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Determining the Obstacles to Green Production with The Dematel Method

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Abstract: Problems such as global warming, pollution, rapid depletion of the present resources, unsuccessful waste management, along with increasing environmental concerns and awareness, are the driving forces pushing producers to adopt green production practices all over the world. With the emergence of urgent requirements to compete efficiently together with global awareness of environmental risks, production systems are transforming into a new paradigm. In this perspective, green production has been conceptualized, and then implemented by large-scale enterprises in developed countries. However, various obstacles emerge in the path of the green production of enterprises due to limited resources. The purpose of this article is to identify and prioritize the obstacles to green production. In this context, the weights of the obstacles that were created based on the literature data, and their relations with each other were identified with the DEMATEL (The Decision Making Trial and Evaluation Laboratory) Method. According to the findings of the study, it was concluded that two of the six common success factors were those that were the affected factors, and four were the affecting factors. The relations among the criteria are presented with the cause and effect diagram.

Keywords: Green Production, DEMATEL, Multi-Criteria Decision-Making

1. Introduction

The rapid depletion of the present natural resources with rapid industrialization and urbanization also brings major problems at the point of facing much larger environmental disasters, and perhaps most importantly, famine for people. These developments caused that green production became a common practice for all members of the cooperating countries to improve this cooperation among countries and protect natural resources (Tol, 2018: 5). In this context, many production businesses in different countries make important strategic decisions on the rapid changes in their sectors, globalization, and increasing concerns about the environment, and initiate green production works to develop more environmentally friendly processes (Cherrafi et al., 2017: 830).

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The term green production is the new production paradigm using a variety of green strategies (i.e. targets and principles) and techniques (i.e. technology and innovations) to become more eco-efficient. Green production involves the creation of products/systems consuming fewer materials and energy, the substitution of the input materials, reduction of unwanted outputs, and transforming outputs into inputs (recycling) (Faris et al., 2019: 477; Cortellini, 2001). A green production concept is an approach focusing on minimizing the negative effects products may cause in the environment from the design stage to the end of its life. This concept is defined as the sum of all the activities performed to minimize the wastes (Mohanty & Deshmukh, 19998: 624). Green production, which meets customer needs and environmental norms, also aims to save energy and develop products with fewer wastes (Dornfeld, 2014: 63). Green production must be considered as an opportunity for enterprises to expand their local and global market shares in a dynamic competitive environment. Understanding and using green production strategies and techniques more effectively will enable producers to realize that -unlike production strategies such as cost and time- being green affects all other production competitive advantages in a positive direction. For example, reducing material wastes and energy consumption will decrease production costs and improve production times (Deif, 2011: 1554).

It is possible to speculate that this new production concept emerged as a result of the changes experienced in technology and the market as in others. Increasing sensitivity and awareness of societies towards environmental problems caused that they adopted more environmentally friendly products. However, it is also possible to argue that the emergence of new technologies enabling more environmentally friendly production and product design and facilitate recycling made the spread of the green production concept easy (Ghazilla et al., 659). Green production addresses production practices intended to reduce or eliminate the negative environmental effects, which may be experienced at any stage of production. It is a production approach, which focuses on the use of processes, technology, and practices, which do not pollute the environment or damage customers, employees, or other relevant stakeholders. With green production, it is possible to argue that enterprises will increase their environmental performance and social benefits directly (King & Lenox, 2001: 245).

Although green production has gained widespread importance in recent years, its adoption rates are still low in developing countries. Studies conducted in this context show that green production is adopted more in developed countries than in developing economies (Panwar et al., 2016:27). It is possible to argue that the reason for this may be the fact that the cultural barriers such as internal resistance and resistance to change are intense especially in developing countries than in developed countries (Delgado et al., 2010: 514). However, since there are strict environmental regulations and policies in effect in developed countries such as the USA, EU, and Germany, such countries have made progress in the transition to green production (Biju et al., 2015: 811).

