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USING DEMATEL-ANP INTEGRATED APPROACH TO DECIDE FOR THE PRODUCTION STRATEGY OF A PRODUCTION LINE

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ABSTRACT

Production planning includes push, pull and hybrid production systems that production firms determine their production strategies according to many variables before starting production. The administration of this process requires experience and time. The intensity of rivalry makes this kind of decision processes important because no firm has the luxury to waste time and to make a wrong decision. In order to solve this problem, the research proposes to use integrated decision-making trial and evaluation laboratory (DEMATEL) and analytic network process (ANP) together which are methods of multi-criteria decision-making models. The process used to establish which options are the most acceptable for operations managers demonstrates how applicable it is by using the generated model in the automotive industry.

Keywords: *DEMATEL-ANP, Multi-Criteria Decision Making; Production Strategies; Push-Pull*
Jel Codes: *C44, M11*

BİR ÜRETİM HATTININ ÜRETİM STRATEJİSİNE KARAR VERMEK İÇİN BÜTÜNLEŞİK DEMATEL-ANP YAKLAŞIMINI KULLANMAK

ÖZ

Üretim firmaları üretime başlamadan önce üretim stratejilerini birçok değişkene göre belirleyerek itme, çekme ve hibrit üretim sistemlerini içeren üretim planlamayı kullanır. Bu sürecin yönetimi deneyim ve zaman gerektirir. Rekabet yoğunluğu, bu tür karar süreçlerini önemli kılar, çünkü hiçbir firmanın zaman kaybetme ve yanlış karar verme lüksü yoktur. Bu sorunun çözümü için araştırma, çok kriterli karar verme modeli yöntemleri olan bütünleşik DEMATEL ve ANP'yi birlikte kullanmayı önermektedir. Hangi seçeneklerin işletme yöneticileri için en kabul edilebilir olduğu tespit etmek için kullanılan süreç, otomotiv endüstrisinde üretilen modelin uygulanması ile ne kadar uygulanabilir olduğunu göstermektedir.

Anahtar kelimeler: *DEMATEL-ANP, Çok Kriterli Karar Verme; İtme-Çekme; Üretim Stratejileri*
Jel Kodları: *C44, M11*

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1. INTRODUCTION

The firms that choose the right strategies direct the dynamic structure of production sector. Giving the right decision on production strategies is essential for businesses to continue their existence. Success in the sector can never be attained unless you become a part of this dynamic structure. The problems to determine production strategy is one of the most hardly worked at and most preferred topics. Senior executives place much importance on this topic, because long term production strategies play a direct role in the success of companies.

Table 1. Push, Pull and Hybrid Strategies

Criterion Code	Criterion	Strategy	References
1	Production time	Pull	(Li and Tzeng, 2009; Kılıç and Durmuşoğlu, 2015)
2	Line interruption	Pull	(Absi et al. 2011; Kılıç and Durmuşoğlu, 2015; Wu et al., 2016)
10	Product variety	Pull	(Sali and Sahin, 2016; Slomp et al., 2009; Faccio, 2014)
7	Product type flexibility	Pull	(Kılıç and Durmuşoğlu, 2015; Slomp et al., 2009; Faccio, 2014)
18	Pricing	Pull	(Ozer and Uncu, 2015; Absi and Kedad-Sidhoum, 2008; Abdal, 1989; McDaniel and Moore, 2005)
19	Technology cost	Pull	(Absi and Kedad-Sidhoum, 2008)
26	Product tracking	Pull	(Battini et al., 2013; Li and Tzeng, 2009; Bryan and Srinivasan, 2014; Holmström et al., 2010)
8	Demand flexibility	Push	(Giard and Jeunet, 2010; Faccio, 2014; Shao et al., 2016)
11	Inventory level	Push	(Li and Tzeng, 2009; Angelos and Kouikogloua, 2011; Slomp et al., 2009; Faccio, 2014)
12	Storage space	Push	(Kılıç and Durmuşoğlu, 2015)
13	Production capacity	Push	(Giard and Jeunet, 2010; Kılıç and Durmuşoğlu, 2015; Sali and Sahin, 2016; Absi and Kedad-Sidhoum, 2008)
14	Investment capacity	Push	(Sali and Sahin, 2016; Absi and Kedad-Sidhoum, 2008)
16	Holding cost	Push	(Absi and Kedad-Sidhoum, 2008)
17	Shortage cost	Push	(Absi and Kedad-Sidhoum, 2008)
20	Supplier product quality	Push	(Battini et al., 2013; Giard and Jeunet, 2010; Razaa and Turiac, 2016)
3	Cycle time	Hybrid	(Li and Tzeng, 2009; Ozer and Uncu, 2015; Slomp et al., 2009)
4	Takt time	Hybrid	(Li and Tzeng, 2009; Ozer and Uncu, 2015; Slomp et al., 2009)
5	Delivery time	Hybrid	(Battini et al., 2013; Li and Tzeng, 2009; Ozer and Uncu, 2015; Bryan and Srinivasan, 2014)
6	Delivery accuracy	Hybrid	(Battini et al., 2013; Bryan and Srinivasan, 2014)
9	Demand	Hybrid	(Angelos and Kouikogloua, 2011; Faccio, 2014; Shao et al., 2016)
15	Product cost	Hybrid	(Absi and Kedad-Sidhoum, 2008)
21	Supplier service level	Hybrid	(Battini et al., 2013; Li and Tzeng, 2009; Holmström et al., 2010)
22	Supplier experience	Hybrid	(Battini et al., 2013; Li and Tzeng, 2009; Shi et al., 2014)
23	Distance of supplier	Hybrid	(Battini et al., 2013; Bryan and Srinivasan, 2014; Holmström et al., 2010; Shi et al., 2014)
24	Supplier service level	Hybrid	(Battini et al., 2013; Giard and Jeunet, 2010; Shi et al., 2014)
25	Supplier technical capacity	Hybrid	(Battini et al., 2013; Giard and Jeunet, 2010; Angelos and Kouikogloua, 2011; Shi et al., 2014)
27	Customer support	Hybrid	(Giard and Jeunet, 2010; Ozer and Uncu, 2015; Long et al., 2013)
28	Favourable market	Hybrid	(Ozer and Uncu, 2015; Abdal, 1989; Razaa and Turiac, 2016)
29	Selling price	Hybrid	(Ozer and Uncu, 2015; Abdal, 1989; Razaa and Turiac, 2016)
30	Product return rate	Hybrid	(Giard and Jeunet, 2010; Bryan and Srinivasan, 2014; Holmström et al., 2010)
31	Product specifications	Hybrid	(Battini et al., 2013; Giard and Jeunet, 2010; Sali and Sahin, 2016)
32	Experience on production	Hybrid	(Giard and Jeunet, 2010; Angelos and Kouikogloua, 2011; Sali and Sahin, 2016)
33	Worker education level	Hybrid	[(Giard and Jeunet, 2010), (Angelos and Kouikogloua, 2011), (Yoon and Mung, 2016)]
34	Number of worker	Hybrid	[(Giard and Jeunet, 2010), (Yoon and Mung, 2016)]

