A NEW METHODOLOGY IN MULTIPLE CRITERIA DECISION-MAKING SYSTEMS: ANALYTIC NETWORK PROCESS (ANP) AND AN APPLICATION

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Çok Kriterli Karar Verme Sistemlerinde Yeni Bir Yöntem: Analitik Network Prosesi (ANP) ve Bir Uygulama

Özet

Analitik Network Prosesi (ANP) Analitik Hiyerarşi Süreci (AHP) yönteminin uzantısı olan yeni bir çoklu kriterli karar-verme sistemidir. AHP'den çok daha kapsamlı bir yöntem olan ANP, karmaşık karar-verme problemlerine uygulanmıştır. ANP, karar verme sücecini etkileyen kriterler ve alt-kriterler arasındaki her türlü bağımlılık ve geri beslemeyi sistematik olarak ortaya koyma olanağı veren ilk metodolojidir. ANP iki alt bölümden oluşmaktadır. İlk bölüm modeldeki karşılıklı etkileşimleri kontrol eden kriterlerin oluşturduğu kontrol hiyerarşisidir. İkincisi ise, kriterler ve kriterlerin oluşturduğu kümeler arasındaki etkileşimlerin oluşturduğu alt-gruplardır. Bu çalışmada, Türk Traktör Fabrikası için en uygun üretim sisteminin belirlenmesi kararı ANP yöntemi kullanılarak belirlenmiş ve "Fabrika Tüm Parça ve Ürünlerin Üretiminde Esnek Üretim Sistemlerine Geçilmesi" alternatifi % 40.1'lik öncelik derecesi ile en uygun alternatif olarak ortaya konmuştur. Kararın ne kadar gerçekçi olduğunu incelemek için duyarlılık analizi yapılmıştır. Duyarlılık analizi göstermiştir ki avantaj, dezavantaj, fırsat ve risklerin ağırlıkları % 5 artırılıp azaltıldığında alternatiflerin öncelik sıralaması deişmemiştir. Türk Traktör Fabrikası "Fabrikada Tüm Parça ve Ürünlerin Üretiminde Esnek Üretim Sistemlerine Geçilmesi" kararını vermelidir.

Abstract

The Analytic Network Process (ANP) is a new theory that extends the Analytic Hierarchy Process (AHP). The ANP is much broader and deeper than the AHP and can be applied to very sophisticated decision problems. ANP allows interactions and feedback within the clusters, and between the clusters. The ANP consists of two parts. The first consists of a control-hierarchy, or, network of criteria, and sub-criteria that control the interactions in the system under study. The second is a network of influences among the elements and clusters. An application of the ANP to the decision, by Türk Traktör Fabrikası, to choose the best production system, is illustrated along with sensitivity analysis. We found out that "Implementing FMS in entire plant" is the best alternative with 40.1%. Our sensitivity analysis indicates that when we aried the weights of the advantages, disadvantages, opportunities, and risks up and down by five percent in all possible combinations, the priorities of the alternatives remained stable in all the cases.

A New Methodology in Multiple Criteria Decision-Making System: Analytic Network Process (ANP) and an Application

1. Analytic Network Process

The Analytic Network Process (ANP) is a new theory that extends the Analytic Hierarchy Process (AHP) to cases of dependence and feedbacks introduced by Thomas L. Saaty in 1980, with a book in 1996 revised and extended in 2001. The ANP includes the AHP as a special case and can be used to treat more sophisticated decision problems than the AHP (TAJI, 2001: 459) (SAATY, 2001b: 12). The ANP makes it possible to deal systematically with all kinds of dependence and feedback in a decision system (FIALA, 2001:102) (CHEN, 2001:73).

The ANP is implemented in the software *Super Decisions©* and has been applied to various decision problems. It is a coupling of two parts. The first consists of a control hierarchy or network of criteria and sub-criteria that control the interactions in the system under study. The second is a network of influences among the elements and clusters (SAATY, 2001 a: 82).

A decision problem that is analyzed with either the ANP (slightly differently with the AHP) is often studied through a control hierarchy or network for benefits, a second for costs, a third for opportunities, and a fourth for risks (SAATY, 2001b: 182). A decision network has clusters, elements, and links. A cluster is a collection of relevant elements within a network or sub-network (SAATY, 1999: 48). For each control criterion (benefits, opportunities, costs, and risks) the clusters of the system with their elements are determined. All interactions and feedbacks within the clusters are called *inner dependencies* whereas interactions and feedbacks between the clusters are called *outer dependencies*. Inner and outer dependencies are the best way decision-makers can capture and represent the concepts of influencing or being influenced, between clusters and between elements with respect to a criterion. (SAATY, 2001a: 83). Then pairwise comparisons are made systematically including all the combinations of element/cluster relationships. ANP uses the same fundamental comparison scale (1-9) as the AHP. This comparison scale enables the decision-maker to incorporate experience and knowledge intuitively (HARKER/VARGAS, 1990:270) and indicate how many times an element dominates another with respect to the criterion. It is a scale of absolute (not ordinal, interval or ratio scale) numbers. The decision-maker can express his preference between each pair of elements verbally as *equally important, moderately more important, strongly more important, very strongly more important,* and *extremely more important*. These descriptive preferences would then be translated into numerical values 1,3,5,7,9 respectively with 2,4,6, and 8 as intermediate values for comparisons between two successive qualitative judgments. Reciprocals of these values are used for the corresponding transposed judgments. The table below shows the comparison scale used by ANP.