When it is considered that it is almost impossible for businesses to survive in global competition without green production, the necessity for enterprises to adapt to green production practices has emerged. It is an expected situation that there will be difficulties or obstacles in the adoption of the green production approach as with all radical innovations. Determining these possible obstacles to ensure the widespread use of green production by businesses in the production sector is of great importance (Mittal et al. 2016: 403; Kaur et al., 2018: 313). In this context, there is a need to examine the obstacles that affect green production. Based on this need, the obstacles affecting green production in production businesses operating in Turkey will be determined in this study by using the DEMATEL method.

2. Literature Review

The obstacles to green production will be determined with a wide literature review in this part of the study. When the literature was reviewed, it was seen that although there are many studies focusing on the benefits of green production, there are few studies on the obstacles to green production. Ghazilla et al. (2015) aimed to determine the obstacles to green production in small and medium-sized enterprises in Malaysia. In their study, 64 obstacles were identified under 8 main titles. They reported obstacles such as weak organizational structure and undeveloped corporate culture, lack of authority, lack of technical expertise, lack of environmental attitude and perception, weak market position, lack of strategy against changes, the society with low green attitudes, low awareness of green products among customers, insufficient R&D and testing in green production processes, lack of environmental inspection, insufficient government support for green production practices, and high initial capital costs.

In their study, Yu et al. (2008) reported six barriers to eco-design in Chinese electrical and electronics companies. Zhang et al. (2009) pointed out ten barriers for businesses to participate in environmental management initiatives in China with their survey study. Cooray (1999) examined the SME-specific barriers to applying for green production programs in SMEs in Sri Lanka in the food and beverage, hospitality, and steel sectors. In their study, Rahimifard et al. (2019) revealed the barriers to recycling in the UK; Yu et al. (2008) the eco-design and production status in automotive enterprises; and Studer et al. (2006) the barriers to environmental initiatives in Hong Kong businesses. In similar studies, Herren and Hadley (2010) reported the barriers to environmental implementations in American businesses; Sing et al. (2012) the barriers to green production practices in Indian industry. Luken and Van Rompaey (2008) conducted another study and revealed the factors that affected the adoption of environmentally sensitive technology in four production sub-sectors in nine developing countries; Seidel et al. (2009) reported the obstacles faced by SMEs in the transition to environmentally friendly production. In their study, Gombault and Versteege (1999) emphasized the barriers to green production as limited time, lack of environmental priorities, and lack of capital assets. Hilson (2000) reported similar results in his study conducted in the USA. In their study conducted on Kenyan businesses, Frijins and Van Vlient (1999) reported that factors such as lack of compliance with environmental regulations, resistance to change, lack of environmental knowledge, and awareness were the barriers to green production implementations. Mitchell (2006) concluded in his study that was conducted in Vietnam that some of the barriers to green production were inadequate sanctions and penalties. Finally, as a result of their study, Silvestre and Silva Neto (2014) reported that insufficient social perception and low competition were among the factors hindering green production.

As found in the reviewed literature, although green production activities and their implementation methods vary a great deal, it is also seen that the obstacles are interrelated. Various studies were conducted to resolve the barriers to green production. Based on this viewpoint, 10 factors different from the studies in the literature were determined. These factors will be analyzed with the help of the DEMATEL Method, which is one of the Multi-Criteria Decision-Making Methods (MCDM), and recommendations will be made to help decision-makers to eliminate the identified obstacles.

3. Method

DEMATEL Method is one of the most effective methods, which can be used to analyze direct and indirect relations between the components of a system according to their types and importance degrees (Geng & Chu, 2012). DEMATEL Method, which is one of the most important and most frequently used multi-criteria decision-making techniques, is a systematic method making use of expert evaluations that may be obtained in clear numerical values to develop a series of relationship matrices (Maduekwe & Oke, 2021). DEMATEL is a comprehensive method for constructing and analyzing a structural model that has causal relations between complex factors. It allows administrators to divide the related variables into cause-effect groups to understand the causal relations between the variables better (Jalal & Shoar, 2017).