A lot of production factories have to use the suitable strategies in the production process. Inappropriate choices reduce the efficiency in workflow processes by increasing costs (Battini et al., 2013). Aim is to eliminate these inappropriate choices. Thus, to produce a model to help executives and engineers decide. Several criteria should be taken into consideration while deter-mining the production strategies. Considered criteria give organizations a direction in determining the right criteria and in making the right decision. This study aims to examine the effects of each criterion which are used in production strategies on these strategies. Priority values and choices of the criteria are made and then they are analyzed and interpreted.

DEMATEL method which is one of the decision-making models is a method constructed to evaluate the relation between the criteria and to get these relations. ANP method is a method generated by developing AHP in order to solve complex problems and to get the best decisions by taking the cluster relations into consideration (Saaty, 2001). Research aims to determine best fitted production strategies according to different production capabilities by using analytic decision making techniques. There are 34 criteria selected for application in Table 1. This study is organized as follows; in the first part the relation of criteria is determined by DEMATEL method and orders of priority are acquired by ANP. In the second part of study, the production concept and management is explained and the aim of production management and the history is mentioned. Then, by mentioning the strategies applied in the production, their comparison is made in terms of production flow and production system. In the last part, criteria of production strategies are mentioned and explained and listed in tabular form. In the third part, DEMATEL, and ANP methods which are key issues of the study are examined. Basic characteristics and differences of each method are revealed. Furthermore, application steps are expressed in detail and literature review is included. In the fourth part, namely application part, the relations between the criteria are determined and criterion weights are expressed. The acquired findings are noted down and the results of the sensitivity analysis are included at the end of the part. In the fifth and the last part, conclusion part, the results obtained from research are included.

2. PRODUCTION STRATEGIES IN AUTOMOTIVE INDUSTRY

The production concept is an activity used for keeping living by people even centuries ago. In order for the economy in the country to live in a healthy way and to grow, manpower and other sources need to be used in a correct level. Production in automotive industry, in the most basic meaning, is forming and realizing goods (Clément et al., 2015). In other words, the

presented activity to reveal something that has economic meaning is named 'production' (Toni and Tonchia, 2002). Engineers, however, describe it as making a change that will enhance the value on a specific physical property or as transforming raw materials and semi-manufactured materials into a product (Boysen et al., 2015; Pandey and Khokhajaikiat, 1996). Production is not only important for enterprises but also for non-profit organizations, because the goods and the service that they produce and present constitute the reason for being of these organizations (Spilbeeck and Houdt, 2015).

Because of the rivalry in production, the interest in production strategies is increasing day by day. Most of the arguments in literature are set on push (e.g., Material requirements planning (MRP)) and pull (e.g., Kanban) systems (Clément et al., 2015). While push type production strategy tabulates the beginning of work with demand forecasting, the starting of work occurs with the realization of demand in pull type production strategy (Battini et al., 2013). The difference between push and pull strategies is done according to the accession way of work orders to work stations. The strategy which hosts both push type and pull type strategy together is called hybrid strategy. Push strategy are generally identified with MRP. MRP is frequently utilized in production planning and material control systems. MRP starts with Master Production Schedule (MPS) and MPS indicates the production order time and production number of last products in prospect period (Clément et al., 2015). This information can be obtained from the stock level aimed at production systems which make production for the stock or from delivery periods of order production systems. MRP detects these requirements for each last product in respect to the bill of material based on master production schedule. In this way, each product is tried to be produced by master production schedule just before the determined delivery period (Jonsson and Ivert, 2015). Pull systems, on the other hand, are systems that latter processes demand and pull pieces just in the consumed amount and time from the previous processes, and so they are named as systems that order pulls, too (Olhager and Östlund, 1990). However there are similar studies which consider different methodologies such as Puchkova et al. (2016) presented an approach for automotive industry by using mathematical models that covers several types of disruptions: resource breakdown, product quality loss, and demand fluctuations criteria then they compared pull and push strategies in their case. Research conducted the most effective strategy criteria are gathered under 6 cluster titles (Service level; Production and Delivery; Production volume, Inventory, and Capacity; Cost; Supplier; Production technology) listed below to be used in research.

