall be obtained (Eq. 17).

$$C = \begin{bmatrix} c_{11} & c_{12} & \cdots & c_{1n} \\ c_{21} & c_{22} & \cdots & c_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ c_{n1} & c_{n2} & \cdots & c_{nn} \end{bmatrix} \tag{17}$$

By using C matrix, percent importance distributions are obtained showing importance values of factors relative to each other. As stated in Eq. 18, arithmetic average of row components forming normalized C matrix is taken and W column vector is created which is named as “Priority Vector’’ (Eq. 19).

$$w_i = \frac{\sum_{j=1}^{n} c_{ij}}{n} \quad (18) \qquad W = \begin{bmatrix} w_1 \\ w_2 \\ . \\ . \\ . \\ w_n \end{bmatrix} \quad (19)$$

3.1.6. Consistency of Factor Comparisons

For reflecting the fact that the results of comparisons made one to one among the factors by decision maker, they have to be consistent. With the resulting Consistency Ratio (*CR*), consistency of found priority vector and hence one to one comparison made among the factors are tested. The essence of *CR* calculation is based on comparison of number of factors with coefficient *(λ)* called *Basic Value.* In order to calculate λ first, *D* column vector is obtained by multiplying *A* comparison matrix with *W* priority vector matrix.

Dividing the mutual elements of *D* column vector and *W* column vector, *E* basic value related to each assessment factor is obtained. Arithmetic mean of these values (Eq. 21) gives (λ) basic value (Eq. 20 and 21).

$$E_i = \frac{d_i}{w_i} \quad i = 1,2,..., n \quad (20) \qquad \lambda = \frac{\sum_{i=1}^{n} E_i}{n} \quad (21)$$

After λ value is calculated, Consistency Index *(CI),* can be calculated with using Eq. 22.

$$CI = \frac{\lambda - n}{n - 1} \quad (22)$$

Saaty et al., formed a Random Index (*RI*) series for calculating consistency ratio. These random consistency index numbers for square matrices with sizes changing 1 to 15 are given in Table 4.

Tablo 4: Random Index (RI)

N	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Randomness Indicator	0	0	0,58	0,9	1,12	1,24	1,32	1,41	1,45	1,49	1,51	1,48	1,56	1,57

Source: Bruce *et al.*, 1989

Data in Table 3 are divided into *CI* value calculated before and *CR* value is reached, as shown in Eq. 23.

$$CR = \frac{CI}{RI} \tag{23}$$

It is desired that the upper limit for the calculated *CR* should be 0,10. The ratio is above 0,10 means that judgment of decision maker is inconsistent.

3.1.7. Finding Percent Importance Distributions for Each Factor at m Decision Point

This step is same as the one explained above except that percent importance distributions of decision points are determined for each factor. However this time, size of *G* comparison matrix used in comparion for each factor shall be *mxm*. After each comparison process *S* column vectors showing percent distributions with respect to decision points of factor assessed and with *mx*1 size shall be obtained. These column vectors are defined as Eq. 24.

$$S_i = \begin{bmatrix} s_{11} \\ s_{21} \\ . \\ . \\ . \\ s_{m1} \end{bmatrix} \tag{24}$$

3.1.8. Finding the Result Distribution on the Decision Points

In this step at first K decision matrix is formed by S column vector with *mx1* sized n units explained above with *mxn* dimension. Decision matrix is defined below (Eq. 25):

$$K = \begin{bmatrix} s_{11} & s_{12} & \cdots & s_{1n} \\ s_{21} & s_{22} & \cdots & s_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ s_{m1} & s_{m2} & \cdots & s_{mn} \end{bmatrix} \tag{25}$$

In conclusion, when decision matrix is multiplied by W column vector (priority vector), L column vector is obtained with m elements. L column vector gives percent distribution of decision points and at the same time shows the importance order of decision points (Eq. 26).

$$L = \begin{bmatrix} s_{11} & s_{12} & \cdots & s_{1n} \\ s_{21} & s_{22} & \cdots & s_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ s_{m1} & s_{m2} & \cdots & s_{mn} \end{bmatrix} x \begin{bmatrix} w_1 \\ w_2 \\ . \\ . \\ . \\ w_n \end{bmatrix} = \begin{bmatrix} l_{11} \\ l_{21} \\ . \\ . \\ . \\ l_{m1} \end{bmatrix} \tag{26}$$

3.2. AN EXAMPLE OF AN AHP DECISION

A simple theoretical example below shows how a broad range of considerations can be managed through use of the AHP.

