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Why Can Smes Not Adopt Green Innovation? An Assessment Via Fuzzy ISM-MICMAC-DEMATEL*

Seda Yıldırım[**], **Gözde Koca**[***], **Özüm Eğilmez**[****]

Abstract

Innovation has become an important competitive tool as it increases the efficiency and profitability of enterprises and provides the opportunity to enter new markets and grow in the existing market area. The important thing is not to harm the environment while the businesses continue their activities. Therefore, the innovations and activities carried out are happened to be environmentally friendly and have an aspect that will reduce the negative effects on the environment. However, Small and Medium Enterprises (SMEs) cannot adopt green practices due to various barriers. In this context, this study aims to analyze and solve the factors that hinder green innovation and green initiatives in SMEs. In the study, firstly, the literature was searched, and six main barriers were determined as "economic barriers", "market barriers", "political barriers", "lack of information", "technological barriers" and "administrative barriers". Barriers were analyzed using Fuzzy ISM-MICMAC and Fuzzy DEMATEL methods by taking expert opinions from 18 SMEs in the Electrical and Electronics sector. The structural relationship model between the barriers was revealed with the Fuzzy ISM-MICMAC analysis methods. The effect-importance degree of the barriers was determined by the Fuzzy DEMATEL method, and their weights were calculated. As a result of the research, the most influential barriers to other barriers were determined as "economic barriers", "political" barriers" and "lack of information".

Keywords

SME, Green Innovation, Multi-Criteria Decision Making, Fuzzy ISM-MICMAC, Fuzzy DEMATEL

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** Seda Yıldırım (Graduate Student), Bilecik Şeyh Edebali University, Institute of Social Sciences, Department of Business, Bilecik, Turkiye. E-mail: sdayldrmm@gmail.com ORCID: 0000-0002-5755-1773

*** **Corresponding author:** Gözde Koca, (Assoc. Prof.), Bilecik Şeyh Edebali University, Faculty of Economics and Administrative Sciences, Bilecik, Turkiye. E-mail: gozde.koca@bilecik.edu.tr ORCID: 0000-0001-6847-6812

**** Özüm Eğilmez, (Assoc. Prof.), Bilecik Şeyh Edebali University, Faculty of Economics and Administrative Sciences, Bilecik, Turkiye. E-mail: ozum.egilmez@bilecik.edu.tr ORCID: 0000-0002-5460-6468

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1. Introduction

The world is facing environmental pollution due to the rapid increase in population, unconscious use of resources, and low sensitivity to the environment. Businesses, which are under the influence of these environmental conditions try to keep up with those changes occurring in their environment and aim to fulfill the requirements of global competition.

The concept of sustainability is, to use today's resources effectively by allocating resources for the future. Companies that see themselves as sustainable businesses use renewable or non-renewable energy resources more responsibly with their environmental performance. Businesses ensure that the materials they use are to be environmentally friendly and minimize the reduction of energy consumption.

Today, it can be said that businesses acknowledged that they cannot continue their activities without being sensitive to environmental problems, no matter the sector they operate. With this changing approach, businesses have to consider the environmental consequences and apply new business strategies and long-term plans (Atay and Dilek, 2013). Creating a good image in the eyes of consumers, using environmentally friendly production technologies, developing environmentally friendly marketing strategies, government incentives for green innovations, and reducing the costs of tools such as recycling lead businesses to green innovation activities are some examples of the implementations (Şenocak and Mohan, 2018). Green innovations contribute to the goal of sustainable development in macro terms and contribute to the economic goals of the enterprise and vice versa. Green innovations are important factors in reducing the costs of businesses, increasing competitiveness, and creating new markets that demand environmentally friendly products and processes. The concept of green innovation, which emerged with the damage to natural resources and increasing competition, ensures customer satisfaction as well as prevents damage to nature. In addition, governments have started to implement strict environmental policies to reduce the pollution caused by the industry, and customers have become more aware of environmental protection.

SMEs, which constitute the majority of the economy, can be a sustainable solution to prevent environmental degradation in terms of adopting green practices and gaining a sustainable competitive advantage eventually. Although SMEs cannot quickly return their green investments compared to large enterprises, they can gain an economic advantage by adopting green practices such as recycling and energy saving. Also, the large enterprises' demand for green products from their suppliers (SMEs) leads SMEs to implement green practices.

However, there are several barriers to the adoption of green practices encountered by SMEs. These barriers differ depending on the background of the country, region, or different sectors. It is therefore important to conduct research based on a particular country, region, or industry. In this context, this study aims to reveal the barriers faced by SMEs in the Electric-Electronics sector in adopting green innovation, to find the degree of importance by presenting the interaction between the barriers with a structural model. By doing this, barriers will be listed and suggestions for the improvement of the barriers will be made. To determine the interaction between the barriers, a structural model-the Fuzzy ISM-MICMAC method was put forward, then the Fuzzy DEMATEL method was applied to determine the impact-importance degree of the barriers.