3. METHODOLOGY

In order to decide on the most important production strategy criteria, MCDM methodology is used in terms of convenience to the problem. DEMATEL method from MCDM methods is chosen in order to indicate the relation between criteria. The advantage of this method is that it contains the indirect relations including reconciliatory cause and effect model. DEMATEL meth-od is an effective method which examines the structure and relations between the system components or alternatives in valid number. This method can organize criteria in terms of their kinds and the importance of their effect on one another in order of precedence. The criteria which have more effect on the other criteria and assumed to have high priority are cause criteria; on the other hand, the criteria which are more under effect and assumed to have low priority are effect criteria (Tseng and Lin, 2008; Golcuk and Baykasoğlu, 2016). After obtaining the relation between the criteria, on the purpose of arraying these criteria which are in relation with one another ANP is utilized. It is a method which considers the relations between the factors during the decision-making process and makes modelling without needing the obligation of the problem to connect to one direction. The decision-making problem is modelled with a network topology in ANP method and the dependencies between the factors in modelling stage and the inner dependencies in the factor are taken into consideration. With the model set up in that way, it is aimed to solve decision-making problems in an effective and realistic way (Saaty, 1996).

There are many studies that use DEMATEL-ANP methods together to overcome the individual weaknesses of using one method only, which are offset by the strength of the other method in real-life problems (Büyüközkan and Güleryüz, 2016). In related literature, integrated DEMATEL and ANP are applied in different decision making subjects however in the automotive industry, such applications are very limited. This study contributes to literature by filling this gap with a real case study.

3.1. DEMATEL

DEMATEL Method was developed by Science and Human Relations Program, Geneva Battelle Memorial Institution between the years of 1972 and 1976. DEMATEL is developed particularly for the purpose of improving the complex and in mesh problem groups and contributing to define the applicable solutions in hierarchical structure (Shao et al., 2016; Aksakal and Dagdeviren, 2010). DEMATEL which is a graph theory based method, is useful for revealing the relation be-tween the factors rather than the hypothesis that it's factors such as AHP, one of the traditional techniques, are independent (Shieh et al., 2010). DEMATEL

can organize criteria in terms of their disparity and the importance of their effect on one another in order of precedence.

DEMATEL method can be summarized in the following steps:

In DEMATEL method, there needs to be n number of criteria evaluated by H numbers of decision-makers/group of experts and affecting one another. After determining the decision-makers and criteria, evaluations can be made by applying the following steps.

Step 1: Forming direct relation matrix and finding average direct relation matrix

Direct relation matrix is determined by making paired comparison between criteria by decision-makers/group of experts.

Table 2. Average Matrix Score Range

Numerical values	Definition
0	No influence
1	Low influence
2	Moderate influence
3	High influence
4	Very High Influence

Decision-makers/ group of experts are asked to give an answer to 'Which criterion is more important than the others while determining the production strategies? Question according to determined one of the scales in Table 2.

Direct relation matrix is $n \times n$ size. Each (i, j) element xij of this matrix demonstrates the direct relation from criterion i to criterion j. Each expert or decision-maker is asked to evaluate one. H number of direct relation matrix is acquired.

Obtained direct relation matrixes are averaged by using the Eq. 1 and average direct relation matrix (A) is formed. This is also group decision.

$$a_{ij} = \frac{1}{H}\sum_{n=1}^{H} x_{ij} \tag{1}$$

Step 2: Forming normalized direct relation matrix

Direct relation matrix (C) normalized by using Eq. 2 and Eq. 3 is formed. a_{ij} elements are written instead of x_{ij} elements; the highest of row and column total in matrix is determined and average direct relation matrix is divided by that value.

$$s = \text{maks}(\text{maks}\ \sum_{j=1}^{n} x_{ij}\ , \text{maks}\ \sum_{i=1}^{n} x_{ij}\ ) \tag{2}$$

$$C = \frac{A}{s} \tag{3}$$

Because row totals of direct relation matrix indicate the total effect of each criterion in row on the others, the first statement which is written in Eq. 2 refers to the total effect of the criterion which has the highest effect on the others. Similarly, total of each i column indicates the total effect on *i* criterion. The maximum is the one which indicates the highest effect. When the higher of these two values and divide each element by this value, C matrix and the elements of this matrix take values between 0 and 1.

Step 3: Forming total relation matrix

$$F = C + C^2 + C^3 + \cdots = C(I - C)^{-1} \quad (4)$$

Here, "I" denotes unit in n×n size expresses identity matrix and C's express gradually decreasing indirect effects. Total relation matrix that includes both direct and indirect effects can be obtained with formula (4).

Step 4: determining affecting and affected criteria groups

Based upon F matrix, i^{th} total row of this matrix Di shows the total of direct and indirect effects sent by i criterion to the other criteria. Total column Ri shows the total of effects sent by the other criteria of the same criterion.

While $D_i + R_i$ values indicate how much importance level criteria have, $D_i - R_i$ values divide criteria as affecting and affected. In general, negative values of $D_i - R_i$ are affected group and positive ones are affecting grouping (Tzeng and Huang, 2011).