A practical example: City Selection

In this section AHP application is shown on a sample problem. Someone considers buying a new house has decided cities as options given below.

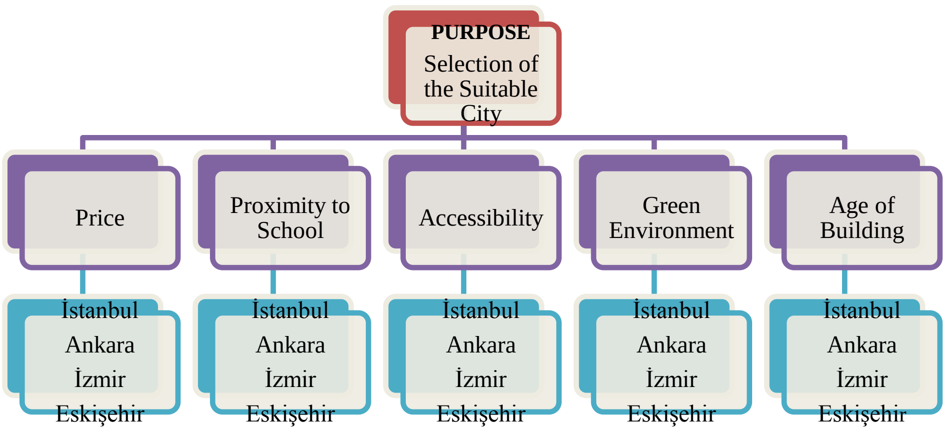
1) İstanbul (A1),
2) Ankara (A2),
3) İzmir (A3),
4) Eskişehir (A4),

In order to select which one of them, five main criteria are determined and these criteria are listed as below.

1) Price (C1)
2) Proximity to school (C2)
3) Green environment (C3)
4) Accessibility (C4)
5) Age of Building (C5)

At first, a decision tree oriented to solution is created in order to facilitate AHP analysis. Decision tree formed for the first step of AHP application is shown in Figure 6.

Figure 6: Decision Tree for the Practical Example



After generating the hierarchical structure, pairwise comparison of criteria depending on the decision maker's choice shown in Table 5, is done by using preference scale.

Tablo 5: Pairwise Comparison Matrix of the Criteria

Criteria	C1	C2	C3	C4	C5
C1	1	3	4	7	5
C2	1/3	1	2	4	3
C3	¼	1/2	1	3	2
C4	1/7	1/4	1/3	1	1/2
C5	1/5	1/3	1/2	2	1
Total	1,926	5,083	7,833	17,000	11,500

After obtaining comparison matrix, it is followed by normalization process and normalized matrix (Table 6) is formed by dividing each element of the matrix by the column total where it belongs. This calculation operation is shown below as an example.

Tablo 6: Normalized Matrix

0,519	0,590	0,511	0,412	0,435
0,173	0,197	0,255	0,235	0,261
0,130	0,098	0,128	0,176	0,174
0,074	0,049	0,043	0,059	0,043
0,104	0,066	0,064	0,118	0,087

$$1/\ \left[1+\left(1/3\right)+\left(1/4\right)+\left(1/7\right)+\left(1/5\right)\right]=0,519$$

Then, priority vectors given in Table 7 are obtained by averaging of total of each row of Table 6. This process explained as follows.

Tablo 7: Priority Vectors of Each Criterion

	Priority Vector
P1	0,493
P2	0,224
P3	0,141
P4	0,054
P5	0,088

$$\mathrm{P1} = \frac{(0,519 + 0,590 + 0,511 + 0,412 + 0,435)}{5} = 0,493$$

At the end of these computations, priority listing of factors affecting city preference is provided. With respect to obtained priority vector, price criterion (C1) has the first degree importance with 49 % ratio. Transportation facility is in the last place with 5% ratio.