2. Literature Review

The concept of green innovation was first discussed by Fussler and James in their book published in 1996. Green innovation is defined as new products and processes that significantly reduce environmental impacts. In the literature, the concept of green innovation can be seen within the framework of different concepts such as environmental innovation, eco-innovation, and sustainable innovation (OECD, 2009). Some of the studies on green innovation are:

In the literature, green innovation is emerging as a new topic and research field. Russo and Fouts (1997) analyzed 243 high-growth firms using environmental ratings, assuming a positive correlation between environmental and economic performance based on the resource-based perspective of businesses. As a result, they concluded that being green is beneficial and growing in the sector is easier and stronger. Bansal and Roth (2000) have discussed possible conditions that lead to high institutional ecological sensitivity. They presented a qualitative study of the motivations and contextual factors that trigger institutional ecological sensitivity. The research is based on data collected from 53 companies in England and Japan. Seuring and Müller (2008) conducted a literature review by examining 191 articles on sustainable supply chain management published between 1994 and 2007. In their studies, they aimed to present green supply chain management in a conceptual framework. Smith, Voß, and Grin (2010) re-evaluated sustainable development, innovation, and technological change. In the study, they presented the history of innovation studies for sustainable development and a multi-level perspective on socio-technical transitions. Finally, they elaborated that green innovation activities, while interesting, have challenges and are more research and development areas. Based on the resource-based perspective of firms, Christmann (2000) analyzed whether complementary assets are required to gain cost advantages from implementing green best practices. Luthra, Kumar, Kharb, Ansari, and Shimmi (2014) analyzed some of the barriers that prevent the rapid deployment of smart grid systems to meet the existing electricity generation and distribution systems in an environmentally sustainable way. After the literature review, they identified 12 barriers and obtained a hierarchical structure by analyzing with ISM. They validated the ISM using the MICMAC method to categorize addiction and impulsive barriers. In addition, different solutions are proposed to overcome these barriers in the article. Mangla, Madaan, and Chan (2013) aimed to analyze flexible decision strategies to improve performance in a sustainability-oriented green product recovery system. In the paper industry study, 14 variables were determined. Supplier commitment, cost, regulations, etc. The interrelationships between green variables were determined. In addition, capacity utilization, customer satisfaction, reduction of energy consumption, etc. variables were accepted as results. In addition, a graphical classification of the effect variables on performance was made using MICMAC analysis. Ansari, Kharb, Luthra, Shimmi, and Chatterji (2013) aimed to explain the barriers to the applications of solar energy institutions with a structural model to increase the economic growth rate with the increase of greenhouse gas emissions in India. 13 barriers to implementing solar energy institutions are identified and the hierarchical structure is shown based on the ISM method. The dependency and driving forces of the barriers are shown with the MICMAC method.

As sustainability is a major topic in today's world, the authors intended to research green innovation barriers that SMEs face, focusing on the electrical and electronics sector sample. Analyzing and revealing the barriers is expected to expand the knowledge regarding the adoption process.

3. Methodology

3.1. Fuzzy ISM-MICMAC Method

The Interpretive Structural Modeling (ISM) model is a qualitative tool developed by Warfield in 1974 to describe the relationship between the components of a topic or problem (Chander, Jain, and Shankar, 2013).

ISM is a method that defines and summarizes the relationships between certain criteria. It is also the managerial research approach, an interactive learning process, and the systematic application of the graphical method that establishes an effectively directed graphical and contextual relationship between items. The ISM model determines the hierarchy of a subject among the variables, and the priority order of a complex subject, and analyzes whether the system factors are related to other factors and the relationship between them (Khanam et al., 2015).

While ISM only shows the presence of interaction, Fuzzy ISM can show the presence of interaction as an extension. Therefore, Fuzzy ISM is one step ahead of ISM. Fuzzy ISM makes ambiguous and poorly expressed system models visible (Saxena, Sushil, and Vrat, 2005). In addition, fuzzy ISM contains elements that show the dominance of interaction. Thus, the interaction between the variables in the interpretive model is shown more clearly. Fuzzy ISM steps are (Joshi, Banwe,t and Shankar, 2009):

Step 1: Criteria or variables related to the problem are determined by expert opinion and literature review.

Step 2: A contextual relationship is established between the variables defined in step 1.

Step 3: A Structural Self-Interaction Matrix (SSIM) is created, showing the pairwise relationships among the variables of the system.

Step 4: The reachability matrix is developed from SSIM, and the resulting matrix is checked for transitivity.

Step 5: The obtained reachability matrix is divided into different levels.

Step 6: Based on the relationships obtained from the reachability matrix, the directed graph is drawn.

Step 7: The resulting graph is converted to Fuzzy ISM by changing the element nodes.

Step 8: The developed ISM model is reviewed to check for conceptual inconsistency and changes are made if necessary.

In the structural-internal interaction matrix, the contextual relationship, and the related direction between the two parameters (i and j) are determined. Symbols such as V, A, X, and O are used to express the direction of the relationship between the parameters (i, j) (Chander et al., 2013).

The definitions of these symbols are as follows:

V: The variable i affects variable j.

(There is a direct relationship from variable i to variable j.)

A: The variable j affects variable i.

(There is a direct relationship from variable j to the variable i.)

X: The variables i and j affect each other.

(There is a bidirectional relationship between the variables i and j.)

O: There is no relationship between the variables i and j.

In the matrix produced from these symbols, the accessibility matrix is formed by writing 1 and 0, instead of the symbols V, A, X, and O.

The numerical equivalents of these numbers are:

V: If (i, j) input becomes 1, (j, i) input becomes 0.

A: If (j, i) input becomes 0, (i, j) input becomes 1.

X: If (j, i) input becomes 1, (i, j) input becomes 1.

O: If (j, i) input becomes 0, (i, j) input becomes 0.

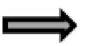
In the next step, the reachability matrix is checked for transitivity and the final reachability matrix is created. For example, If there is a relationship between 1 and 3 in the reachability matrix, if there is a relationship between 3 and 2, 1 and 2 reachability is obtained.