Step 5: Determining threshold value and drawing influence diagram

Determining threshold value is important in terms of detection of high priority and remarkable values in F matrix. Each element in F matrix represents the influence sent by ith criterion to jth criterion in this matrix. If all of the values taking place in the matrix are taken into consideration, the possibility to move away from the target in inter-criteria effect values which is supposed to reveal the importance in problem increases. Similarly, it causes the effect diagram to be more complex (Fazli et al., 2015).

Detecting threshold value by experts or decision-makers is a traditional approach. The threshold value has been determined through discussions with respondents or chosen subjectively by researchers. However, because of the expert number kept in more number from time to time, it is getting difficult to detect threshold value (Li and Tzeng, 2009). Influence diagram whose threshold value is determined is obtained by showing *(D+R, D-R)* points on a coordinate plane whose horizontal axis is *D+R* and vertical axis is *D-R*.

3.2. Analytic Network Process (ANP)

ANP is a method which considers the relations between decision criteria and eliminates the necessity to model by adhering to one direction to the decision problem. It is a general form of analytic hierarchy process used in multi-criteria decision analysis and it is developed by Thomas L. Saaty (2001).

ANP Method can be summarized in the following steps:

Step 1: Structuring the problem and forming the model

In the first step, the problem is identified. Problem components such as aim, criteria, sub-criteria, alternatives, scenarios and dependencies among them are determined.

Step 2: Making pairwise comparisons

Paired comparison which is necessary according to the network topology obtained in the first step is made by experts. All the components affected by an x component are compared in pairs in terms of the importance of affecting x component. Saaty's (2001) 1-9 scale is used for these comparisons. The scores obtained from the experts are integrated in order to form a comparison matrix. Row average values obtained after the normalization of this matrix's rows indicate the weight of each component. However, in order to accept these values, comparison matrix needs to be consistent. If consistency index is under 0.10, matrix is accepted to be consistent and operations are maintained. Otherwise, rates in matrix need to be reviewed.

Step 3: Forming super matrix

Super matrix is a matrix structure in which all relations between the factors in network are demonstrated. Local priority vectors obtained from paired comparisons are written on the columns of super matrix. Actually, a super matrix is a bitty matrix and each matrix section here indicates the relation between two factors in the system (Chemweno et al., 2015). If none of the factors in a component affects factors in another component, in that case, zero is written to the relevant parts of the super matrix. In the obtained super matrix, a weight super matrix is formed by normalizing the columns whose total are above 1.

Step 5: Forming limit super matrix

Weight super matrix is multiplied by itself until each row converges to a value. These values show the weights of elements in network. However, in order to find the weight of each element in its own group, it is necessary to normalize the elements of that group.

4. APPLICATION OF THE CASE

Purpose of the case is to select most significant and influential success factors selection with an automotive spare part production based point of view. Research conducted 46 senior production managers whom have similar production line that manufactures variety of automobile spare parts. The structure of the application consists of the combination of two methods. One of them is DEMATEL method and the other is ANP. Research put into practice the following steps by using the relevant criteria got in the literature study.

4.1. Case Study

Step 1: As the first step of DEMATEL technique, direct relation matrix (X) is obtained with comparison scale indicated in subsection 3.2. In the study, because criteria number is 34, direct relation matrix is obtained as a *34x34* matrix. In accordance with the method, diagonal values in the matrix are set as zero. The number of experts (H) is set as 1 and thus direct relation matrix (X) equals to average direct relation matrix, Matrix X ($=A$).

Step 2: Normalized direct relation matrix (C) is obtained by normalizing matrix A in step 1. Total row and column of normalization form is calculated. Maximum of total rows are found as 79 while maximum of total columns is obtained as 61. With the help of Eq. 2, normalization value s is calculated as follows:

$$s = maks\,(79,61) = 79$$

As indicated in Eq. 3, all values of matrix A are divided by normalize s value and matrix C is obtained.

Step 3: Total relation matrix (F) which includes both direct and indirect relations is obtained with the help of Eq. 4. *34x34* units used in calculation in the matrix.

Step 4: Effect index is found with the help of total rows and columns in total relation matrix (F). While Di indicates total row values, Ri indicates total column values. $Di + Ri$ total value shows the participation of criterion in problem. Criteria and their participation are demonstrated in Table 3.

Table 3. Factor Role Index

$D_i + R_i$ Value Interval	Number of Factors
≤ 1	2
$1 < D_i + R_i \leq 2$	0
$2 < D_i + R_i \leq 2.5$	10
$2.5 < D_i + R_i \leq 3$	6
> 3	16

High value indicates that more success factor take place in the model. The values are between *0.73805 – 3.96433*.

While some criteria and participation weights are seen to be close to one another, some are seen to be different from other criteria. Important criteria are demonstrated in Table 4. In order to analyze this distribution clearly, values above *2.5* are taken. The ones which have a participation value above *2.5* are stated to be important. There are *22* significant criteria in the model. The best three criteria are found to be delivery time, production capacity and amount of stock. Value shows the effect directions of criteria. If value is positive, criterion *i* is an affecting criterion. If value is negative, criterion *i* is an affected criterion. Distribution can be examined. According to the obtained information, while *15* criteria take positive values and affected the others, *19* criteria take negative values and are affected by the other criteria.