The DEMATEL Method is mostly used for decision-making qualifications based on the pairwise comparison. The different steps in the DEMATEL Method are as follows (Wu & Chang, 2015; Nilazsh et al., 2015)

Step 1: Creating the Direct Relationship Matrix (D)

$$D=\begin{bmatrix} d_{11} & d_{1j} & \cdots & d_{1s} \\ d_{i1} & d_{ij} & \cdots & d_{is} \\ \vdots & \vdots & \cdots & \vdots \\ d_{s1} & d_{sj} & \cdots & d_{ss} \end{bmatrix} \text{ (i,j=1,2…,s)} \quad [1]$$

At this stage, a Direct Relationship Matrix is created based on expert opinions. Here, the factors are compared in pairs with an effect ranging between 0 and 4. K1, K2, and K3 represent decision-makers. The first stage is completed by taking the arithmetic averages of the answers given by all the decision-makers to form the Direct Relationship Matrix. 0 means no effect, and 4 shows a high effect level.

Table 1. Pairwise Comparison Scale

Numerical Value	Definition
0	Ineffective
1	Low Impact
2	Moderate Impact
3	High Impact
4	Very High Impact

Reference: Nilashi et al. (2015)

Step 2: Normalization of the Decision Matrix

$$n=\frac{1}{maks\sum_{j=1}^{s} dij}, \text{(i, j=1,2,.. s)} \qquad \tilde{D}=n(.)D \quad [2]$$

At this stage, the direct relation matrix shown with D is normalized, and the normalized direct relation matrix shown with $\widetilde{D}$ is created.

Step 3: Creating the Total Relationship Matrix

$$T = \widetilde{D}(I - \widetilde{D})^{-1} \quad [3]$$

The Total Relationship Matrix represented with T is created in this step.

Step 4: Creating the Cause and Effect Matrix

$$V = \left[\sum_{j=1}^{s} t_{ij}\right]_{sx1} \quad Y = \left[\sum_{j=1}^{s} t_{ij}\right]_{1xs} \quad \propto = \frac{\sum_{i=1}^{s}\sum_{j=1}^{s}[t_{ij}]}{s} \quad [4]$$

Calculating the alpha (threshold value) is performed at this stage where vector values are also found to draw the diagram, which also shows the interaction between the system elements. The X vector represents the sum of the lines in the total relationship matrix, and the Y vector represents the sum of the columns. The horizontal axis vector (V+Y), which shows how important the criteria are, is also calculated at this stage. Similarly, the vertical axis vector (V-Y) is calculated and determined according to the threshold value. If the effect of this vector is negative, it indicates that the criterion is included in the affecting group (cause), and if it is positive, it indicates that the criterion is included in the affected group (effect). This (X+Y, V-Y) is used in the creation of the Dataset Relationship Diagram (Uludağ & Doğan, 2021: 331).

Step 5: Obtaining the Internal Dependency Matrix and the diagram showing the effect relationship

$$V_i + Y_i,\ V_i - Y_i \qquad C_i = \sqrt{((V_i + Y_i)^2 + (V_i - Y_i)^2)} \quad [5]$$

At this stage, the weight coefficients of the criteria, , i.e.C_i values are calculated by using the relevant formula.

Step 6: Determination of criterion weights

$$w_i = \frac{Y_i}{\sum_{i=1}^{s} Y_i} \quad [6]$$

In the final step, criteria weights obtained by using the formula are normalized with the relevant formula. In this way, the weight of each factor, i.e. the w_i values are calculated.