Reachability and antecedent sets are generated for each parameter from the final reachability matrix. The accessibility set consists of the parameter itself and any other parameter that can be affected, while the antecedent set consists of the element itself and the parameters that can affect it. Clusters with the same reachability and intersection sets are at the top of the ISM hierarchy. The top-level parameter in the hierarchy does not lead to any other parameter above its level and is separated from the other parameters. The same process is repeated to find other parameters. The process continues until the level of each parameter is found (Chander et al., 2013).

The final reachability matrix is fuzzyficated to show the degree of dominance of the interaction. The fuzzy number scale showing the degree of influence is as follows.

Table 1

Qualitative consideration on 0-1 scale for dominance of interaction (Saxena et al., 2005)

Dominance of interaction	**No**	**Very low**	**Low**	**Medium**	**High**	**Very high**	**Full**
Value on the scale	0	0,1	0,3	0,5	0,7	0,9	1
Symbol							

Matrice d'Impacts Croise's Multiplication Appliquee a un Classement (MICMAC) analysis is performed according to the dependency and influencing the degree of criteria or variables. Fuzzy MICMAC also includes the dominance of interaction, and the influence and dependency levels in the fuzzy final access matrix are used. In the fuzzy MICMAC method, the variables are divided into four regions according to the driving and addiction power (Khanam, Siddiqui, and Talib, 2015):

Autonomous Region: It shows the variables with weak driving power and weak dependency and has weaker connectivity than other variables.

Dependent Region: Variables in this region have high dependency and low driving power. These variables are strongly dependent on the system.

Linkage Region: Variables with a strong driving force and high dependency. Any effect on these variables will affect the entire system.

Independent Region: It refers to the variables with strong driving power but low dependency power and consists of the most important and important variables of the system.

3.2. Fuzzy DEMATEL Method

DEMATEL (The Decision-Making Experiment and Evaluation Laboratory) was founded by the Battelle Memorial Institute at the Geneva Research Center to solve complex problems (Shieh, Wu, and Huang, 2010; Muhammad and Cavus, 2017; Gabus and Fontela, 1972, 1973). Using this method, the relationship between causes and effects can be transformed into a reasoned model of the chosen system (Dalalah, Hayajneh, and Batieha, 2011; Wu and Lee, 2007).

In this study, the Fuzzy DEMATEL method was used to reveal the relationships with a more accurate analysis and to eliminate the uncertainties The steps of Fuzzy DEMATEL are presented below: (Tseng, 2009).

Step 1: Selection of an expert group: People who have sufficient knowledge and experience on the subject are called experts and their opinions are taken.

Step 2: Identification of the factors and creation of the fuzzy scale: In terms of accurate analysis and evaluation, important factors are determined in this stage. Next, a linguistic variable is used according to five fuzzy scales (no effect=0 [0,0,0.25], very low impact=1 [0,0.25,0.50], low impact=2 [0.25,0.50,0.75], high effect=3 [0.50,0.75,1.00], and very high impact=4 [0.75,1.00,1.00]).

Step 3: Assessment of decision-makers: Pairwise comparison is obtained in terms of linguistic variables. In addition, fuzzy assessments are collected as a defuzzified and crisp value. As a result, the initial direct relationship fuzzy matrix ($\tilde{E}$) is constructed (Equality (1)- Equality (2)). The average of the expert opinions is taken.

$$\tilde{E} = \begin{bmatrix} 0 & \cdots & \tilde{e}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{e}_{1n} & \cdots & 0 \end{bmatrix} \quad (1)$$

$$\tilde{e}_{ij} = \left(l_{ij}, m_{ij}, u_{ij}\right) \quad (2)$$

Step 4: Creation of normalized direct-relation fuzzy matrix: In the presence of the initial direct-relationship matrix, a normalized direct-relationship fuzzy matrix is generated. $\tilde{\beta}$ and γ are considered triangular fuzzy numbers to achieve that. The below calculation is carried out respectively (Equality (3) – Equality (4)).

$$\tilde{\beta} = \sum \tilde{e}_{ij} = \left(\sum_{j=1}^{n} l_{ij}, \sum_{j=1}^{n} m_{ij}, \sum_{j=1}^{n} u_{ij}\right) \quad (3)$$

$$\gamma = \max\left(\sum_{j=1}^{n} u_{ij}\right) \quad (4)$$

The normalized direct-relation fuzzy matrix ($\tilde{F}$)can be shown as below (Equality (5) – Equality (6)).

$$\tilde{F} = \begin{bmatrix} \tilde{f}_{11} & \cdots & \tilde{f}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{f}_{n1} & \cdots & \tilde{f}_{nn} \end{bmatrix} \quad (5)$$

$$\text{Where } \tilde{f}_{ij} = \frac{\tilde{e}_{ij}}{\gamma} = \left(\frac{\tilde{e}_{ij}}{\gamma}, \frac{\tilde{e}_{ij}}{\gamma}, \frac{\tilde{e}_{ij}}{\gamma}\right) \quad (6)$$

Step 5: Calculation of total-relation fuzzy matrix: After having established a normalized direct-relation fuzzy matrix, a total-relation fuzzy matrix is calculated to ensure lim$\omega \rightarrow \infty$ $F\omega = 0$ (Equality-7). After, the crisp case of the total-relation fuzzy matrix (Equality (8)) is identified as follows. For each of the triangular fuzzy numbers (l, m, u) (Equality-8) which is shown below, it is carried out by dealing with them as a separate matrix and combined into a single total relation matrix represented by $\tilde{T}$ (Equality (10)- Equality (11)- Equality (12)).