Table 1. The Fundamental Scale

Intensity of Importance	**Definition**	**Explanation**
1	Equal Importance	Two activities contribute equally to the objecte
3	Moderate Importance	Experience and judgement slightly favor one activity over other
5	Strong Importanece	Experience and judgment strongly favor one activity over another
7	Very strong Importance	An activity is favored very strongly over another, its dominance demonstrated in practice
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2,4,6,8	For compromise between the above values	Sometimes one needs to interpolate a compromise judgment numerically because there is no good word to describe it.

(Source: SAATY, 2001b: 26)

Following all pairwise comparisons, the synthesized results would come up. The benefits, opportunities, costs, and risks (BOCR) are rated separately (and can also be carried out for each alternative individually), one at a time, with respect to high-level personal or corporate strategic criteria. Finally, the synthesized results of the four control systems are combined to determine the best outcome by using these ratings respectively to multiply the benefit priorities of the alternatives, opportunity priorities of the alternatives, the normalized reciprocals of the cost priorities of the alternatives, and the normalized reciprocals of the risk priorities of the alternatives (SAATY, 2001c: 6). The result is a set of priorities of the alternatives. Sensitivity analysis is used to investigate the sensitivity of the alternatives when the priorities of BOCR and the criteria are changed.

2. Methodology

For this study the ANP was selected as the decision analysis tool and *Super Decisions©* as the software. The main reason why ANP was selected as a methodology is because of the interactions and dependencies among the criteria in our decision-making model. The database is taken from research carried out at Türk Traktör Fabrikası in the year 2000.

3. Background

3-1. Flexible Manufacturing Systems

Flexible Manufacturing Systems (FMS) are groups of production machines, arranged in a sequence, connected by automated materials-handling and transferring machines (GAITHER/FRAZIER, 2002: 237) (ZUKIN/DALCOL, 2000: 19). In an FMS, a comprehensive computer control system is used to run the entire system (CHASE vd, 2001: 723). The main impetus to switch from a traditional system to an FMS is to introduce flexibility in manufacturing operations so that a firm can compete more efficiently in the marketplace (MOHAMED vd, 2001: 708). An FMS system has three key components:

1. Several computer-controlled workstations, such as CNC machines or robots, that perform a series of operations;
2. A computer-controlled transport system for moving materials and parts from one machine to another and in and out of the system;
3. Loading and unloading stations (KRAJEWSKI/RITZMAN, 2001: 135).

In these systems, kits of materials and parts for a product are loaded on the automated materials-handling system. A code is then entered into the computer system identifying the product to be produced and the location of the product in sequence. As partially completed products finish at one production machine, they are automatically passed to the next production machine. Each production machine receives its settings and instructions from the computer, automatically loads and unloads tools are required, and completes its work without the need for workers to attend its operations (GAITHER/FRAZIER, 2002: 237, 238) (RENDER/HEIZER, 1996: 329).

An FMS is very expensive to acquire but is sufficiently flexible to accommodate new product families.

3-2. Türk Traktör Fabrikası

Türk Traktör Fabrikası was established in 1948 as a main tractor manufacturer in Turkey. It has continued to be the leading industry in the manufacture of tractors in Turkey. In the last six years, it has invested $ 100,000,000 in acquiring the latest technologies such as Computer Aided Design (CAD), Computer Numerically Controlled Machines (CNC), and Flexible Manufacturing Systems. Türk Traktör Fabrikası is currently one of a few companies that implements FMS in Turkey.

Türk Traktör Fabrikası requested from the supplier company an FMS that can meet its specific needs. It had had some difficulties during the implementation of FMS. By having an FMS, considerable benefits were gained such as reducing setup time, increasing customer satisfaction, increasing flexibility, etc.

Three different production systems are implemented in Türk Traktör Fabrikası. They are *cellular manufacturing, flexible manufacturing systems*, and *mass production*. Seven flexible manufacturing lines have been established in Türk Traktör Fabrikası. Each line consists of four CNC machines linked by handling devices. These four lines are controlled by a central computer system. The computer directs the overall sequence of operations and routes the workpiece to the appropriate machine, selects and loads the proper tools, and controls the operations performed by the machine. The system has two load/unload stations. The operator loads and unloads tools and parts onto the standardized fixtures at the workstations. The parts are delivered to the machines from load stations and returned to the unloading areas when the operations are completed. Tools can also be exchanged automatically at the machines. Türk Traktör Fabrikası is now considering the implementation of FMS in the entire organization.