4. Implementation

The purpose of the DEMATEL Method is to determine and prioritize the relations between obstacles to green production. Here, the first thing to do is identifying the obstacles. In line with the detailed literature review and expert opinions, the factors that would be used in the present study were identified, and are presented in Table 2:

Table 2. Factors Regarding the Obstacles to Green Production

No	**Factors**	**Explanation**	**Reference**
1	Lack of Investment Capital	It is an obstacle that enterprises do not have sufficient capital to make new investments during the transition to green production practices.	Govindan et al. (2016), Mittal & Sangwan, (2013)
2	High Short-Term Costs	High cost of buying newer efficient technology and its implementation	Koho et al. (2011), Herren & Hadley (2010)
3	Low Commercial Advantages	Uncertainty of achievable benefits after making huge investments in newer technologies	Govidan et al. (2016), Luken & Van Ronpaey (2008).
4	Lack of Technical Knowledge	Insufficient information about the available technology choices and limited access to green literature or the information diffusion	Silva et al. (2013), Hammed & Mahgary (2004)
5	Low Environmental Awareness	The lack of environment knowledge seems a significant barrier in implementing the green practices.	Koefoed & Buckley, (2008)
6	Lack of Legislation	Complete absence of environmental laws or complex and ineffective environmental legislation	Sing et al. (2012), Mittal & Sangwan, (2013)
7	Low Sanction/Punishment	Ineffective enforcement of environmental laws because of lack of organizational infrastructure, lack of trained human resources, cost of monitoring and dishonest officials	Zhu & Geng (2013), Mittal & Sangwan, (2013)
8	Low Administrative Support	Low top management commitment deterring ability to influence, support and champion the actual formulation and deployment of environmental initiatives across the organization	Koefoed & Buckley, (2008), Koho et al. (2011)
9	Resistance to Change	Employee of organizations, show resistance for any changes in daily routine work and also unease comes amongst them because of unpredictable output.	Sindhwani et al. (2019), Pihlak and Alas (2012)
10	Low Community Pressure	The absence of pressure by key social actors such as local communities, media, banks, insurance companies or politicians	Mittal &Sangwan, (2013), Govidan et al. (2016),

After the factors that would be used in the study were identified, the opinions of the experts, one of whom was an academician, and the other two in the position of company management, were taken. What was planned here was to ask the decision-makers to evaluate the obstacles individually by comparing them. K1, K2, and K3 represent the decision-makers. Factors were coded as follows:

Lack of Investment Capital (LIC), High Short-Term Costs (HSTC), Low Commercial Advantages (LCA), Lack of Technical Knowledge (LTK), Low Environmental Awareness (LEA), Lack of Legislation (LoL),

Low Sanctions/Punishment (LS/P), Low Administrative Support (LAS), Resistance to Change (RC), and Low Community Pressure (LCP).

Table 3. Factor Evaluation of K1, K2, and K3 decision-makers

	LIC	**HSTC**	**LCA**	**LTK**	**LEA**	**LoL**	**LS/P**	**LAS**	**RC**	**LCP**
LIC	0,000	2,000	2,667	1,667	1,667	1,333	1,667	3,000	2,000	1,333
HSTC	2,667	0,000	3,000	2,333	2,333	1,333	2,000	3,667	1,000	1,333
LCA	1,333	1,667	0,000	2,333	3,667	1,333	2,667	2,333	2,667	1,667
LTK	1,000	1,667	1,000	0,000	3,000	1,333	2,000	2,333	3,000	2,000
LEA	1,333	1,333	1,333	2,000	0,000	2,667	3,000	2,333	3,333	1,667
LoL	1,333	2,000	1,667	2,333	3,000	0,000	3,333	2,667	2,333	2,333
LS/P	2,000	2,000	2,000	2,000	2,667	3,000	0,000	3,333	2,667	2,333
LAS	2,000	2,333	2,000	3,333	2,333	2,333	1,667	0,000	2,000	1,333
RC	2,000	2,333	1,333	2,000	1,667	1,667	2,333	3,000	0,000	2,333
LCP	0,667	2,667	2,000	1,667	2,000	1,667	2,000	1,667	3,000	0,000

The Direct Relationship Matrix is created by taking the arithmetic averages of the individual evaluations of the decision-makers. The Normalized Decision Matrix is created after calculating the normalized values. The sums of the lines and columns of the Direct Relationship Matrix are calculated to calculate the normalized values. The Normalized Decision Matrix is formed with the factor values rated to the highest value in the line or column.