$$\tilde{T} = \lim_{\omega \rightarrow \infty} (\tilde{F} + \tilde{F}^{2} + \cdots + \tilde{F}^{\omega}) = \tilde{F}(I - \tilde{F})^{-} \quad (7)$$

$$\tilde{T} = \begin{bmatrix} \tilde{t}_{11} & \cdots & \tilde{t}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{t}_{n1} & \cdots & \tilde{t}_{nn} \end{bmatrix} \quad (8)$$

$$\tilde{t}_{ij} = \left(l''_{ij}, m''_{ij}, u''_{ij}\right) \quad (9)$$

$$\text{Matrix}\left[l''_{ij}\right] = F_{l} \chi \, (I - F_{l})^{-1} \quad (10)$$

$$\text{Matrix}\left[m''_{ij}\right] = F_{m} \chi \, (I - F_{m})^{-1} \quad (11)$$

$$\text{Matrix}\left[u''_{ij}\right] = F_{u} \chi \, (I - F_{u})^{-1} \quad (12)$$

Step 6: Analyzing the structural model: After having calculated matrix T(Equality 13), $\tilde{R}_i + \tilde{C}_j$ and $\tilde{R}_i - \tilde{C}_j$ are determined. In Equality (14) and Equality (15), $\tilde{R}_i$ and $\tilde{C}_j$ denote the sum of the rows and columns of the matrix $\tilde{T}$. While $\tilde{R}_i + \tilde{C}_j$ shows the importance of factor i, $\tilde{R}_i - \tilde{C}_j$ denotes the net effect of factor i.

$$T = \lfloor t_{ij} \rfloor_{nxn} \; i, j = 1,2,\ldots,n \tag{13}$$

$$R_i = \sum_{1 \le j \le n}^{n} t_{ij} \tag{14}$$

$$C_j = \sum_{1 \le i \le n}^{n} t_{ij} \tag{15}$$

Step 7: Defuzzification (def) of $\widetilde{R}_i + \widetilde{C}_j$ and $\widetilde{R}_i - \widetilde{C}_j$: In this step, $\widetilde{R}_i + \widetilde{C}_j$ and $\widetilde{R}_i - \widetilde{C}_j$ are defuzzified by using Equation (16) and Equation (17).

$$\widetilde{R}_i^{def} + \widetilde{C}_j^{def} = \frac{1}{4}(l + 2m + h) \tag{16}$$

$$\widetilde{R}_i^{def} + \widetilde{C}_j^{def} = \frac{1}{4}(l + 2m + h) \tag{17}$$

Step 8: Creating the cause-effect relationship diagram: In this step, the cause-effect relationship diagram is created using the $\widetilde{R}_i + \widetilde{C}_j$ and $\widetilde{R}_i - \widetilde{C}_j$ dataset.

Step 9: Factor weights are calculated using the Equation (18) below.

$$w_i = \sqrt{(\widetilde{R}_i^{def} + \widetilde{C}_j^{def})^2 + (\widetilde{R}_i^{def} - \widetilde{C}_j^{def})^2} \tag{18}$$

The importance weight of each factor is normalized to Equation (19) shown below:

$$W_i = \frac{w_i}{\sum_{i}^{n} w_i} \tag{19}$$

4. Research Findings and Discussion

This research examines the barriers to green innovation in small and medium-sized enterprises using fuzzy MCDM methods, comprehensively. To do this, 18 experts experienced in the Electrical and Electronics sector participated in responding to a survey. In the questionnaires, information was given about the barriers to green innovation, and questions were asked about the interaction of the barriers with each other.

Barriers were created by reviewing the literature. Then, a hierarchical structure was created by determining the interaction-dependency levels of the barriers with the

Fuzzy ISM-MICMAC methods. Finally, the effect-importance degrees of the barriers on each other were calculated with the Fuzzy DEMATEL method. The barriers are listed as follows:

Economic Barriers (B1)

The economic barriers that businesses face in green purchasing activities are the additional costs of switching to a new system. Since companies think that environmental programs are costly, they create a barrier to green practices (Peker, 2010).

Market Barriers (B2)

The fact that suppliers do not participate in green practices prevents SMEs from being sensitive to the environment. The lack of infrastructure, financial, technological, and human resources required for green practices by suppliers creates a barrier for businesses to adopt green practices (Sarkar and Mohapatra, 2006; Abbasnejad, Khaksar, Gashtasbi and Darabi, 2015; Hsu and Hu, 2008; Kumar, Chattopadhyaya, and Sharma, 2012).

Political Barriers (B3)

The lack of incentives offered by governments against green practices and the inadequacy of legal regulations to protect the environment create a barrier for SMEs to switch to green practices (Scupola, 2003; AlKhidir and Zailani, 2009; Sarkis, 2012; Srivastava, 2007; Beamon, 1999; Walker, Di Sisto and McBain, 2008; Srivastav and Gaur, 2015).

Lack of Knowledge (B4)

The lack of education and experience of the stakeholders, the lack of training given to the employees, and the lack of environmental knowledge constitute a barrier to green practices (Balasubramanian, 2012; Khiewnavawongsa and Schmidt, 2013; Yu Lin and Hui Ho, 2008; Ravi and Shankar, 2005; Holt and Ghobadian, 2009).