4. The ANP Decision Model

The purpose of using an ANP model is to determine the best production system for Türk Traktör Fabrikası. In this model, there are four feedback networks one for each of very general control criteria: advantages, opportunities, disadvantages, and risks.* These are called the merits of the decision. This model is used to derive different weights for the merits. The four networks have different components. We also have three alternatives:

* Although the ANP uses a control hierarchy of benefits, a second for costs, a third for opportunities, and a fourth for risks, we used another terminology appropriately. Advantage is used instead of benefit whereas disadvantage is used instead of cost.

- Implementation of Flexible Manufacturing Systems in the entire plant (FMS),
- Keeping the current mix production system (MIX),
- Eliminating current Flexible Manufacturing Lines and switching to traditional production systems (TPS).

The figure below shows the ANP main top-level structure.

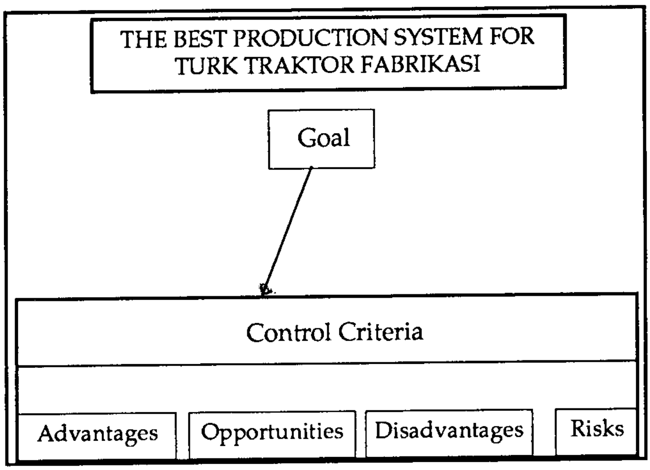

Figure 1. The ANP Main Top-level Structure

4-1. BOCR Weight Development

The strategic criteria used to determine the priorities of the BOCR merits are shown in Figure 2 by using the *Rating* approach of AHP. These are: *Amount of capital required, Manufacturing flexibility, Amount of time required for implementation,* and *Effect on product quality*. These are the main criteria needed when a company makes a decision about implementing a production system. *Amount of capital required* refers to the amount of capital required for each production system alternative. *Manufacturing flexibility* means how much the production system alternatives are likely to affect product flexibility. *Amount of time required for implementation* refers to how much time the production system alternatives will require for implementation. *Effect on product quality* refers to how much the production systems is likely to affect product quality.

The four merits of: advantages, opportunities, disadvantages, and risks were rated according to five intensities (*very high, high, medium, very low, low*) listed below along with their priorities. For example, "*Manufacturing flexibility*" creates several advantages to the company but has neither risk nor disadvantage. "*Amount of capital required*" represents capital investment and creates disadvantages and risks to the company. The BOCR priority calculations are summarized in the table below, and these priorities are used in the main top-level structure to synthesize the results.

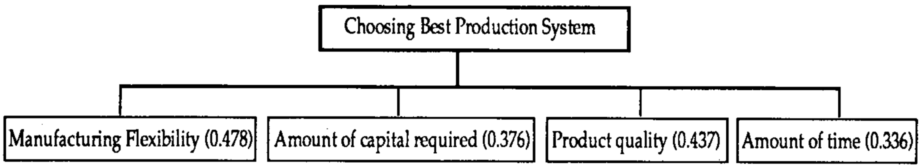

Figure 2. BOCR Merit Criteria

The intensities immediately below Table 2 were derived from pairwise comparisons. The results for each cell are computed by multiplying the weight of the strategic criteria in the left column by the priority of the rating selected and adding across each row. For example, the (Amount of capital, Advantages) cell in the table below is assigned a rating of *very low.* So the value for *very low* 0.095, is multiplied by the value for Amount of capital, 0.376, to give the value for that cell. The total score is the sum of the numbers in the row. The totals thus obtained are normalized to yield the numbers in bold in Table 2.

Table 2. Priority Ratings for the Merits: Advantages, Opportunities, Disadvantages and Risks

	Advantages	Opportunities	Disadvantages	Risks
Manufacturing Flexibility (0.478)	Very high	High	Very low	Very low
Amount of capital (0.376)	Very low	Very low	Very high	Medium
Effect on product quality (0.437)	Very High	High	Very low	Very low
Amount of time required for implementation (0.336)	Low	Very low	High	High
Priorities	**0.328**	**0.248**	**0.207**	**0.217**

5. Control Criteria Networks

Under the advantages, opportunities, disadvantages, and risks networks, there are different clusters established that interact with respect to the control criteria network. The advantages network is divided into three clusters: *Advantages to Customers, Advantages to Company* and *Alternatives.* The Opportunities Network consists of two clusters: *Potential Benefits* and *Alternatives.* The Disadvantages network consists of *Limitations* and *Alternatives* whereas the Risks Network consists of Restrictions and Alternatives. Within each network, several clusters are connected when it seems logical that they have an influence on each other. Through cluster comparisons, the weight/priority of each connection is determined. In a second step, pairwise comparisons are performed with respect to all those elements that have an impact on other elements within their own cluster or other clusters of the network.