Table 4. Significant Criteria On Model

Value Interval	Criterion No	Role Value ($D_i + R_i$)
$D_i + R_i > 3$	5	3.96434
	13	3.90127
	11	3.78518
	28	3.71400
	15	3.62772
	1	3.61019
	10	3.56165
	32	3.47251
	2	3.38172
	14	3.34521
	9	3.23992
	4	3.20612
	6	3.14960
	7	3.09304
	3	3.05137
	17	3.01362
$2,5 < D_i + R_i \leq 3$	33	2.98708
	25	2.88371
	8	2.81991
	23	2.78379
	16	2.67747
	24	2.61532

A positive correlation between importance value and effect directions does not exist. In other words, the importance state of a criterion cannot guarantee whether it is an affecting or affected criterion. In research, 13 affecting criteria and 9 affected criteria are the most important 22 criteria. Affecting and affected criteria are demonstrated in Table 4 and Table 5.

Cost factors have a structure that affects other factors more. %60 (3 of 5 criteria) of cost factors are in the affecting table. %50 (3 of 6 criteria) of both production and delivery criteria, and production volume, inventory and capacity criteria take place in affecting table. %50 (1 of 2 criteria) of production technology elasticity criteria take place in affecting table. %33.33 (3 of 9 criteria) of service level criteria take place in affecting table. %33.33 (2 of 6 criteria) exist in affecting table.

Step 5: Threshold value is decided by the researcher in this study. In order to determine the appropriate threshold value, total relation matrix (F) values are demonstrated in scatter diagram graphic. Threshold value is found to be 0,08. Arranging threshold value has a significant place in studies. If threshold value is selected very low, effect network gets complex and interpreting becomes difficult. If threshold value is selected very high, criteria effects do not emerge and some criteria may seem as independent although they are not independent. After taking threshold value as 0.08, 63 criteria are selected.

Table 5. Affecting Success Criteria

Factor No	$D_i - R_i$	Criteria Cluster
33	1,83167	Service level
34	1,40793	Service level
5	0,89147	Production and Delivery
32	0,80352	Service level
17	0,75078	Cost
16	0,61607	Cost
15	0,48622	Cost
13	0,41825	Production volume, Inventory, and Capacity
1	0,27494	Production and Delivery
10	0,19669	Production volume, Inventory, and Capacity
11	0,13738	Production volume, Inventory, and Capacity
6	0,07082	Production and Delivery
23	0,07027	Supplier
7	0,02521	Production technology
22	0,01307	Supplier

Table 6. Affected Criteria

Criterion No	$D_i - R_i$	Criterion No	$D_i - R_i$
4	-0,02241	29	-0,28636
18	-0,04328	31	-0,43509
2	-0,16055	19	-0,43859
14	-0,17267	25	-0,48045
9	-0,18519	8	-0,48597
21	-0,20266	30	-0,52495
12	-0,20739	3	-0,55871
20	-0,22066	26	-0,92444
28	-0,25355	27	-1,79960
24	-0,27671		

Matrix (E) is found by converting the values under the threshold value to zero. Influence map is obtained by means of threshold value. There are 63 relation arrows among 34 criteria with high threshold value. Influence map helps criteria relations seem better shown in Fig 1. According to and values, criterion 34 (education levels of workers) is the most affecting criterion with the highest value in model. Criterion 5 (delivery time) is the most important criterion with the highest value in model.

