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Evaluation of Green Innovation Criteria by Using Pythagorean Fuzzy AHP Method

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Abstract

Businesses have become more sensitive to the environment as the problems arising due to climate change cause great dangers and the society's awareness of this issue. With this awareness, companies have turned to green innovation activities and started to gain competitive advantage. Waste recycling, less material use, eco-design, green product, pollution prevention are among the environmental activities of green innovation.

In this study, it is aimed to rank the green innovation criteria according to their importance. Renewable energy use, waste recycling, energy saving, pollution prevention, green product design, green marketing process, green supply chain, reduced carbon footprint, less material use criteria were used in the study. The ranking of the green innovation criteria was made using the Pythagorean Fuzzy AHP (Analytical Hierarchy Process) method. As a result of the study, it was seen that the "Reduced carbon footprint" criterion is the most important criterion. It was concluded that the criterion of "green product design" ranked second and the criterion of "use of renewable energy" ranked third. As a result of the study, it is clearly seen that the criteria in the first three are among the most important current issues discussed and addressed in the world.

Keywords: Green innovation, reduced carbon footprint, Pythagorean fuzzy AHP, environmental problems.

1. Introduction

Today, the increase in population, the development of technology and the increase in market share have also led to an increase in the global competition between businesses. Businesses both try to keep up with these changes and try to struggle with global competition [1]. In this context, one of the most important strategic tools and resources used by businesses in the fight against global competition is innovation [2]. In the Oslo Manual, innovation is defined as "the implementation of a new or significantly improved product or process, a new marketing method, or a new organizational method" [3]. There are many reasons why innovation has become an important tool lately. Innovation is a very important factor in providing competitive advantage, increasing the welfare level, contributing to the development of the economic structure of the society and increasing employment, and increasing the capacity and performance of enterprises [4, 5]. With environmental disasters, changes in the climate, greenhouse gas emissions, deterioration of ecological balance, increase in pollution, global warming and depletion of natural resources in the world, businesses have become more sensitive to the environment [6-8]. Businesses have started to develop strategies by adopting environmentally oriented approaches in the activities they will implement [9]. At the same time, creating a good impression by developing environmental plans and thus providing a competitive advantage, benefiting from the incentives given by the government in this area, and reducing the costs of the recycling vehicles to be used encourage businesses to a new concept called green innovation [10]. Therefore, it has become very important for all organizations to make their innovations as green innovations. While making these innovations, they need to know very well the important criteria/features that should be included in their innovations.

Therefore, in this study, it is aimed to rank the green innovation criteria according to their importance weights. Using renewable energies, waste recycling, energy-saving, pollution prevention, green product design, green marketing process, green supply chain,

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reduced carbon footprint, less material use criteria were used and the ranking process was carried out with the Pythagorean fuzzy AHP method.

The rest of the study consists of the following parts: In the second part, the concept of green innovation is examined and studies in the literature on green innovation are included. In the third part, the material-method is explained, in the fourth part the findings obtained from the study are given, and in the fifth part, the results of the study are mentioned.

2. Green Innovation

Green innovation is a type of innovation that develops smart solutions for a sustainable environment, ensures the conscious use of limited and important resources, and reduces all kinds of negative effects on the environment [11]. Green innovation is defined as "hardware, software or corporate environmental management related to green products or processes, including pollution prevention, energy conservation, waste recycling, green product design [12]. Green innovation is the activities applied to minimize the negative impact on the environment in all processes from the production of a product to waste [13]. Reuse of recyclable materials, waste recycling, products that do not harm the environment, green management, renewable energy, reduction of greenhouse gas emissions are among the environmental applications of green innovation. Considering the environmental protection at all stages of production is also among the green innovation practices. The goal of green innovation is the implementation of thoughts and behaviours towards reducing and protecting environmental pollution [14, 15]. The aim of the activities for the protection of the environment is not to ensure economic growth, but to consider business and environmental policies as a whole [16]. The reason for the implementation of green innovation is to ensure that all production processes in enterprises cause less damage to the environment, reduce pollution and carbon emissions [17]. Green innovation contributes both to the goals and strategies of companies and to the sustainable goals of the country. Green innovation is a major factor in preventing environmental damage, reducing costs, and increasing customer satisfaction thanks to the green concept [1]. Green innovation activities reduce costs, increase efficiency, and increase the benefits of innovative activities and technological opportunities when applied as opposed to increasing operating costs [18-20]. It is among the goals of green innovation to design and produce products that are easy to recycle, that are produced by requiring less raw materials and that do not harm the environment when used [21]. In order for the changes to be considered as green innovation, the following conditions must be met [1]: using production processes that do not harm the environment, efficient and effective use of resources, using more recycling materials, production of environmentally friendly products, reducing greenhouse gas emissions.