In order to test the consistency, *CI* and *CR* calculation steps with the help of the first comparison matrix values and priority vectors are shown in detail as following.

$$\left(1*0,493\right)+\left(3*0,224\right)+\left(4*0,141\right)+\left(7*0,054\right)\ )+\left(5*0,088\right)\ =2,544$$

$$\text{CI=}\left(\frac{\frac{2,544}{0,493}+\frac{1,148}{0,224}+\frac{0,713}{0,141}+\frac{0,271}{0,054}+\frac{0,439}{0,088}}{5}-5\right)/(5-1)=0,02$$

In order to get the CR value, CI is divided by the related RI value stated in Table 3 according factor number.

$$CR = \frac{0,02}{1,12} = 0,01$$

As the last step, it is necessary to do pairwise comparisons of each alternative with respect to related criterion. These comparisons using preference scale are given with priority vectors at 8, 9, 10, 11 and 12 together with related consistency ratios.

Tablo 8: Alternative Comparison Matrix and Priority Vectors for the Criterion of Price

Price	A1	A2	A3	A4	Priority Vector
A1	1	1/6	1/4	2	0,091
A2	6	1	2	8	0,528
A3	4	1/2	1	7	0,328
A4	1/2	1/8	1/7	1	0,053

CR: 0,01

Tablo 9: Alternative Comparison Matrix and Priority Vector for the Criterion of Proximity to School

Proximity to School	A1	A2	A3	A4	Priority Vector
A1	1	5	9	7	0,658
A2	1/5	1	4	2	0,182
A3	1/9	1/4	1	2	0,087
A4	1/7	1/2	1/2	1	0,073

CR: 0,08

Tablo 10: Alternative Comparison Matrix and Priority Vector for the Criterion of Green Environment

Green Environment	A1	A2	A3	A4	Priority Vector
A1	1	1/8	1/3	1/5	0,053
A2	8	1	5	6	0,631
A3	3	1/5	1	2	0,169
A4	5	1/6	1/2	1	0,147

CR: 0,09

Tablo 11: Alternative Comparison Matrix and Priority Vector for the Criterion of Accessibility

Accessibility	A1	A2	A3	A4	Priority Vector
A1	1	1/2	3	1/4	0,148
A2	2	1	5	1/2	0,280
A3	1/3	1/5	1	1/7	0,059
A4	4	2	7	1	0,513

CR: 0,01

Tablo 12: Alternative Comparison Matrix and Priority Vector for the Criterion of Age of Building

Age of Building	A1	A2	A3	A4	Priority Vector
A1	1	1/3	1/4	3	0,134
A2	3	1	2	6	0,451
A3	4	1/2	1	7	0,359
A4	1/3	1/6	1/7	1	0,056

CR: 0,05

The next thing to do is multiplying preference matrixes according to the cities and criteria. Importance level of all alternatives is shown in Table 13 and calculation process of the first one is explained in detail as an example below.