5-1. The Advantages Network

Advantages reflect the benefits of the production systems proposed. The clusters in the advantages network are categorized into "Advantages To Customer", "Advantages To Company", and "Alternatives" that each contains several specific elements. "Advantages To Customer" has four elements. They are: *quality improvement, faster delivery, product variety, and customer satisfaction.* "Advantages To Company" has nine elements. They are: *setup time, number of operations, number of operators, number of machine tools, production time, MKK, labor cost, productivity,* and *cutting speed.* The figure below shows the advantages network.*

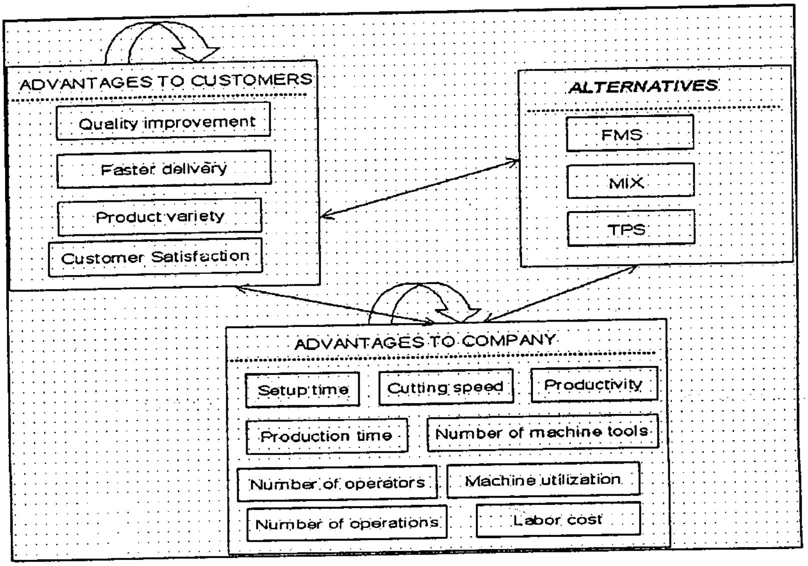

Figure 3. The Advantages Network

* Note that the inner dependencies are shown by the circle arrows, and outer dependencies are shown by the straight arrows.

5-2. The Opportunities Network

The opportunities reflect the potential benefits of the production systems proposed. We have two clusters in this subnet: "Potential Benefits" and "Alternatives". Competitive power and profitability are among the expected benefits. Figure 4 shows the opportunities network.

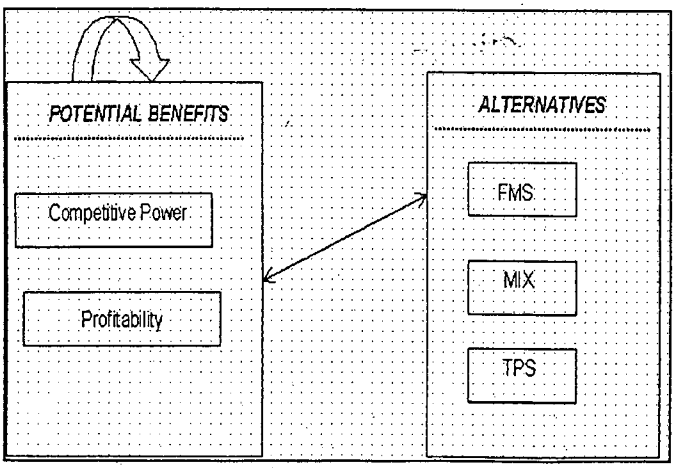

Figure 4. The Opportunities Network

5-3. The Disadvantages Network

The disadvantages reflect the limitations of the production systems proposed. We have two clusters in this subnet. They are: Limitations and Alternatives. There are six elements in the Limitations cluster. They are: *high initial costs, space requirements, labor requirements, central computer control, long implementation lead time, and necessity of developing company specific models.* Figure 5 shows the disadvantages network.