According to the results of the Community innovation survey, there are 9 types of green innovations in total and they are divided into 2 categories. Three types of innovation express the benefits related to the use of goods or services after sales. These; recycling used product, reducing energy use and reducing pollution (soil, air, water or noise). The remaining 6 types of innovation are related to the environmental benefits arising from the production of goods and services: reducing the use of materials polluting the environment, using less materials, reducing carbon footprint, using less energy, recycling, reducing pollution [22].

When the literature is examined, it is seen that there are not enough studies in the field of green innovation. Işık and Barlak [16] surveyed the managers of 76 hotels with 3, 4 and 5 stars operating in Istanbul and investigated the managers' thoughts and expectations about green innovation, green innovation activities applied in the business and environmental awareness. As a result of the study, it was seen that green innovation was not fully adopted. Seman et.al., [23] determined the relationship between green innovation and environmental performance of green supply chain management. The study was conducted for 123 companies with ISO 14001 certificate. The study revealed that green supply chain management has a positive and significant relationship between green innovation and environmental performance, and that green innovation has a positive effect on environmental performance, and that green innovation acts as a bridge between green supply chain management and environmental performance. Singh et.al., [24] tried to determine the relationship between green human resource management, green innovation, green transformational leadership and environmental performance by applying a survey to a total of 309 small and medium-sized enterprises operating in the manufacturing sector. As a result of the study, they determined that there is a significant relationship between each other. Seyhan [25], brought together the concept of green innovation in the Web of

Science database and studies involving managerial practices, and applied the bibliometric analysis method, determined the missing aspects and made predictions about the future. Kırbaşlı and Avunduk [6] examined the green innovation activities of a bank with the case study method. In the study, it was concluded that the bank took successful steps in the field of green innovation by effectively implementing green marketing, green product and green process innovations. Irfan et.al., [7] tested the impact of green finance on green innovation using China's regional data from 2010 to 2019. First, the concepts of green finance and green innovation were analyzed. Then, DID (difference-in-differences) and PVAR (panel vector autoregressive) models were used to determine the effect of green finance on green innovation. Research results show that green finance will have significant effects on green innovation by contributing to the development of R&D investments, economic growth and industrial structure. Le at.al., [26] examined the relationship between sustainable corporate performance and corporate social responsibility of SMEs where green innovation and green supply chain management are applied. The least squares structural equation model (PLS-SEM) was used in the study. According to the modelling result, it was determined that there is a positive relationship between corporate social responsibility and sustainable corporate performance thanks to green innovation and green supply chain management. There are studies in which literature studies on green innovation are conducted [27-31].

3. Material Method

In the study, it is aimed to rank the green innovation criteria that institutions / organizations consider in their product, process, service, marketing and organizational innovations according to their importance weights. In this way, it is aimed to determine the green innovation criteria that should be included in the innovation studies to be carried out and to benefit institutions and organizations.

In the first stage of the study, the required green innovation criteria in product, service, process, marketing and organizational innovations were determined in line with the literature research and the opinions of two experts in innovation management and are given in Table 1.

The Pythagorean fuzzy AHP method was used to prioritize the criteria given in Table 1, and this method is briefly explained below.