$$(0,091*0,493)+(0,658*0,224)+(0,053*0,141)+(0,148*0,054)+(0,134*0,088)=0,219$$

Tablo 13: Calculation of Priority Vector for the Entire Problem

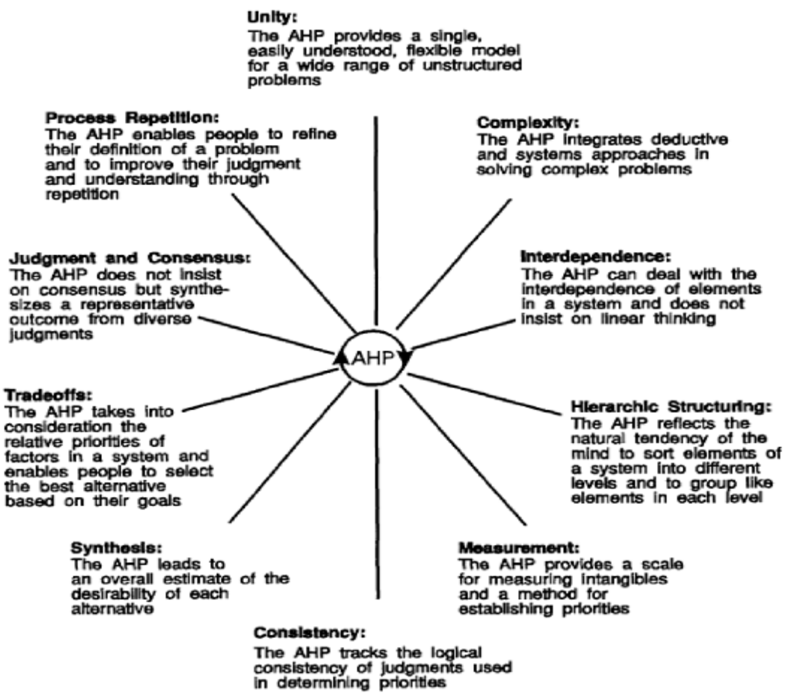
City / Priority Vector	C1	C2	C3	C4	C5	Priority Vector for the Entire Problem
	0,493	0,224	0,141	0,054	0,088	
A1	0,091	0,658	0,053	0,148	0,134	0,219
A2	0,528	0,182	0,631	0,280	0,451	0,447
A3	0,328	0,087	0,169	0,059	0,359	0,241
A4	0,053	0,073	0,147	0,513	0,056	0,096

Finally when the results are analyzed Ankara city (A2) received the highest score and Eskisehir region (A4) received the lowest score.

3.3. ADVANTAGES AND DISADVANTAGES OF THE AHP

Advantages of AHP method is summarized in Figure 7.

Figure 7: Advantages of the Analytic Hierarchy Process



Source: (Saaty, 1999).

Even if AHP method has many advantages many critics have been brought on subjects about scale, eigen vector, priorities and scoring (Ünal, 2010). Although many critics are brought, method is used frequently by decision makers. Having many applications shows that it is better than other decision making tools (Vila and Beccue, 1995).

CHAPTER FOUR
IMPLEMENTATION OF AHP METHOD FOR FACILITY LOCATION SELECTION

4.1. PURPOSE OF STUDY

In this study new facility location selection problem for a company active in apparel sector at Izmir is considered by using AHP Method as one of MCDM methods. When the share of apparel sector in Turkish and World economy is considered, it is clear that decision making on facility location selection of a company presents importance on the decision to be made. In this selection process, it has purpose of assessing the results by AHP method for the advantage of simplicity, straightforward, convenient in different situation and ease of use for pairwise comparison of different alternatives.

4.2. DEFINING THE PROBLEM AND SOLUTION PROCESS

Considered factory for application produces finished goods from knitted fabric since 1993 and turns this production to export in 2002 which at the moment carrying its business in production and export fields. Optimal facility location problem oriented to determination of a new production site with the nature of strategic decision for the apparel company is discussed. For new production site, primarily incentives for supporting investments on apparel sector were taken into account. Below incentives are given to investments in the determined sector at minimum investment amounts and to maximum investments to be done (Dtajans: 2014):

1. Customs duty exemption,
2. VAT exception,
3. Tax Relief,
4. Insurance premium employer share support,
5. Land allocation
6. Interest support.

Cities in incentive systems are in the Table 14 below.

Tablo 14: Cities in Incentive Systems

1st Region	2nd Region	3rd Region	4th Region	5th Region	6th Region
Ankara	Adana	Balıkesir	Afyonkarahisar	Adıyaman	Ağrı
Antalya	Aydın	Bilecik	Amasya	Aksaray	Ardahan
Bursa	Bolu	Burdur	Artvin	Bayburt	Batman
Eskişehir	Çanakkale	Gaziantep	Bartın	Çankırı	Bingöl
Istanbul	Denizli	Karabük	Çorum	Erzurum	Bitlis
Izmit	Edirne	Karaman	Düzce	Giresun	Diyarbakır
Kocaeli	Isparta	Manias	Elazığ	Gümüşhane	Hakkari
Muğla	Kayseri	Mersin	Erzincan	K.Maraş	Iğdır
	Kırklareli	Samsun	Hatay	Kilis	Kars
	Konya	Trabzon	Kastamonu	Niğde	Mardin
	Sakarya	Uşak	Kırıkkale	Ordu	Muş
	Tekirdağ	Zonguldak	Kırşehir	Osmaniye	Siirt
	Yalova		Kütahya	Sinop	Şanlıurfa
			Malatya	Tokat	Şırnak
			Nevşehir	Tunceli	Van
			Rize	Yozgat	
			Sivas		