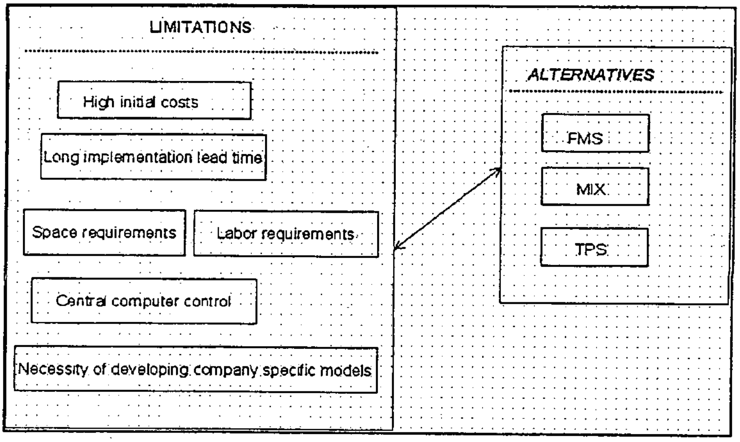

Figure 5. The Disadvantages Network

5-4. The Risks Network

The risks reflect the possible shortcomings of the production systems proposed. We have two clusters in the subnet of risks. They are: Restrictions and Alternatives. Restrictions consist of seven elements: Training employees, material availability, delays in entire production process, top management commitment, delivery dependability, workers involvement, and unstable conditions.

Figure 6 shows the risks network.

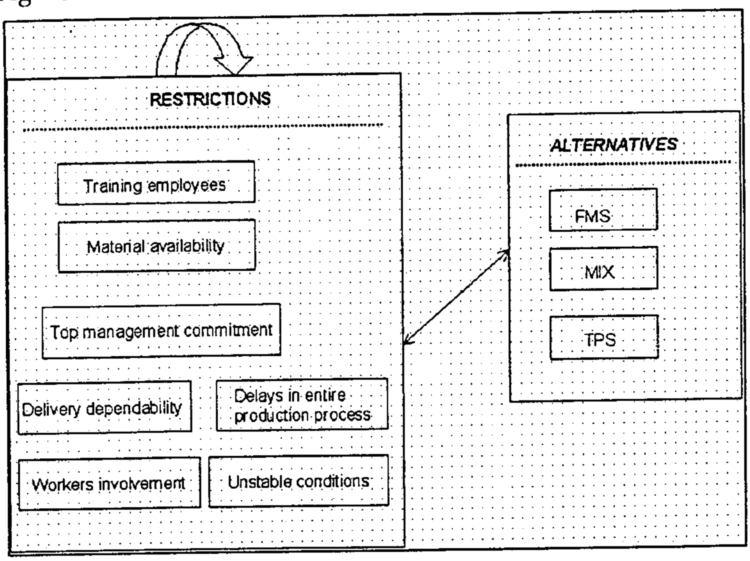

Figure 6. The Risks Network

6. Definitions of the Elements in the Clusters

The control criteria in the feedback networks were developed by considering the results from research done at Türk Traktör Fabrikası described below:*

- Quality improvement: Because of the ability to make things that could not be made by hand (e.g., microprocessors) and because of improved inspection capabilities, quality is improved.
- **Faster Delivery:** The managers pointed out that the firm delivered its products to the market just in time. On-time delivery frequency is increased remarkably.

* Although the elements in the clusters are determined according to the results of implementating FMS in Türk Traktör Fabrikası, pairwise comparisons are made accordingly.

- **Product Variety:** The managers reported that product variety is increased due to scope economies as a result of implementing FMS.
- **Customer satisfaction:** Because of product variety, improved quality, and the ability to produce in small quantities, customer satisfaction is also increased.
- **Setup Time:** The managers reported that they have achieved zero setup time.
- **Cutting Speed:** The managers reported that cutting speed, which reduces cutting times, is much better than before. They increased cutting speed 1000%.
- **Production Time:** Because machining times went down from 410,240 minutes to 352,402 minutes, reduction in production times was achieved.
- **Labor cost:** The managers reported that they have been provided with a significant cost reduction because of decrease in the number of operators.
- **Number of operators:** Since both machining and material handling are under computer control, operators are needed only to perform necessary loading and unloading operations. The managers reported that the number of operators went down from 23 to 12.
- **Number of operations:** The managers reported that the number of operations went down from 30 to 10.
- **Number of machine tools:** The managers reported that the number of machine tools went down from 32 to 12.
- **Productivity:** The managers reported that productivity is increased by reducing the nonproductive time on a part spent on the shop floor.
- **Machine utilization:** The managers reported that they have achieved higher machine utilization because of reduced setup times, efficiently handled parts, and simultaneously produced several parts.
- **Profitability:** All these advantages achieved in Türk Traktör Fabrikası may help to increase profitability in the long-term.
- **Long-term competitive power:** All these advantages achieved in Türk Traktör Fabrikası may help to increase its competitive power in the long-term.
- **Top Management Commitment:** The managers pointed out that FMS begins with top management's commitment and involvement. FMS requires a high degree of management commitment and effort. Many

problems on the managerial side result from a lack of top management support. Top management must be committed and involved. Management may not be willing to adopt new technology. On the other hand managers may quickly abandon the current technology when there are short-term failures.