3.1. Pythagorean Fuzzy AHP

Analytical Hierarchy Method (AHP), one of the multi-criteria decision-making methods, was developed by Thomas L. Saaty [32]. AHP is a method that evaluates the criteria according to more than one alternative and ranks them according to their importance in the decision problem. With this method, it is aimed for decision makers to make decisions that will provide maximum benefit by considering the importance of criteria [33]. In this method, a hierarchical structure is created between the 'main aim, criteria and alternatives' of the problem [34]. By using hierarchical structure in this way, complex problems become much more understandable [35]. In the AHP method decision makers can include their objective and subjective views in the decision process. In other words, knowledge, experience and thoughts are modelled by combining them logically [34]. When the AHP method is considered in general terms, it covers a process used in absolute and relative measurements, where precise measurements adhere to various standards and are associated with memory. It also aims to measure the subjective distances between criteria [36].

Table 1. Green innovation criteria determined within the scope of the study

Criteria No	Criteria
C1	Using Renewable Energies
C2	Waste Recycling
C3	Energy-Saving
C4	Pollution Prevention
C5	Green Product Design
C6	Green Marketing Process
C7	Green Supply Chain
C8	Reduced Carbon Footprint
C9	Less Material Use

Table 2. Linguistic variables and pythagorean fuzzy numbers

Linguistic Variables	Interval Pythagorean Fuzzy Numbers			
	The lower value of the membership degree (μL)	The upper value of the membership degree (μU)	The lower value of the non-membership degree (vL)	The upper value of the non-membership degree (vU)
Certainly Low Importance (CLI)	0	0	0.9	1
Very Low Importance (VLI)	0.1	0.2	0.8	0.9
Low Importance (LI)	0.2	0.35	0.65	0.8
Below Average Importance (BAI)	0.35	0.45	0.55	0.65
Average Importance (AI)	0.45	0.55	0.45	0.55
Above Average Importance (AAI)	0.55	0.65	0.35	0.45
High Importance (HI)	0.65	0.8	0.2	0.35
Very High Importance (VHI)	0.8	0.9	0.1	0.2
Certainly High Importance (CHI)	0.9	1	0	0
Exactly Equal (EE)	0.1965	0.1965	0.1965	0.1965

However, there are deficiencies in the full reflection of human thoughts in the AHP method. Fuzzy AHP has emerged by combining AHP with fuzzy logic to eliminate this deficiency. Instead of the net values used in the traditional AHP method, in the fuzzy AHP method, the comparison ratios are determined using a set of values. Then, the Pythagorean fuzzy sets were integrated into the AHP method to reduce or eliminate the uncertainty [37]. In this methodology, instead of assigning a precise number for evaluation, decision makers use linguistic terms and related Pythagorean fuzzy numbers that provide more area for their opinions [38]. Pythagorean fuzzy sets are an extension of heuristic fuzzy sets. These sets, and in some cases heuristic fuzzy sets, cannot handle uncertainty. This achievement makes Pythagorean fuzzy sets more powerful and flexible for solving problems involving uncertainty [39, 40]. Fuzzy sets can be expressed as membership function, non-membership function and uncertainty degree. However, in a situation where membership and non-membership degrees are greater than 1, heuristic fuzzy sets cannot handle the uncertainty. In Pythagorean fuzzy sets, the sum of the membership and non-membership degrees can be greater than 1, but not the sum of their squares. This means that for every point (x, y) that is the heuristic member grade as well as the Pythagorean member grade, the heuristic membership grades are all points below the line $x + y \leq 1$, while the Pythagorean membership grades are all points $x^2 + y^2 \leq 1$. Therefore, the set of Pythagorean membership notes is larger than the intuitive set of membership notes. Thus, Pythagorean fuzzy sets give decision makers more freedom to express their views on the uncertainty and uncertainty of the problem [41]. Because of these features, the Pythagorean fuzzy AHP method was used in this study.

In Pythagorean fuzzy numbers, the scale shown in Table 2 is used for decision makers to evaluate alternatives or criteria [42].