Technological Barriers (B5)

New production technologies, deficiencies in environmental monitoring, and information technology appear as a barrier to the successful implementation of green practices (Balasubramanian, 2012).

Administrative Barriers (B6)

Prejudice and resistance against green practices constitute an obstacle to transitioning to green practices (Nakıboğlu, 2017).

4.1. Evaluation of Barriers with Fuzzy ISM-MICMAC

Fuzzy ISM methodology was used to develop a hierarchical structural model among barriers to identifying green innovation in SMEs and to identify the relationship between cause-and-effect barriers. In the survey, each barrier was explained, thus enabling the experts who answered the survey to focus on the direct relationships between each pair of barriers.

Creation of Structural Self-Interaction Matrix (SSIM)

As a result of combining the expert opinions, Structural Self-Interaction Matrix (SSIM) matrix given in Table 2 was created by using the symbols V, A, X, O. B1 represents "economic barriers", B2 "market barriers", B3 "political barriers", B4 "lack of knowledge", B5 "technological barriers" and B6 "managerial barriers".

Table 2

Structural Self-Interaction Matrix (SSIM)

Barriers	**B6**	**B5**	**B4**	**B3**	**B2**
B1	O	V	V	X	V
B2	X	O	O	A	
B3	O	V	V		
B4	V	V			
B5	A				
B6					

Creation of Initial reachability matrix

At this stage, the initial reachability matrix is first created. When creating this matrix, the values 1 or 0 are assigned instead of the symbols V, X, A, O. The initial reachability matrix is shown in Table 3.

Table 3

Initial Reachability Matrix

Barriers	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**
B1	1	1	1	1	1	0
B2	0	1	0	0	0	1
B3	1	1	1	1	1	0
B4	0	0	0	1	1	1
B5	0	0	0	0	1	0
B6	0	1	0	0	1	1

Creation of Final Reachability Matrix

At this stage, the initial reachability matrix is checked for transitivity. For example, If barrier B1 affects barrier B2, if barrier B2 affects barrier B6, barrier B1 also affects barrier B6. Likewise, since the B2 barrier affects the B6 barrier, if the B6 barrier also affects the B5 barrier, the B2 barrier also affects the B5 barrier. The final reachability matrix is shown in Table 4.

Table 4

Final Reachability Matrix

Barriers	B1	B2	B3	B4	B5	B6
B1	1	1	1	1	1	1
B2	0	1	0	0	1	1
B3	1	1	1	1	1	1
B4	0	1	0	1	1	1
B5	0	0	0	0	1	0
B6	0	1	0	0	1	1

Development of Fuzzy Conical Matrix.

For the fuzzy process, the final reachability matrix is considered. The dominance of interactions is made by experts valuing the final reachability matrix. In the crisp ISM technique with absolute numbers, the driving and dependency figures are expressed only as “1”, while in fuzzy ISM, the values are expressed as continuous numbers between “0 and 1” (Table 1). After receiving expert opinions again, a fuzzy conical matrix is created. The fuzzy conical matrix is shown in Table 5.

Table 5

Fuzzy Conical Matrix

Barriers	B1	B2	B3	B4	B5	B6	Driving Power
B1	1	0,5	0,9	0,7	0,5	0,3	**3,9**
B2	0	1	0	0	0,9	0,9	**2,8**
B3	0,7	0,5	1	0,7	0,7	0,3	**3,9**
B4	0	0,9	0	1	0,9	0,9	**3,7**
B5	0	0	0	0	1	0	**1**
B6	0	0,9	0	0	0,7	1	**2,6**
Dependence Power	**1,7**	**3,8**	**1,9**	**2,4**	**4,7**	**3,4**	

Division into Levels

For level separation, the reachability set, antecedent set, and intersection set of each variable are determined. The reachability set consists of all the variables that a variable access. The antecedent set consists of other variables that can access this variable. The intersection set is the intersection of the reachability set and the antecedent set. If the reachability set and the intersection set are equal, it forms the 1st level of this variable.

Barrier B5 at Level 1 will be at the top of the hierarchical structure (Table 6). The same procedure is applied to the remaining barriers. As seen in Table 7, B2 and B6 are at Level 2. After this level is determined, the level division process continues among the remaining B1, B3, and B4 barriers. As can be seen in Table 8, barrier B4 constitutes the 3rd level of the hierarchical structure. Since there are no exposed barriers in Table 9, barriers B1 and B3 are at Level 4 of the hierarchy and form the root barriers.

Tablo 6

Level Partition-Iteration I

Barriers	Reachability Set (R)	Antecedent Set (C)	Intersection Set (RC)	Level
B1	1,2,3,4,5,6	1,3	1,3	
B2	2,5,6	1,2,3,4,6	2,6	
B3	1,2,3,4,5,6	1,3	1,3	
B4	2,4,5,6	1,3,4	4	
B5	5	1,2,3,4,5,6	5	**1**
B6	2,5,6	1,2,3,4,6	2,6	

Tablo 7

Level Partition-Iteration II

Barriers	Reachability Set (R)	Antecedent Set (C)	Intersection Set (RC)	Level
B1	1,2,3,4,6	1,3	1,3	
B2	2,6	1,2,3,4,6	2,6	**2**
B3	1,2,3,4,6	1,3	1,3	
B4	2,4,6	1,3,4	4	
B6	2,6	1,2,3,4,6	2,6	**2**

Tablo 8

Level Partition-Iteration III

Barriers	Reachability Set (R)	Antecedent Set (C)	Intersection Set (RC)	Level
B1	1,3,4	1,3	1,3	
B3	1,3,4	1,3	1,3	
B4	4	1,3,4	4	**3**

Tablo 9

Level Partition-Iteration IV

Barriers	Reachability Set (R)	Antecedent Set (C)	Intersection Set (RC)	Level
B1	1,3	1,3	1,3	**4**
B3	1,3	1,3	1,3	**4**

Creation of Hierarchical Structure

After level separation, the hierarchical structure of the barriers was created as in Figure 1. The colored boxes indicate the level of the structure, green (4th level), pink (3rd), blue (2nd), and orange (1st). While creating the hierarchical structure, the dominance degrees given in Table 1 are given.