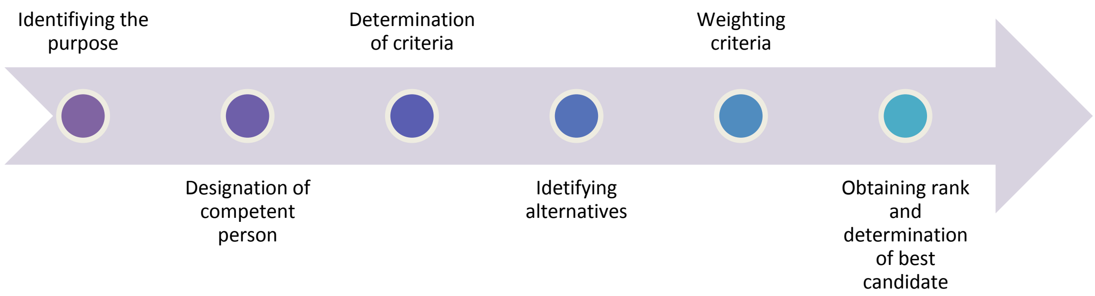
Source: Dtajans: 2014.

Under the investments in the State Aid Incentive System; Ağrı, Ardahan, Batman, Bingöl, Bitlis, Diyarbakir, Hakkari, Iğdır, Kars, Mardin, Muş, Siirt, Şanlıurfa, Şırnak, Van provinces, and in the sectors identified for Bozcaada and Gökçeada districts, "Regional Incentives" is given in order to support investments made by entrepreneurs for investments of 500 thousand TL and more (Dtajans: 2014).

It is observed that application to 5th and 6th regions for Textile and Apparel sector investments are intensive. According to recent information obtained, export values have showed an increasing trend up to 40 percent in eastern and southeastern region. That the region is close to Iran, Middle East and Gulf countries has great effect on growth of exports.

Information obtained company for this study wishes to determine its new production site on the 6th Region and the path to be followed at this study is shown below in Figure 8.

Figure 8: Steps of Proposed Method



4.2.1. Determination of Criteria

Criteria to be taken into account in selection of facility location for apparel firm are determined by the authorized people in the company and classified as shown below (Dtajans: 2014);

1. Utilization from incentives (C1),
2. Proximity to raw material (C2),
3. Labor (C3),
4. Subsidiary industry (C4),
5. Transportation facilities (C5),
6. Proximity to market (C6).

4.2.2. Determination of Alternatives

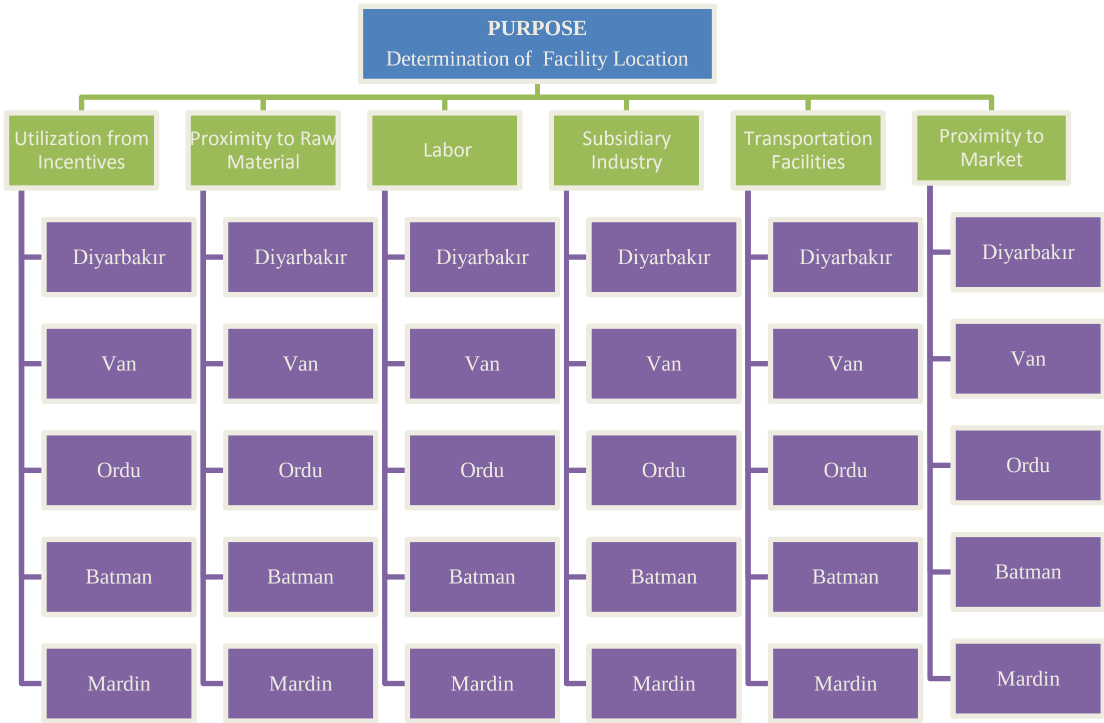
Alternative cities as the site for new facility location on the 6th Region were determined by results of interview in the same way and they are given below.