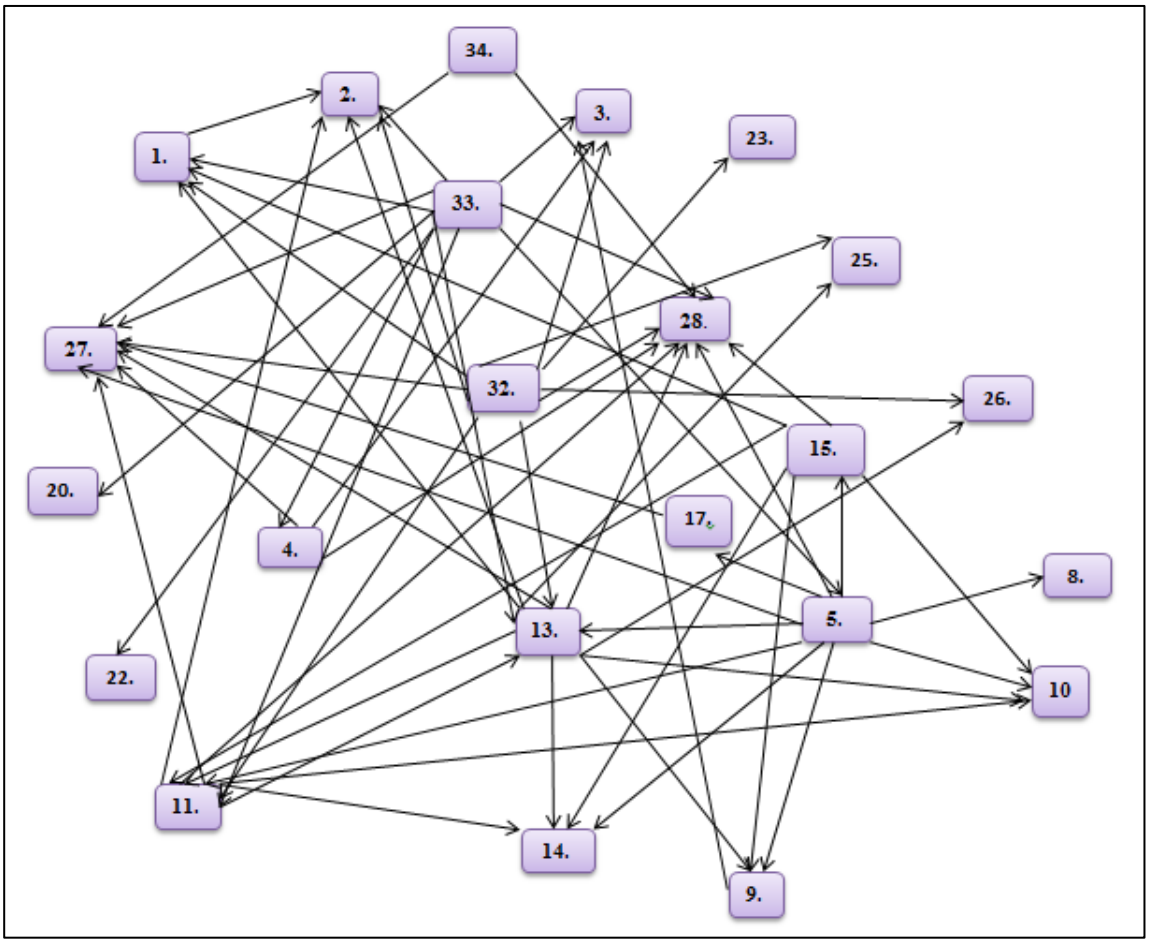

Figure 1. Criteria Influence Map

ANP Solver software is used as a calculation tool in research, while ANP is analyzed. According to the ANP Solver software design, there are 9 different screens and these screens are in relation with each other. While 6 of 9 screens necessitate entering inputs by the user, 3 others contain the results calculated by the software. Moreover, definitions, steps and related date input of the application are shown and explained below.

Calculating limit matrix is the last step of ANP. Important values are obtained in that stage. Inter criteria sort is made by means of these importance values. The result of limit matrix is shown in Table 7 according to the decreasing value.

Table 7. ANP Limit Matrix Results

Criterion No	Criterion definition	ANP Limit Matrix Value
27	Customer support	0,249
28	Market availability	0,247
10	Product variety	0,244
14	Investment capacity	0,097
13	Production capacity	0,075
1	Production time	0,030
9	Demand	0,026
26	Product tracking	0,025
2	Line interruption	0,006
11	Inventory level	0,003

4.2. Sensitivity Analysis

Sensitivity analysis about cluster importance is a common method. The weights of the clusters were assumed to be equal in application. However, because there are clusters which cannot have relations, the weights were changed in the calculation. The weight of production and delivery cluster id changed for this practical application and changed criterion weights are monitored. Three different weights are used in order to determine the changed criterion weights. Cluster weight changes are shown in Table 8.

Table 8. Sensitivity Analysis

Criteria Cluster	Case	Anly.1	Anly. 2	Anly. 3
Production and Delivery	0,192	0,151	0,156	0,159
Production volume, inventory and capacity	0,192	0,165	0,173	0,176
Service level	0,197	0,231	0,225	0,222

According to the ANP results in the application, 3 of 10 criteria are above average. These criteria which are selected by the researcher should be paid attention during the changes. 2 of 3 criteria belong to service level and the remaining one criterion belongs to

production volume, inventory and capacity. After the matrix calculations, limit matrix solutions and criteria list are demonstrated in Table 9.

Table 9. Limit Matrix Sensitivity

Cluster	Criterion Code	Case	1	2	3
Production and Delivery	1	0,030	0,007	0,011	0,012
Production and Delivery	2	0,006	0,001	0,002	0,002
Production volume, inventory and capacity	9	0,026	0,006	0,009	0,011
Production volume, inventory and capacity	10	0,244	0,263	0,260	0,259
Production volume, inventory and capacity	11	0,003	0,001	0,001	0,001
Production volume, inventory and capacity	13	0,075	0,082	0,081	0,081
Production volume, inventory and capacity	14	0,097	0,104	0,103	0,103
Service level	26	0,025	0,006	0,009	0,010
Service level	27	0,249	0,264	0,262	0,261
Service level	28	0,247	0,264	0,261	0,260

Each time the threshold value increases, some factors or relationships will be removed from the map so sensitivity analysis considered those changes.

5. RESULTS

According to DEMATEL findings, some of the most important criteria belong to production and delivery cluster. 6 criteria of production and delivery cluster among the most important criteria. These are as follows: delivery time, production time, cease of line, tact time, delivery in right amount and online time. Another most important criteria cluster is production volume, inventory and capacity. There are 5 important criteria belonging to this cluster. These are as follows: production volume, stock amount, product variety, investment capacity and demand. The clusters following this cluster are as follows, service level cluster with 2 most important criteria (market convenience and experience), cost cluster with 2 most important criteria (product cost and shortage cost) and production technology elasticity criteria cluster with 1 most important criterion (product type flexibility). Just one element belonging to supplier general state cluster does not take place in the most important criteria cluster.

Although there is not an absolute relation between contribution and effect, 13 of 22 most important criteria are found to be affecting (positive) criteria and 9 of them are found to be affected (negative) criteria. Furthermore, cost cluster criteria have a structure that affects other criteria more. 60% of cost criteria (3 of 5 criteria) have positive values. The most affecting criterion is found to be worker education level and the most affected criterion is found to be tact time in model. This kind of elements are detected to be the most important and elusive topics to emphasize while determining the production strategies.

Cluster and node comparisons are identified and super matrix and limit matrix are obtained in ANP method. Providing consistency index helps paired matrix evaluations to be rational. All node comparison matrix indexes are below Saaty's threshold value, 0,10. According to ANP findings, 'customer support' is detected to be the first criterion with the weight of 0,249 in criteria sort. Average weight of criteria is calculated as 0,10020.