The steps of the Pythagorean Fuzzy AHP method are as follows [42].

Step 1: According to the scale given in Table 3, the decision makers compare the criteria or alternatives in pairs and accordingly create the pairwise comparison matrix.

Step 2: Calculation of the difference matrix between the lower and upper points of the membership and non-membership functions with the help of equations (1) and (2)

$$d_{ik_l} = \mu_{ik_l}^2 - v_{ik_u}^2 \quad (1)$$

$$d_{ik_u} = \mu_{ik_u}^2 - v_{ik_l}^2 \quad (2)$$

Step 3: Calculation of the multiplicative matrix using equations (3) and (4)

$$s_{ik_l} = \sqrt{1000^{d_l}} \quad (3)$$

$$s_{ik_u} = \sqrt{1000^{d_u}} \quad (4)$$

Step 4: Calculation the degrees of uncertainty for each criterion with the help of equation (5)

$$\tau_{ik} = 1 - (\mu_{ik_u}^2 - \mu_{ik_l}^2) - (\nu_{ik_u}^2 - \nu_{ik_l}^2) \quad (5)$$

Step 5: Determining the non-normalized weights using both the degrees of uncertainty and the multiplication matrix with the help of equation (6).

$$t_{ik} = \left(\frac{s_{ik_l} + s_{ik_u}}{2}\right) \tau_{ik} \quad (6)$$

Step 6: Calculation of weights of importance (w_i)

$$w_i = \frac{\sum_{k=1}^{m} t_{ik}}{\sum_{i=1}^{m}\sum_{k=1}^{m} t_{ik}} \quad (7)$$

4. Findings

According to the steps described above, the prioritization of green innovation criteria was carried out.

Step 1: The criteria given in Table 1 were evaluated according to the scale given in Table 2 by two innovation management experts and 1 industrial engineer in line with the consensus, and the pairwise comparison matrix given in Table 3 was obtained.

Step 2: The difference matrix between the lower and upper points of the membership and non-membership functions is calculated with the help of equations (2) and (3) and given in Table 4-5.

Step 3: Multiplicative matrix was calculated using equation (3) and (4) and given in Table 6-7.

Step 4: In Table 8, the degrees of uncertainty are given for each criterion calculated with the help of equation (5).

Step 5: Unnormalized importance weights are calculated with the help of equation (6) and given in Table 9.

Step 6: The importance weights of each criterion were calculated using equation (7) and given in Table 10.

When Table 10 is examined, it is seen that the "Reduced Carbon Footprint" criterion is the most important criterion among the green innovation criteria with an importance weight value of 0.283. “Green Product Design” is the second and “Pollution Prevention” is the third important criterion. “Using Renewable Energies” was determined as the last criterion.

Table 3. Pairwise comparison matrix of green innovation criteria

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9
C1	EE	AI	AAI	LI	LI	AI	BAI	VLI	BAI
C2	AI	EE	AAI	AI	LI	HI	AAI	VLI	BAI
C3	BAI	BAI	EE	AI	BAI	AAI	AI	HI	AAI
C4	HI	AI	AI	EE	AAI	HI	HI	BAI	AI
C5	HI	HI	AAI	BAI	EE	HI	AAI	BAI	HI
C6	AI	LI	BAI	LI	LI	EE	AI	VHI	BAI
C7	AAI	BAI	AI	LI	BAI	AI	EE	VLI	BAI
C8	VHI	VHI	LI	AAI	AAI	VLI	VHI	EE	HI
C9	AAI	AAI	BAI	AI	LI	AAI	AAI	LI	EE

Table 4. The difference matrix between lower points of membership and non-membership functions