Table 4. Normalized Direct Relationship Matrix

	LIC	**HSTC**	**LCA**	**LTK**	**LEA**	**LoL**	**LS/P**	**LAS**	**RC**	**LCP**
LIC	0,000	0,082	0,110	0,069	0,069	0,055	0,069	0,123	0,082	0,055
HSTC	0,110	0,000	0,123	0,096	0,096	0,055	0,082	0,151	0,041	0,055
LCA	0,055	0,069	0,000	0,096	0,151	0,055	0,110	0,096	0,110	0,069
LTK	0,041	0,069	0,041	0,000	0,123	0,055	0,082	0,096	0,123	0,082
LEA	0,055	0,055	0,055	0,082	0,000	0,110	0,123	0,096	0,137	0,069
LoL	0,055	0,082	0,069	0,096	0,123	0,000	0,137	0,110	0,096	0,096
LS/P	0,082	0,082	0,082	0,082	0,110	0,123	0,000	0,137	0,110	0,096
LAS	0,082	0,096	0,082	0,137	0,096	0,096	0,069	0,000	0,082	0,055
RC	0,082	0,096	0,055	0,082	0,069	0,069	0,096	0,123	0,000	0,096
LCP	0,027	0,110	0,082	0,069	0,082	0,069	0,082	0,069	0,123	0,000

The Total Relationship Matrix is formed. The related formulas are made use of to calculate the V and Y values for the relationship diagram. Here, the purpose is to determine the factors according to their importance and effect types. Alpha (i.e. the Threshold Value) is calculated to avoid weak relations from being shown on the diagram (0.056). The relations between the factors below this value compared to the alpha value will not be shown in the relationship diagram.

Table 5. Total Relationship Matrix

	LIC	HSTC	LCA	LTK	LEA	LoL	LS/P	LAS	RC	LCP
LIC	0,000	0,027	0,037	0,024	0,026	0,016	0,024	0,055	0,032	0,016
HSTC	0,037	0,000	0,047	0,039	0,042	0,018	0,033	0,077	0,016	0,017
LCA	0,016	0,024	0,000	0,039	0,073	0,018	0,047	0,045	0,050	0,023
LTK	0,010	0,022	0,011	0,000	0,052	0,016	0,030	0,041	0,052	0,026
LEA	0,016	0,018	0,017	0,032	0,000	0,041	0,053	0,044	0,064	0,022
LoL	0,017	0,032	0,024	0,041	0,060	0,000	0,065	0,055	0,044	0,036
LS/P	0,028	0,033	0,031	0,035	0,054	0,052	0,000	0,075	0,053	0,037
LAS	0,025	0,035	0,028	0,060	0,042	0,034	0,026	0,000	0,034	0,017
RC	0,025	0,035	0,017	0,031	0,027	0,022	0,038	0,058	0,000	0,033
LCP	0,007	0,039	0,026	0,024	0,032	0,021	0,030	0,028	0,052	0,000
Total	0,180	0,265	0,238	0,325	0,407	0,239	0,348	0,479	0,397	0,225

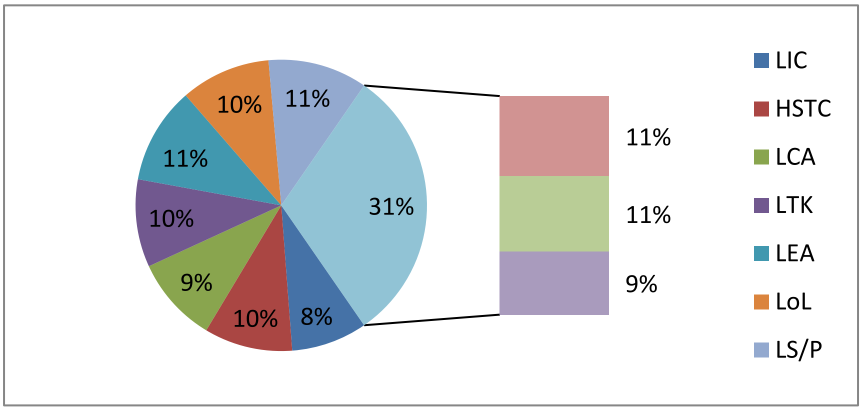
Once the relationship diagram is formed in line with the threshold value, the weight coefficients of the factors are calculated. In the final stage, the weights of the factors are calculated, and the factors are ranked according to their importance; and in this way, the relations between the factors are analyzed with the DEMATEL Method.