Service level cluster has a large weight in the model with the weight of 0,519. Production volume, inventory and capacity cluster with 0,444, production and delivery cluster with 0,036 have the lowest weight. Production technology elasticity cluster, cost cluster and supplier general state cluster are not found to have a weight on the model. Although the most important criteria belong to service level, making a distinction in the other two clusters (production volume, inventory and capacity, production and delivery) is not a preferred situation. This application is just one proof that service level criteria are more dominant than determining production strategies.

As a result of the limit matrix findings obtained from research, hybrid strategy is determined. The importance level of the criteria belonging to the hybrid strategy is seen to be higher than the other criteria.

6. CONCLUSION

The model that acquired in application is determined to have an applicable structure by engineers and executives. That DEMATEL and ANP methods are efficient in MCDM an application from automotive sector, model may give different results in different sectors and areas. Paper proposes DEMATEL as a tool for managers to use with input while deciding production strategies.

Service level, production volume, inventory and capacity, production and delivery criteria from three clusters in model are important and needs to pay attention to. Any negligence in these three clusters may cause various problems. Although technical quality and work success of a company is generally for the sake of performance analyses and development of the company, service level elements that stay in the background are very important for the success of the company.

Because the highest weight is obtained from 'customer support', rather than a customer-based strategy which is focusing on caring to find new customers and selling your products to whomever can buy, the companies should focus on increasing the possible share of purchase of available customers. Being customer-based is trying to plan any actions and

decisions, presented products and services to create satisfaction on the customers as the company and all the workers and at the end being a constantly preferred organization. An important component of being customer-based is customer satisfaction and evaluation. Customer satisfaction is the state of providing an overlap between the customer's expectations and the ones he obtained. Although intercorporate importance level of customer support criterion is underestimated, its importance level in real life is an unquestionable topic. Being customer-based is a strategy that will ensure profit all the time in providing company success.

The companies are supposed to determine the most appropriate strategy for themselves according to the criterion selections. Before decision making methodology is applied, company has to determine their needs and their criteria to find meaningful solutions.

7. LIMITATIONS AND FUTURE WORK

Criteria sorting and criteria selection is commonly used in researches. Qualitative and quantitative methods provide making a choice between some criteria or making easier interpretations by getting sort of all criteria in situations where data are complex. Choice between criteria is made in this study. Because selection structure is formed, it does not require sorting all criteria. It is recommended to increase criteria number and make a sorting between criteria for the future researches. It is also suggested to use Fuzzy DEMATEL and Fuzzy ANP methods to present more clear solutions to the dilemmas that decision-makers may fall into. Research can be applied to different sectors and a common decision result can be obtained.

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REFERENCES

Abdal,. P.L. (1989). Multi-product multi-market model for co-ordination of marketing and production decisions, International Journal of Systems Science 20(11). doi:10.1080/00207728908910284

Absi, N., Kedad-Sidhoum, S. (2008). The multi-item capacitated lot-sizing problem with setup times and shortage costs, European Journal of Operational Research 185(3): 1351–1374. doi: 10.1016/j.ejor.2006.01.053

Absi N., Kedad-Sidhoum, S., Dauzère-Pérès, S. (2011). Uncapacitated lot-sizing problem with production time windows, early productions, backlogs and lost sales, International Journal of Production Research 49(9): 2551-2566. DOI:10.1080/00207543.2010.532920.

Aksakal, E., Dagdeviren, M. (2010). ANP ve DEMATEL Yöntemleri İle Personel Seçimi Problemine Bütünleşik Bir Yaklaşım, Gazi Üniversitesi Mühendislik ve Mimarlık Fakültesi Dergisi, 25(4): 905-913.

Angelos A.E., Kouikogloua, V.S. (2011). Lead-time analysis and a control policy for production lines, International Journal of Production Research 49(7). DOI:10.1080/00207541003627845

Battini D., Boysen N., Emde. S. (2013). Just-in-time supermarkets for part supply in the automobile industry, Journal of Management Control, 24: 209–217, doi: 10.1007/s00187-012-0154-y.

Boysen, N., Emde, S., Hoeck, M., Kauderer, M. (2015). Part logistics in the automotive industry: decision problems, literature review and research agenda, European Journal of Operational Research, 242(1): 107–120. http://dx.doi:10.1016/j.ejor.2014.09.065

Bryan, N., Srinivasan, M.M. (2014). Real-time order tracking for supply systems with multiple transportation stages." European Journal of Operational Research 236(2): 548-560. doi.org/10.1016/j.ejor.2014.01.062.

Büyüközkan, G., and Güleryüz, S. (2016). An integrated DEMATEL-ANP approach for renewable energy resources selection in Turkey. An integrated DEMATEL-ANP approach for renewable energy resources selection in Turkey Volume 182, December 2016, Pages 435–448.

Clément, C., Giard, V., Sali, M. (2015). High variety impacts on Master Production Schedule: a case study from the automotive industry, IFAC-PapersOnLine 48(3): 1073-1078.

Chemweno, P., Pintelon, L., Van Horenbeek, A., Muchiri, P. (2015). Development of a risk assessment selection methodology for asset maintenance decision making: An analytic network process (ANP) approach, International Journal of Production Economics (170): 663-676.

Faccio, M. (2014). "The impact of production mix variations and models varieties on the parts feeding policy selection in a JIT assembly system, International Journal Advance Manufacturing Technology 42(1–4): 543–560. DOI 10.1007/s00170-014-5675-0.