1. Diyarbakır (A1)
2. Van (A2)
3. Ordu (A3)
4. Batman (A4) Mardin (A5)

4.2.3. Formation of AHP Structure

Starting from the determined purpose for creation of hierarchic structure as one of the important processes to criteria and alternatives a hierarchic structure is formed. Hierarchical structure created for criteria and alternatives determined to be purpose oriented is given in the Figure 9.

Figure 9: Hierarchical Structure Created for the Problem



4.2.4. Pairwise Comparison of Criteria

After determination of hierarchic structure for the problem, as a result of interview with related people in the company criteria are assessed mutually by 1-9 scale of Saaty as shown in Table 3 and the values given in the matrix in Table 15 were obtained. Since comparison of one element by itself is expressed as number 1 in this matrix, diagonal matrix has received value of 1. Since in a matrix with *N* elements can do $n(n+1)/2$ comparisons, this study has done 21 comparisons.

Tablo 15: Comperative Scores of Criteria

Criteria	C1	C2	C3	C4	C5	C6
C1	1	5	2	3	6	7
C2	1/5	1	¼	1/2	2	3
C3	1/2	4	1	3	4	5
C4	1/3	2	1/3	1	3	4
C5	1/6	1/2	¼	1/3	1	2
C6	1/7	1/3	1/5	1/4	1/2	1
Total	2,343	12,833	4,033	8,083	16,500	22,000

According to Table 15, it can be explained as while Utilization from Incentives (C1) criterion shows highly important condition to Proximity to Raw Material (C2) criterion, it is rather important to Subsidiary Industry (C4) criterion.

After completing the first step of AHP method, in behalf of obtaining priority vector normalization process is followed by as the next step. Normalized pairwise comparison matrix is formed by dividing values of each column by the related column total. Next, each row is added, their average is calculated and priority vector given in Table 16 is obtained.

Tablo 16: Normalized Criteria Comparions

Criteria	C1	C2	C3	C4	C5	C6	Priority Vector
C1	0,427	0,390	0,496	0,371	0,364	0,318	0,394
C2	0,085	0,078	0,062	0,062	0,121	0,136	0,091
C3	0,213	0,312	0,248	0,371	0,242	0,227	0,269
C4	0,142	0,156	0,083	0,124	0,182	0,182	0,145
C5	0,071	0,039	0,062	0,041	0,061	0,091	0,061
C6	0,061	0,026	0,050	0,031	0,030	0,045	0,041

CR= 0,02

After finding priority vector prosess, accuracy of evaluation was investigated. Thus, consistency index was found as *CI* = 0,03 at criteria comparison according to the method. With the help of Eq.23, calculated *CR* was found as 0,02 by using values from table y. Since this value is less than 0,10, it is understood that criteria comparison table created is consistent.