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9
C1	0	-0,1	0,1	-0,6	-0,6	-0,1	-0,3	-0,8	-0,3
C2	-0,1	0	0,1	-0,1	-0,6	0,3	0,1	-0,8	-0,3
C3	-0,3	-0,3	0	-0,1	-0,3	0,1	-0,1	0,3	0,1
C4	0,3	-0,1	-0,1	0	0,1	0,3	0,3	-0,3	-0,1
C5	0,3	0,3	0,1	-0,3	0	0,3	0,1	-0,3	0,3
C6	-0,1	-0,6	-0,3	-0,6	-0,6	0	-0,1	0,6	-0,3
C7	0,1	-0,3	-0,1	-0,6	-0,3	-0,1	0	-0,8	-0,3
C8	0,6	0,6	-0,6	0,1	0,1	-0,8	0,6	0	0,3
C9	0,1	0,1	-0,3	-0,1	-0,6	0,1	0,1	-0,6	0

Table 5. The difference matrix between upper points of membership and non-membership functions

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9
C1	0	0,1	0,3	-0,3	-0,3	0,1	-0,1	-0,6	-0,1
C2	0,1	0	0,3	0,1	-0,3	0,6	0,3	-0,6	-0,1
C3	-0,1	-0,1	0	0,1	-0,1	0,3	0,1	0,6	0,3
C4	0,6	0,1	0,1	0	0,3	0,6	0,6	-0,1	0,1
C5	0,6	0,6	0,3	-0,1	0	0,6	0,3	-0,1	0,6
C6	0,1	-0,3	-0,1	-0,3	-0,3	0	0,1	0,8	-0,1
C7	0,3	-0,1	0,1	-0,3	-0,1	0,1	0	-0,6	-0,1
C8	0,8	0,8	-0,3	0,3	0,3	-0,6	0,8	0	0,6
C9	0,3	0,3	-0,1	0,1	-0,3	0,3	0,3	-0,3	0

Table 6. The multiplicative matrix of the lower points

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9
C1	1,00	0,71	1,41	0,13	0,13	0,71	0,35	0,06	0,35
C2	0,71	1,00	1,41	0,71	0,13	2,82	1,41	0,06	0,35
C3	0,35	0,35	1,00	0,71	0,35	1,41	0,71	2,82	1,41
C4	2,82	0,71	0,71	1,00	1,41	2,82	2,82	0,35	0,71
C5	2,82	2,82	1,41	0,35	1,00	2,82	1,41	0,35	2,82
C6	0,71	0,13	0,35	0,13	0,13	1,00	0,71	7,94	0,35
C7	1,41	0,35	0,71	0,13	0,35	0,71	1,00	0,06	0,35
C8	7,94	7,94	0,13	1,41	1,41	0,06	7,94	1,00	2,82
C9	1,41	1,41	0,35	0,71	0,13	1,41	1,41	0,13	1,00

Table 7. The multiplicative matrix of upper points

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9
C1	1,00	1,41	2,82	0,35	0,35	1,41	0,71	0,13	0,71
C2	1,41	1,00	2,82	1,41	0,35	7,94	2,82	0,13	0,71
C3	0,71	0,71	1,00	1,41	0,71	2,82	1,41	7,94	2,82
C4	7,94	1,41	1,41	1,00	2,82	7,94	7,94	0,71	1,41
C5	7,94	7,94	2,82	0,71	1,00	7,94	2,82	0,71	7,94
C6	1,41	0,35	0,71	0,35	0,35	1,00	1,41	15,85	0,71
C7	2,82	0,71	1,41	0,35	0,71	1,41	1,00	0,13	0,71
C8	15,85	15,85	0,35	2,82	2,82	0,13	15,85	1,00	7,94
C9	2,82	2,82	0,71	1,41	0,35	2,82	2,82	0,35	1,00

Table 8. Uncertainty degrees of the criteria

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9
C1	1,00	0,80	0,80	0,70	0,70	0,80	0,80	0,80	0,80
C2	0,80	1,00	0,80	0,80	0,70	0,70	0,80	0,80	0,80
C3	0,80	0,80	1,00	0,80	0,80	0,80	0,80	0,70	0,80
C4	0,70	0,80	0,80	1,00	0,80	0,70	0,70	0,80	0,80
C5	0,70	0,70	0,80	0,80	1,00	0,70	0,80	0,80	0,70
C6	0,80	0,70	0,80	0,70	0,70	1,00	0,80	0,80	0,80
C7	0,80	0,80	0,80	0,70	0,80	0,80	1,00	0,80	0,80
C8	0,80	0,80	0,70	0,80	0,80	0,80	0,80	1,00	0,70
C9	0,80	0,80	0,80	0,80	0,70	0,80	0,80	0,70	1,00