Table 6. Impact Status and Factor Weights of Factors

Factors	V Vector	Y Vector	V+Y Vector	V-Y Vector	Effect Type	w	W	W %
LIC	3,384	2,869	6,253	0,515	Affecting	6,274201	0,084271	8,42%
HSTC	3,797	3,499	7,295	0,298	Affecting	7,301536	0,098069	9,80%
LCA	3,811	3,267	7,078	0,543	Affecting	7,099196	0,095352	9,53%
LTK	3,380	3,852	7,231	-0,472	Affected	7,246667	0,097333	9,73%
LEA	3,714	4,261	7,975	-0,548	Affected	7,994149	0,107372	10,73%
LoL	4,065	3,334	7,399	0,730	Affecting	7,434916	0,099861	9,98%
LS/P	4,227	3,977	8,204	0,250	Affecting	8,208098	0,110246	11,02%
LAS	3,732	4,624	8,356	-0,892	Affected	8,403623	0,112872	11,28%
RC	3,620	4,232	7,852	-0,612	Affected	7,875997	0,105785	10,57%
LCP	3,399	3,212	6,612	0,187	Affecting	6,614316	0,088839	8,88%
					Total	74,4527	1	100,00%

The values enabling that the factors are evaluated according to their effects and the factor weights are shown in Table 6 and Table 7. In this context, when the importance weights of the factors were examined, it was determined that the first three obstacles were low management support, low sanction/punishment, and low environmental awareness. This result shows that enterprises should give importance to these three factors to manage green production processes accurately.

Figure 1. Distribution of Factor Weights



4. Implementation

Production companies have to choose among alternatives in many cases in our present day. Some of these are a selection of the establishment, green machine selection, and green raw material selection or selection of green production practices. The selection of the best alternative is very important for the sustainability and competitiveness of businesses. In the present study, in which the DEMATEL Methodwas used, as one of the multi-criteria decision-making methods used to choose between alternatives,, the weights and effects of the factors according to the results of the analysis can be interpreted as follows, as given in Table 6. Among the factors that express the obstacles to green production were Lack of Investment Capital (LIC), High Short-Term Costs (HSTC), Low Commercial Advantages (LCA), Lack of Legislation (LoL), Low Sanctions/Punishment (LS/P), and Low Community Pressure (LCP) as obstacles that clearly affected green production; and Lack of Technical Knowledge (LTK), Low Environmental Awareness (LEA), Low Administrative Support (LAS), and Resistance to Change (RC) were identified as the factors that were clearly affected in terms of green production. For this reason, it was determined that the factors that had priority among the obstacles to green production activities in businesses were analyzed in terms of investment capital, costs, sanctions, or legislation. On the other hand, it was determined that the administrative support, low social pressure, and low environmental awareness of the businesses were also affected by these factors. The effects of the factors were determined by considering the weight values in Table 6. Accordingly, it is possible to say that low administrative support (8,403623) has the highest effect. Similarly, it was also found that the sanction/punishment factor, which is one of the obstacles to green production, has secondary importance with its weight value of 8.208098, and is in the affecting category. As a result, among the factors whose weights were determined by the DEMATEL Method, the obstacles that had the highest weight values are ranked respectively as Low Administrative Support, Low Sanction/Punishment, and Low Environmental Awareness. Therefore, by adopting the importance degrees in these values, important obstacles to green production can be eliminated, and measures that must be taken by decision-makers on issues such as increasing environmental awareness can be identified. In this way, the evaluation of factors in transforming obstacles into success can be evaluated in guiding and problem-solving process for decision-making. The present study constitutes the basis for similar studies, and it can be argued that it has a guiding feature for solving other problems with integrated methods.

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