- **Training Employees:** Due to timing delays for comprehensive training program including programming, technical, operating training, it was reported that there were some difficulties in training personnel as to how to use new machine tools.
- **Unstable conditions:** Turkey is a dynamic country with ups and downs in its economy. The managers reported that because of these unstable conditions, they are very afraid to try new things.
- **Workers involvement:** The managers pointed out that there might be silent resistance from the workers against the new system. Even if there is support from the workers initially, workers support might be lost later on as the study progresses.
- **Delivery dependability:** Until there is some experience in how to maintain machine tools, they had to work with the service team of the supplier company. As a result of this, there were delays
- **Material availability:** Since they did not have sufficient information about the material they will need, they had some difficulties to procure such materials.
- **Delays in the entire production process:** There were certain shortcomings occurring during the implementation of synchronized activities of FMS. These shortcomings caused delays in the entire production process.
- **High Initial Costs:** The managers pointed out that FMS required large capital investments that exceed $10 million.
- **Necessity of developing company-specific models:** FMS must be custom-designed to a company's specific needs. The managers reported that they had difficulties when they were developing their own model.
- **Space Requirements:** The managers reported that installing FMS increased space requirements in the entire plant.
- **Long implementation lead-time:** The managers reported that installing and running FMS took several years.
- **Labor Requirements:** The managers reported that the company needed experts and qualified employees during the *implementation process of* FMS.

- **Central computer control:** Since a comprehensive computer control system is used to run the entire system, if the computer breaks down, the production line would stop and delays and errors would occur in the production process.

7. Feedback Relationships

The next step in formulating the model was to decide on which clusters/elements have direct influence on other clusters/elements. Since the elements in the cluster of advantages to customers are linked to elements in its own cluster, there is inner dependence among these elements. For example, since the element *increase in customer satisfaction* is linked to *quality improvement*, and to *increase in product variety* and to *faster delivery*, there is inner dependence among them. Also since the elements in the cluster *advantages to customers* are linked to elements in the clusters *advantages to company* and *alternatives*, there is outer dependence among them. We made pairwise comparisons systematically to include all the combinations of elements/clusters relationships. The question asked when formulating these relationships was: When considering a given subcriterion, with respect to a specific cluster/element, which of a pair of clusters or elements had more influence with respect to that subcriterion? For example, when considering *advantages to customers*, **with respect to** *increase in customer satisfaction*, which affects *customer satisfaction more, quality improvement or faster delivery, quality improvement or product variety?*

8. Synthesis of Judgments

When we synthesized the advantages network we found that within the cluster of *advantages to customers*, the most important element is "customer satisfaction" with 69.8%; within the cluster of *advantages to company*, the most important element is *productivity* with 25.6%. *Implementation of FMS in entire plant* is the most advantageous alternative with 61.5%.

When we synthesized the opportunities network we found that the most important element is *competitive power* with 55.6%. *Implementation of FMS in entire plant* is the most promising alternative with 66.6% in terms of expected benefits.

When we synthesized the disadvantages network we found that within the cluster of *Limitations* the most disadvantageous element is *high initial costs*. *Implementation of FMS in entire plant* is the least preferred alternative with 0.077% priority.

When we synthesized the risks network we found that within the cluster of *Restrictions* the most risky element is *Delays in entire production process* with 17.5% priority. According to the synthesized results, *Implementation of FMS in entire plant* is the most risky alternative. *Elimination Of Current FMS Lines And Starting Traditional Production Systems* is the most preferred alternative with 71.8% priority.

The last column of Table 2 shows the normalized global priorities of the criteria. These priorities are obtained by weighting their priorities by the priority of their merit. For example, for quality improvement we have 0.328 x 0.112 ≈ 0.037 which becomes 0.028 after normalization. The global priorities indicate that *customer satisfaction* is the most important element with 17.3% globally. The second is *high initial cost* with 9.3% priority.

Table 2. Synthesized Priorities of the Criteria

Merits	**Clusters**	**Criteria**	**Global Priorities** (Normalized)
Advantages (0.328)	Advantages to Customers	Quality improvement (0.112)	0.028
		Faster delivery (0.117)	0.029
		Customer satisfaction (0.698)	0.173
		Product variety (0.072)	0.018
	Advantages to Company	Setup time (0.138)	0.034
		Number of operations (0.054)	0.013
		Number of operators (0.052)	0.013
		Number of (0.012)	0.005
		Production time (0.201)	0.050
		(0.034)	0.008
		Labor cost (0.202)	0.050
		Productivity (0.256)	0.084
		Cutting speed (0.044)	0.011
Opportunities (0.207)	Potential Benefis	Profitability (0.444)	0.070
		Competitive power (0.556)	0.087
Disadvantages (0.248)	Limitations	High initial costs (0.494)	0.093
		Space requirements (0.003)	0.001
		Labor requirements (0.121)	0.023
		Long implementation lead time (0.080)	0.015
		Central computer control (0.224)	0.042