Table 9. Unnormalized weights

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9
C1	1,00	0,85	1,69	0,17	0,17	0,85	0,43	0,08	0,43
C2	0,85	1,00	1,69	0,85	0,17	3,77	1,69	0,08	0,43
C3	0,43	0,43	1,00	0,85	0,43	1,69	0,85	3,77	1,69
C4	3,77	0,85	0,85	1,00	1,69	3,77	3,77	0,43	0,85
C5	3,77	3,77	1,69	0,43	1,00	3,77	1,69	0,43	3,77
C6	0,85	0,17	0,43	0,17	0,17	1,00	0,85	9,52	0,43
C7	1,69	0,43	0,85	0,17	0,43	0,85	1,00	0,08	0,43
C8	9,52	9,52	0,17	1,69	1,69	0,08	9,52	1,00	3,77
C9	1,69	1,69	0,43	0,85	0,17	1,69	1,69	0,17	1,00

Table 10. Importance weight and ranking of criteria

Criteria	Unnormalized importance weights	Normalized importance weights	Ranking
Using Renewable Energies	5,65	0,043	9
Waste Recycling	10,52	0,081	6
Energy-Saving	11,12	0,085	5
Pollution Prevention	16,96	0,130	3
Green Product Design	20,30	0,156	2
Green Marketing Process	13,57	0,104	4
Green Supply Chain	5,91	0,045	8
Reduced Carbon Footprint	36,95	0,283	1
Less Material Use	9,38	0,072	7

5. Conclusion and Evaluation

As the effects of global warming on our lives increase, the concept of natural and environmentally friendly products, which has a very limited area of influence in the industrial society, has started to spread rapidly towards large consumer masses. Accordingly, companies started to be more sensitive to the environment in their production and started to focus on issues such as carbon emissions and sustainability. In the researches, it is said that after 10 years, companies that invest in low carbon consumption or build their production on low carbon consumption will gain more than their competitors. In fact, it is stated that technologies that take into account the environment will make much more changes in our lives in the next 20 years than information technologies have made. Therefore, while companies are innovating, products, services, processes, marketing, etc., which are more environmentally friendly. innovations are required. When it comes to environmentally friendly innovation, we come across the concept of green innovation. While doing green innovation, some criteria or features should be taken into consideration. However, the issue of which features or criteria should be in the innovation to be made is also very important.

In our study, green innovation criteria were ranked according to their importance weights using the Pythagorean Fuzzy AHP method. Considering the results obtained, the criterion of "Reduced Carbon Footprint" was determined as the most important criterion. The fact that this criterion is in the first place is in parallel with the "zero carbon emission" emphasized in recent studies and reveals that carbon emissions must be reduced in innovation studies. When we look at another result obtained from the study, it is seen that the criteria (reduced carbon footprint, green product design, using renewable energies) that are in the first three importance are related to the most talked about and most important issues and situations in the world today.

When the literature is examined, the study is the first in which the green innovation criteria are evaluated according to the degree of importance. Therefore, it is thought that all organizations can use the criteria and method used in the study to determine their work that will turn into green innovation and provide economic return. In future studies, it is aimed to make evaluations according to more green innovation criteria.

References

[1] Yıldırım, S. (2022). Kobilerin yeşil inovasyonu benimseme konusunda karşılaştıkları engellerin bulanık ISM-MICMAC-DEMATEL ile değerlendirilmesi. Yüksek Lisans Tezi, Bilecik Şeyh Edebali Üniversitesi, Sosyal Bilimler Enstitüsü, Türkiye.