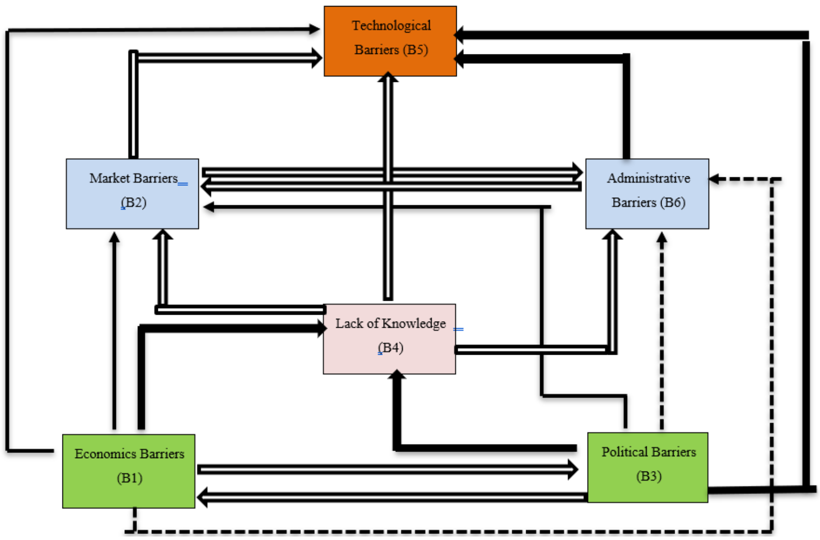


Figure 1. Hierarchical structure of barriers

As it is shown, the hierarchical structure in Figure 1, B5 (Technological barriers), which is at the top level, is affected by all other barriers. For example, B4 (Lack of Knowledge) highly affects the B5 barrier. The lack of sufficient resources and experts in SMEs deprives them of technological developments. Looking at the second level, it is seen that there are B2 (Market Barriers) and B6 (Administrative Barriers) and they influence each other. The reluctance of suppliers and customers about green practices leads to hesitant business management. In the same way, the reluctance of the management to green practices, not giving importance to green innovations in their purchases, and not informing the customers affect the market barriers. Therefore, there is a bidirectional relationship between the two barriers. B4 (Lack of Knowledge) constitutes the third level of the structure. For example, the B4 barrier affects the B6 barrier. This situation, the lack of experts to manage green practices in SMEs can be explained as the inability to use information and technology, and the lack of a certain reward system in SMEs. B1 (Economic Barriers) and B3 (Political Barriers) constitute the fourth level of the structure and affect all other barriers with them. So, these are the two most important barriers to be considered. The effects of economic and political barriers on each other can be explained as insufficient financing for SMEs, inadequacy of bank loans, and the inadequacy of state-supported initiatives.

Dependence and driving power generated from the Fuzzy Final Reachability Matrix are used for MICMAC analysis. Dependence and driving power are shown in Table 10.

Table 10

Dependence Power and Driving Power

Barriers	Dependence Power	Driving Power
B1	1,7	3,9
B2	3,6	2,8
B3	1,9	3,9
B4	2,4	3,7
B5	4,7	1
B6	3,2	2,6

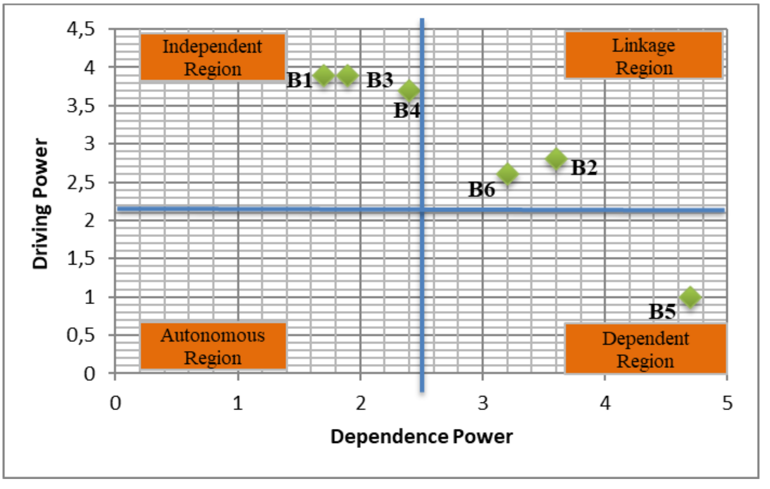


Figure 2. MICMAC Diagram

While the B5 barrier in the second region is highly affected by the related and influencing variables, it does not show an effect on other variables. The B2 and B6 barriers in the third region have high influence and high dependency, exhibiting an unstable feature. Any effect on these barriers will also affect other barriers. Therefore, they are barriers that should be considered when evaluating barriers. The B1, B3, and B4 barriers in the fourth region have very high influence and very low dependency power. These barriers affect the rest of the system and are the ones to be considered the most.