		Necessity of developing company specific models (0.047)	0.001
Risks (0.217)	Restrictions	Training employees (0.162)	0.027
		Delays in entire production process (0.175)	0.034
		Material availability (0.169)	0.028
		Top management commitment (0.137)	0.023
		Delivery dependability (0.037)	0.006
		Workers involvement (0.145)	0.024
		Unstable conditions (0.015)	0.002
		(0.159)	0.026

9. Overall Outcome

The alternatives that have the highest priority under *Disadvantages* and Risks are less preferred. If we take their normalized reciprocals, those with smaller values would now become more preferred and can be added to their values for advantages and opportunities. Thus, to convert the priorities in which the less preferred alternatives have larger values than the more preferred ones, we took the reciprocal of each alternatives priority, as shown in the table below, then we normalized these reciprocals (SAATY, 2001 b: 246). For example, although implementing FMS is the most disadvantageous and most risky alternative, it has the lowest priority (0.070). After inverting the priorities of the disadvantages and risks, it has the highest priority.

Table 3. Inverting Disadvantages and Risks Priorities for Use in an Additive Formula

Alternatives	**Disad.**	**1/Disad. Normalized**	**1/Disad.**	**Risks**	**1/Risks**	**1/Risks normalized**
FMS	0.070	14.286	0.677	0.077	12.987	0.653
MIX	0.183	5.464	0.259	0.180	5.556	0.279
TPS	0.748	1.337	0.063	0.743	1.346	0.068
Sum	1.000	21.087	1.000	1.000	19.888	1.000

The priorities of BOCR are used in the main top-level structure to synthesize the results. The priorities for each subnet are shown in the Table 4 below.

Table 4. Local Priority for Each Control Criterion

	Advantages (0.328)	Opportunities (0.248)	Disadvantages (0.207)	Risks (0.217)
1. FMS	0.628	0.661	0.677	0.653
2. MIX	0.302	0.277	0.259	0.279
3. TPS	0.007	0.062	0.063	0.068

Table 5 gives the overall results.

Table 5. Overall Results

Alternatives	Overall Results
1. FMS	**0.652**
2. MIX	0.282
3. TPS	0.066

"*Implementing FMS in the entire plant*" scores the highest (0.652). It is a comprehensive result that takes into consideration all four networks. The conclusion of this analysis is that "*Implementing FMS in the entire plant*" is the best alternative. This is because, as shown in Table 4, this alternative has the highest priorities for the four merits: advantages, opportunities, disadvantages and risks. But we must now examine how realistic this outcome is.

10. Sensitivity Analysis

To ensure the stability of the outcome of our analysis, we conducted sensitivity analysis. We increased and decreased one of the four merits of BOCR keeping the others proportionally the same.

10-1. Sensitivity Analysis for Benefits

If benefits were to be increased from its original priority 0.328 to 0.934, *Implementing FMS in entire organization* is still preserved as the best alternative (Figure 7 shows). We found that no matter how much we increased or decreased the priorities of advantages, the overall rank of the final outcome were preserved although these experiments changed the magnitude of the superiority of the best alternative, "Implementing FMS" (For example, from 0.652 to 0.630).

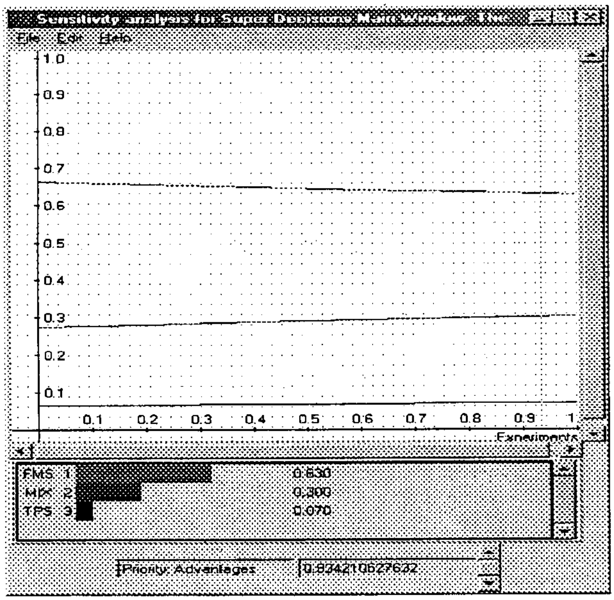

Figure 7. Sensitivity Analysis for Benefits

10-2. Sensitivity Analysis for Opportunities

If opportunities were to be decreased from its original priority 0.248 to 0.802 "Implementing FMS" is still preserved as the best alternative (Figure 8 shows). We found that no matter how much we increased or decreased the priorities of opportunities, the overall rank of the final outcome were preserved.