With respect to importance of main criteria, it was observed that the first rank of priority vector is incentive criterion with 39% and the second rank is labor criterion with 27% ratios whereas proximity to market criterion has the last rank for apparel company.

4.2.5. Comparison of Alternative Suppliers with Respect to Criteria

After finding criteria weights, the same processes for determining alternative scores according to criteria are applied. Pairwise comparison matrices for each evaluation criteria, priority vectors and consistency ratios are calculated as shown in Table 17, 18, 19, 20, 21 and 22.

Tablo 17: Comparison of Alternatives with Respect to the Criterion of Utilization from Incentives

C1	A1	A2	A3	A4	A5	Priority Vector
A1	1	1/3	3	5	6	0,273
A2	3	1	3	4	7	0,419
A3	1/3	1/3	1	5	7	0,199
A4	1/5	1/4	1/5	1	2	0,069
A5	1/6	1/7	1/7	1/2	1	0,040

CR = 0,09

Tablo 18: Comparison of Alternatives with Respect to the Criterion of Proximity to Raw Material

C2	A1	A2	A3	A4	A5	Priority Vector
A1	1	1/2	2	1/4	4	0,153
A2	2	1	4	2	6	0,370
A3	1/2	1/4	1	1/5	3	0,091
A4	4	1/2	5	1	6	0,341
A5	1/4	1/6	1/3	1/6	1	0,045

CR = 0,05

Tablo 19: Comparison of Alternatives with Respect to the Criterion of Labor

C3	A1	A2	A3	A4	A5	Priority Vector
A1	1	1/3	2	1/2	4	0,155
A2	3	1	5	3	7	0,458
A3	1/2	1/5	1	1/5	3	0,089
A4	2	1/3	5	1	4	0,250
A5	1/4	1/7	1/3	1/4	1	0,047

CR = 0,04

Tablo 20: Comparison of Alternatives with Respect to the Criterion of Subsidiary Industry

C4	A1	A2	A3	A4	A5	Priority Vector
A1	1	1/3	3	1/5	4	0,142
A2	3	1	4	1/2	5	0,273
A3	1/3	1/4	1	1/6	2	0,072
A4	5	2	6	1	7	0,466
A5	1/4	1/5	1/2	1/7	1	0,047

CR = 0,04

Tablo 21: Comparison of Alternatives with Respect to the Criterion of Transportation Facilities

C5	A1	A2	A3	A4	A5	Priority Vector
A1	1	1/3	3	1/4	2	0,126
A2	3	1	5	1/2	3	0,265
A3	1/3	1/5	1	1/7	1/5	0,045
A4	4	2	7	1	6	0,456
A5	1/2	1/3	5	1/6	1	0,109

CR = 0,06

Tablo 22: Comparison of Alternatives with Respect to the Criterion of Proximity to Market

C6	A1	A2	A3	A4	A5	Priority Vector
A1	1	1/6	1/4	1/8	1/2	0,043
A2	6	1	2	1/3	5	0,259
A3	4	1/2	1	1/4	2	0,140
A4	8	3	4	1	5	0,482
A5	2	1/5	1/2	1/5	1	0,076

CR = 0,02

4.2.6. Ranking

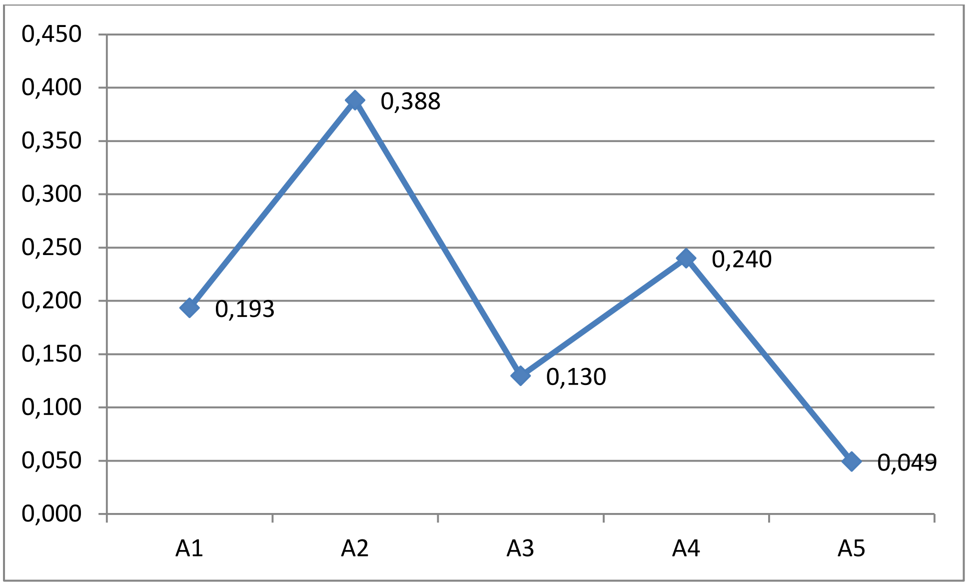
Under the last step of method in order to determine the importance ranks of decision points, priority vectors come together in matrix format and multiplied by the vector for weight values from the former step.