4.2. Evaluation of Barriers with Fuzzy DEMATEL

The fuzzy DEMATEL method was applied to determine the relationship between the barriers. A survey was conducted with 18 experts to determine the relationships between barriers. The conversion of the evaluation results of the 1st expert into fuzzy numbers is shown in Table 11. The direct relationship matrix was obtained by averaging the triangular fuzzy numbers obtained using Equations (2) and (3). The direct relationship matrix is shown in Table 12. The fuzzy relationship matrix, normalized using Equation (4) based on data from 18 experts, is shown in Table 13. The normalized direct relationship matrix is obtained by dividing the fuzzy direct relationship matrix by the maximum total "l, m, u" value. The total correlation matrix was obtained by using Equation (6). The total relationship matrix is shown in Table 14.

Table 11

The Evaluation Results of the 1st Expert

1st Expert Barriers	**B1**			**B2**			**B3**			**B4**			**B5**			**B6**		
B1	0	0	0,25	0,5	0,75	1	0	0,25	0,5	0,25	0,5	0,75	0,75	1	1	0,75	1	1
B2	0,25	0,5	0,75	0	0	0,25	0	0	0,25	0,25	0,5	0,75	0	0,25	0,5	0,25	0,5	0,75
B3	0,5	0,75	1	0,75	1	1	0	0	0,25	0,5	0,75	1	0,5	0,75	1	0,5	0,75	1
B4	0	0	0,25	0	0	0,25	0	0	0,25	0	0	0,25	0	0	0,25	0	0	0,25
B5	0	0,25	0,5	0	0,25	0,5	0	0	0,25	0	0	0,25	0	0	0,25	0,25	0,5	0,75
B6	0	0,25	0,5	0	0,25	0,5	0	0	0,25	0	0	0,25	0	0	0,25	0	0	0,25

Table 12

The Fuzzy Relationship Matrix

Barriers	**B1**			**B2**			**B3**			**B4**			**B5**			**B6**		
B1	0	0	0,25	0,3472	0,5556	0,7639	0,1250	0,2917	0,5417	0,2639	0,4861	0,6944	0,5556	0,7917	0,9306	0,25	0,4722	0,6944
B2	0,2083	0,4444	0,6944	0	0	0,25	0,1528	0,3611	0,6111	0,1667	0,3333	0,5833	0,1806	0,4028	0,6389	0,1667	0,3611	0,6111
B3	0,3056	0,5556	0,7917	0,5556	0,8056	0,9306	0	0	0,25	0,2083	0,4167	0,6667	0,2639	0,4861	0,7361	0,1944	0,3889	0,6389
B4	0,2917	0,4861	0,7361	0,2500	0,4722	0,7222	0,1389	0,3056	0,5556	0	0	0,25	0,4306	0,6667	0,8056	0,3472	0,5833	0,7917
B5	0,2222	0,4167	0,6667	0,1944	0,4167	0,6667	0,0694	0,1528	0,4028	0,3611	0,5833	0,7500	0	0	0,25	0,0972	0,2222	0,4722
B6	0,1944	0,3472	0,5972	0,1944	0,3750	0,6111	0,1944	0,3333	0,5833	0,2361	0,4722	0,6944	0,1944	0,4028	0,6528	0	0	0,25
Total	**1,2222**	**2,2500**	**3,7361**	**1,5417**	**2,625**	**3,94444**	**0,6806**	**1,4444**	**2,9444**	**1,2361**	**2,2917**	**3,6389**	**1,6250**	**2,7500**	**4,0139**	**1,0556**	**2,0278**	**3,4583**

Table 13

The Normalized Direct Relationship Matrix

Barriers	B1			B2			B3			B4			B5			B6		
B1	0	0	0,0623	0,2137	0,2020	0,1903	0,0769	0,1060	0,1349	0,1624	0,1768	0,1730	0,3419	0,2879	0,2318	0,1538	0,1717	0.1730
B2	0,1282	0,1616	0,1730	0	0	0,0623	0,0940	0,1313	0,1522	0,1026	0,1212	0,1453	0,1111	0,1465	0,1592	0,1026	0,1313	0,1522
B3	0,1880	0,2020	0,1972	0,3419	0,2929	0,2318	0	0	0,062284	0,1282	0,1515	0,1661	0,1624	0,1768	0,1834	0,1197	0,1414	0,1592
B4	0,1795	0,1768	0,1834	0,1538	0,1717	0,1799	0,0855	0,1111	0,1384	0	0	0,062284	0,2650	0,2424	0,2007	0,2137	0,2121	0,1972
B5	0,1368	0,1515	0,1661	0,1197	0,1515	0,1661	0,0427	0,0556	0,1003	0,2222	0,2121	0,1869	0	0	0,0623	0,0598	0,0808	0,1176
B6	0,1197	0,1263	0,1488	0,1197	0,1364	0,1522	0,1197	0,1212	0,1453	0,1453	0,1717	0,1730	0,1197	0,1465	0,1626	0	0	0,0623