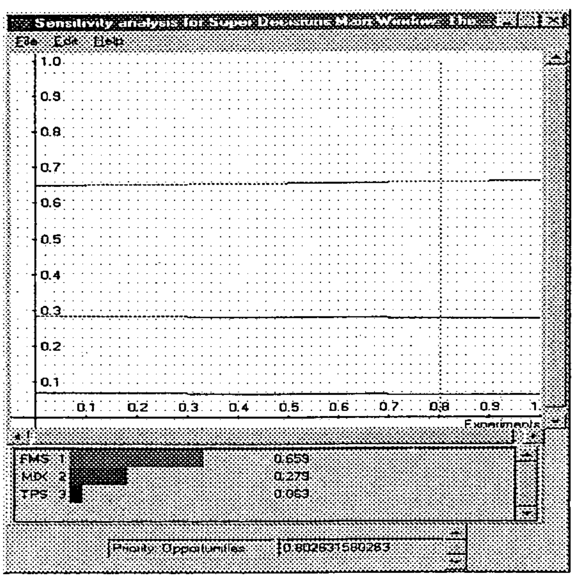

Figure 8. Sensitivity Analysis for Opportunities

10-3. Sensitivity Analysis for Disadvantages

Our results seem to be not very sensitive to importance rating of disadvantages. Even if the rating goes up to 91.3% from 20.7%, which is the original rating, *"Implementing FMS"* is still more preferable than the other alternatives.

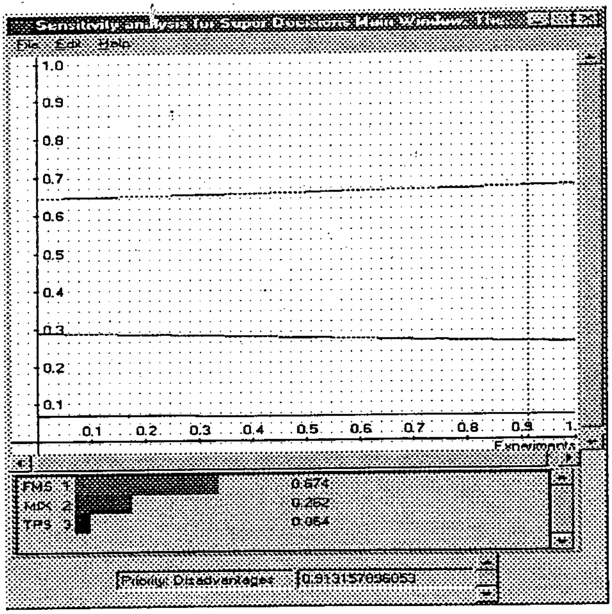

Figure 9. Sensitivity Analysis for Disadvantages

10-4. Sensitivity Analysis for Risks

If risks were to be increased from its original priority 0.217 to 0.753, *"Implementing FMS"* is still preserved as the best alternative (Figure 9 shows).

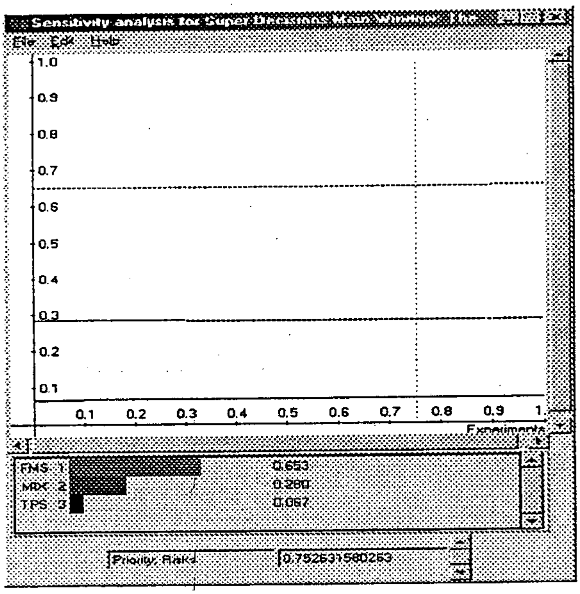

Figure 10 Sensitivity Analysis for Risks

11. Conclusion

The Analytic Network Process is a new methodology that allows interaction and feedback within the clusters and between the clusters in multiple criteria decision-making systems. In this paper, we have determined the best production system for Türk Traktör Fabrikası by using the ANP. We discovered that "Implementing FMS in entire plant" is the best alternative with relative priority 65.2%. We performed sensitivity analysis to test the stability of the outcome in this analysis. Our sensitivity analysis indicates that the final priorities of the alternatives could change, but such change requires making extreme assumptions on the priorities of BOCR. Thus, the outcome of this analysis is very stable and Türk Traktör Fabrikası should choose "Implementing FMS in entire plant" as the best alternative for the decision.

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