Tablo 23: Ranking

City/ Priority Vector	C1	C2	C3	C4	C5	C6	Priority vector for the entire problem
	0,394	0,091	0,269	0,145	0,061	0,041	
A1	0,273	0,153	0,155	0,142	0,126	0,043	0,193
A2	0,419	0,370	0,458	0,273	0,265	0,259	0,388
A3	0,199	0,091	0,089	0,072	0,045	0,140	0,130
A4	0,069	0,341	0,250	0,466	0,456	0,482	0,240
A5	0,040	0,045	0,047	0,047	0,109	0,076	0,049

According to obtained values of column vector, 0,193 shows importance level of A1 alternative, 0,388 importance level of A2 alternative, 0,130 importance level of A3 alternative, 0,240 importance level of A4 alternative, 0,049 importance level of A5 alternative respectively. If they are ranked by the orders of magnitude, order of importance is as A2, A4, A1, A3 and A5 which is shown in the Figure 10.

Figure 10: Performance Values of Each Alternative



CONCLUSION

Although plant location is the place for realization of purposes of firms in the best way, keeping the plant costs in minimum level and raising the incomes to highest level which means providing the highest profit, it is one of the mostly encountered optimization problems in real life.

Whether it is public or private enterprise all organisations are encountered with such problem and they have to make a critical decision. Especially when the issue is taken into account together with cost elements, in behalf of providing success for the long term, it becomes one of the most important decisions of the organization. Difficulty of the problem originates from taking into attention many parameters at the same time.

Textile and apparel sector for Turkey and the World has important place due to employment created, added value at production process, share among foreign trade numbers, cause to increase in social welfare and it is a sector which its name is most talked about. With parameters such as its share in gross domestic product and use of national input being in the first rank, this sector has caused the foundation of our existence in global markets.

Textile in Turkey has position with the tenth rank as supplier in the world, the second rank as supplier in EU and as apparel, the fourth rank supplier in the world and the second rank as supplier in EU. When informality of the sector at 80 % levels is considered, its real weight in the economy of our nation is far greater clearly.

Decisions to be made on the issue of location site for apparel plants as the subject of the study are among the strategic decision and its results have long term effect on profitability, productivity, performance and success of the plant. Plants have hard times in making decision under the influence of various factors and at situations where there are many alternatives to be selected. At this point selecting scientific methods rather than individualistic decision making prevents possible errors and brings certain advantages accordingly. At such type decision steps, multi-criteria decision making methods step in.

In this study five plant locations for an apparel plant are analyzed with AHP method as multi-criteria decision making methods. Results showed that Van province is placed to first rank with advantages of utilization from incentives and labor.

In textile and apparel industry, 369 of 1214 investing companies taking highest regional incentives since June 2012 are headed towards 5^{th} and 6^{th} Regions. Incentive to input and labor cost at stated regions becomes effective at this point. It is defended that labor intensive Textile shall support national development with investing to East which shall decrease costs and provide employment.

As a result, before starting the selection of plant location, it is important to study the existing structure of sector, to determine trends and to place the targets of company clearly. If necessary, taking professional help about the issue would be useful for avoiding errors. Furthermore, selection results among the existing alternatives may be compared with each other by applying different methods.

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