Tablo 14

The Total Relationship Matrix

Barriers	l						m						h					
B1	1,4274	0,6666	0,3196	0,5996	0,8332	0,5042	1,6253	0,8641	0,5164	0,8020	0,9849	0,7153	2,5128	1,6917	1,2933	1,5852	1,7629	1,5124
B2	0,3862	1,3197	0,2457	0,3799	0,4591	0,3328	0,6300	1,5500	0,4472	0,6164	0,7195	0,5639	1,4581	2,4179	1,1847	1,4097	1,5389	1,3523
B3	0,5912	0,7837	1,2551	0,5632	0,7001	0,4837	0,8199	0,9639	1,4410	0,8005	0,9309	0,7162	1,6913	1,7882	2,2738	1,6350	1,7862	1,5563
B4	0,5666	0,6090	0,3216	1,4436	0,7610	0,5421	0,7606	0,8264	0,5120	1,6366	0,9348	0,7342	1,6201	1,6827	1,2966	2,4848	1,7374	1,5328
B5	0,4177	0,4462	0,2156	0,4995	1,3988	0,3262	0,5978	0,6491	0,3704	0,6599	1,5669	0,5069	1,3874	1,4426	1,0884	1,3802	2,3818	1,2641
B6	0,4201	0,4733	0,2904	0,4541	0,5163	1,2758	0,6087	0,6743	0,4430	0,6600	0,7253	1,4543	1,4371	1,4988	1,1780	1,4316	1,5400	2,2692

Table 15

Affecting and Affected Factor Groups

Barriers	R			C			R+C			R-C		
	l	m	h	l	m	h	l	m	h	l	m	h
B1	3,3505	4,5080	9,3583	2,8091	4,0422	9,1068	6,1597	8,5502	18,465	0,5413	0,4657	0,2515
B2	2,1234	3,5269	8,3616	3,2985	4,5278	9,5219	5,4220	8,0547	17,883	-1,175	-1,000	-1,160
B3	3,3769	4,6724	9,7307	1,648	2,7299	7,3148	5,0249	7,4023	17,045	1,7289	1,9424	2,4159
B4	3,2438	4,4045	9,3543	2,9398	4,1754	8,9264	6,1836	8,5799	18,280	0,3040	0,2290	0,4278
B5	2,3040	3,3509	7,9444	3,668	4,8622	9,7471	5,9724	8,2131	17,691	-1,364	-1,511	-1,802
B6	2,4300	3,5656	8,3546	2,4649	3,6907	8,4870	4,8949	7,2563	16,841	-0,034	-0,125	-0,132

Table 15 presents "Affecting and Affected Factor Groups". The R and C values in Table 15 were calculated as triangular fuzzy numbers (1, m, h) using Equation (14) and Equation (15). Then the R and C values are added together and subtracted from each other. To convert these numbers into a crisp number, the number of Equations (16) and (17) were used for the decimation. Therefore, each factor $(\widetilde{R}_i + \widetilde{C}_i)$ and $(\widetilde{R}_i - \widetilde{C}_i)$ the obtained new values are shown in Table 16.

Table 16

Defuzzification of Affecting and Affected Factor Groups

Barriers	R+C	R-C
B1	10,4314	0,4311
B2	9,8538	-1,0843
B3	9,2188	2,0075
B4	10,4061	0,2975
B5	10,0226	-1,5474
B6	9,0624	-0,1044

In order to determine the factor weights in Table 17, Equations (18) and (19) were used.

Table 17

Factor Weights

Barriers	wi	Wi
B1	10,4403	0,1758
B2	9,9133	0,1669
B3	9,4348	0,1588
B4	10,4104	0,1752
B5	10,1413	0,1707
B6	9,0630	0,1526

5. Conclusion and Recommendations

As a result of the research, it is determined that the biggest obstacle for SMEs to adopt green innovation is financial inadequacies. Buildings, machinery, and equipment required for green practices emerge as a costly element for businesses. In addition, it can be said that high loan rates are another obstacle for SMEs to adopt green innovations. As a solution, banks should provide the necessary loans for green practices and low loan interest rates should be applied.

In addition, since the efforts of governments to encourage green innovation practices (such as tax reductions, incentive packages, and training-consulting services) are insufficient, it also emerges as an important obstacle to the realization of innovation practices. It is necessary to regulate environmental policies to provide bonuses and incentives for environmental friendly-production, and to impose heavy penalties on the supply chain that causes environmental pollution on the other side.

The lack of qualified human resources to use and develop green practices or the difficulty of reaching these qualified people emerge as another obstacle for businesses to switch to green practices. Therefore, training occurs as a necessity for human resources and experts who will create and use technological infrastructure.

Infrastructure deficiencies in the design, development, and execution of computer-based information systems create an obstacle for enterprises to make green innovations. As a solution to this, green systems should be encouraged and promoted, and businesses should be made aware of green systems.

The resistance and reluctance of suppliers to implement green practices cause disagreements among businesses. The lack of shared knowledge between suppliers and the business emerges as a barrier to green innovations. In this context, it is necessary to raise awareness of suppliers and customers about green practices through public institutions, encouraging suppliers to green practices, raising awareness of their customers about green products, and encouraging them to these products might be a solution.

The lack of green awareness of the top management, weak and unstable management, lack of participation and support, and resistance to change emerge as obstacles for businesses in green practices. To remove these obstacles, the top management should not only set innovative goals, but also motivate employees toward green initiatives. As a result of this study, the ranking of the degree of influence and importance of the barriers that have relations with each other and affect each other is revealed. Additionally, the barriers, their importance, and solutions to eliminate other barriers are offered.

Suggestions for future work:

· Further research can be done on diffent SMEs on various sectors.

· Different comparisons can be made using different methods.

· Barriers can be examined more broadly by increasing the number of assessing experts.

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