Fazli, S., Kiani Mavi R., Vosooghidizaji, M. (2015). Crude oil supply chain risk management with DEMATEL–ANP, Operational Research 15:453–480 http://dx.doi.org/10.1007/s12351-015-0182-0

Giard, V., Jeunet, J. (2010). Optimal sequencing of mixed models with sequence-dependent setups and utility workers on an assembly line, International Journal of Production Economics 123(2): 290-300. http://dx.doi:10.1016/j.ijpe.2009.09.001

Golcuk, I., . Baykasoğlu, A. (2016). An analysis of DEMATEL approaches for criteria interaction handling within ANP, Expert Systems with Applications 46: 346-366.

Holmström, J., Främling, K., Ala-Risku, T. (2010). The uses of tracking in operations management: Synthesis of a research program, International Journal of Production Economics 126(2): 267-275. http://dx.dodoi:10.1016/j.ijpe.2010.03.017.

Jonsson, P., Ivert, L.K. (2015). Improving performance with sophisticated master production scheduling, International Journal of Production Economics 168: 118-130.

Kılıç, H.S., Durmuşoğlu, M.B. (2015). Advances in assembly line parts feeding policies: a literature review, Assembly Automation 35(1): 57 – 68. http://dx.doi.org/10.1108/AA-05-2014-047.

Li, C.W., Tzeng G H. (2009). Identification of a threshold Value for the DEMATEL method using the maximum mean de-entropy algorithm to find critical services provided by a semiconductor intellectual property mall, Expert Systems with Applications 36(6): 9891-9898.

Long, H.J., Wang, L.Y., Shen J., Wu, M.X., Jiang, Z.B. (2013). Product service system configuration based on support vector machine considering customer perception, International Journal of Production Research 51(18): 5450-5468. http://dx.doi.org/10.1080/00207543.2013.778432

McDaniel, S.W., Moore, S.B. 2005. Pre-Production Relationship Marketing, Journal of Relationship Marketing 4:(1-2) 73-90. doi:10.1300/J366v04n01_06

Olhager, J., Östlund, B. (1990). An integrated push-pull manufacturing strategy, European Journal of Operational Research 45(2–3): 135-142.

Ozer, O., Uncu, O. (2015). Integrating dynamic time-to-market, pricing, production and sales channel decisions, European Journal of Operational Research 242(2): 487-500. http://dx.doi.org/10.1016/j.ejor.2014.09.001.

Pandey, P.C., Khokhajaikiat, P. (1996). Performance modelling of multistage production systems operating under hybrid push/pull control, International Journal of Production Economics 43(2–3): 115-126.

Puchkova, A., Romancer, J.L, McFarla, D. (2016). Balancing Push and Pull Strategies within the Production System. IFAC-PapersOnLine 49-2 (2016) 066–071. DOI. 10.1016/j.ifacol.2016.03.012

Razaa, S.A., Turiac, M. (2016). Joint optimal determination of process mean, production quantity, pricing, and market segmentation with demand leakage, European Journal of Operational Research 249(1): 312-326. http://dx.doi.org/10.1016/j.ejor.2015.08.032

Saaty, T.L. (2001). The analytic network process RWS Publications, Pittsburgh.

Saaty, T.L. (1996). Dependence and Feedback the Analytic Network Process. RWS Publications, Pittsburgh.

Sali, M., Sahin E. (2016). Line feeding optimization for Just in Time assembly lines: An application to the automotive industry. International Journal of Production Economics 174: 54–67. doi:10.1016/j.ijpe.2016.01.009

Shao, J., Taisch, M., Ortega-Mier, M. (2016). A grey-DEMATEL analysis on the barriers between environmentally friendly products and consumers: practitioners' viewpoints on the European automobile industry, Journal of Cleaner Production 112: 3185-3194.

Shi, N., Zhou, S., Wang, F., Xu S., Xiong, S. (2014). Horizontal cooperation and information sharing between suppliers in the manufacturer–supplier triad, International Journal of Production Research 52(15): 4526-4547. DOI:10.1080/00207543.2013.869630

Shieh, J.I., Wu, H.H., Huang, K.K. (2010). A dematel metot in identifying key success factors of hospital service quality, Knowledge-Based Systems 23(3): 277-282.

Slomp, J., Bokhorst, J.A.C., Germs, R. (2009). A lean production control system for high-variety/low-volume environments: a case study implementation, Production Planning & Control 20(7): 586-595. doi:10.1080/09537280903086164

Spilbeeck, I V., Houdt, B.V. (2015). Performance of rate-based pull and push strategies in heterogeneous networks, Performance Evaluation (91): 2-15.

Toni, A.D., Tonchia, S. (2002). New production models: A strategic view, International Journal of Production Research 40(18).

Tseng, M.L., Lin, Y.H. (2008). Application of Fuzzy DEMATEL to Develop a Cause and Effect Model of Municipal Solid Waste, Environment Assessment 158: 519-533.

Tzeng, G.H. Huang, J.J. (2011). Multi Attribute Decision Making: Methods and Applications, USA, CRC Press.

Wu, K., Zhao, N., Gao, L., Lee, C.K.M. (2016). Production control policy for tandem workstations with constant service times and queue time constraints, International Journal of Production Research. Published online: 05 Jan 2016. DOI:10.1080/00207543.2015.1129468

Yoon , S.Y., Ko, J., Mung, M. (2016). A model for developing job rotation schedules that eliminate sequential high workloads and minimize between-worker variability in cumulative daily workloads: Application to automotive assembly lines, Applied Ergonomics 55: 8–15. http://dx.doi:10.1016/j.apergo.2016.01.011