[2] Zawislak, P. A., Cherubini Alves, A., Tello-Gamarra, J., Barbieux, D., & Reichert, F. M. (2012). Innovation capability: From technology development to transaction capability. Journal of technology management & innovation, 7(2), 14-27.

[3] OECD, Eurostat, Oslo Klavuzu (2005). Yenilik verilerinin toplanması ve yorumlanması için ilkeler, TÜBİTAK 3. Basım, Ankara.

[4] Uzkurt, C. (2008). Yenilik yönetimi ve yenilikçi örgüt kültürü, pazarlamada değer yaratma aracı olarak. İstanbul: Beta Yayınları.

[5] Naktiyok, A. (2007). Yenilik yönelimi ve örgütsel faktörler. Atatürk Üniversitesi İktisadi ve İdari Bilimler Dergisi, 21(2), 211-230.

[6] Kırbaşlı, M., & Avunduk, Z. B. (2022). Yeşil hizmet inovasyonu: bankacılık sektöründe kalitatif bir araştırma. Yönetim Bilimleri Dergisi, (Özel Sayı), 26-52.

[7] Irfan, M., Razzaq, A., Sharif, A., & Yang, X. (2022). Influence mechanism between green finance and green innovation: exploring regional policy intervention effects in China. Technological Forecasting and Social Change, 182, 121882.

[8] Zhang, Z., Gong, B., Tang, J., Liu, Z., & Zheng, X. (2019). The joint dynamic green innovation and pricing strategies for a hybrid system of manufacturing and remanufacturing with carbon emission constraints. Kybernetes, 48(8), 1699–1730.

[9] Atay, L., & Dilek, S. E. (2013). Konaklama işletmelerinde yeşil pazarlama uygulamaları: İbis otel örneği. Süleyman Demirel Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi, 18(1), 203-219.

[10] Şenocak, B., & Bursalı, Y. (2018). İşletmelerde çevresel sürdürülebilirlik bilinci ve yeşil işletmecilik uygulamaları ile işletme başarısı arasındaki ilişki. Süleyman Demirel Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi, 23(1), 161-183.

[11] Saatçi, G., Demirbulat, Ö. G., & Avcıkurt, C. (2013). Konaklama İşletmelerinde Yeşil İnovasyon Uygulamaları: Bursa Örneği. 14. Ulusal Turizm Kongresi, 20-38.

[12] Chen, Y. S., Lai. S. B. ve Wen, C. T. (2006). The Influence of Green Innovation Performance on Corporate Advantage in Taiwan. Journal of Business Ethics, 67 (4), 331-339.

[13] Büyükkeklik, A. G. A., Toksarı, M., & Bülbül, H. (2010). Çevresel duyarlılık ve yenilikçilik üzerine bir araştırma. Süleyman Demirel Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi, 15(3), 373-393.

[14] Rennings, K. (2000). Redefining innovation eco-innovation research and the contribution from ecological economics. Ecological economics, 32(2), 319-332.

[15] Yıldız, A. (2012). Çevre yönetimi uygulayan yeşil otel işletmelerinde yeşil müşteri deneyimi üzerine bir araştırma. Yüksek Lisans Tezi, Anadolu Üniversitesi, Sosyal Bilimler Enstitüsü Türkiye.

[16] Işık, C., & Barlak, S. (2018). Otel yöneticilerinin yeşil inovasyon algıları: İstanbul ili örneği. Journal of Tourism Intelligence and Smartness, 1(1), 14-26.

[17] Zhang, D., Rong, Z., & Ji, Q. (2019). Green innovation and firm performance: Evidence from listed companies in China. Resources, Conservation and Recycling, 144, 48-55.

[18] Porter, M., & Van der Linde, C. (1996). Green and competitive: Ending the stalemate in Welford R and Starkey R Business and the Environment. London, Earthscan, 61-77.

[19] Horbach, J. (2008). Determinants of environmental innovation-New evidence from German panel data sources. Research policy, 37(1), 163-173.

[20] Ma, W., Zhang, R., & Chai, S. (2019). What drives green innovation? A game theoretic analysis of government subsidy and cooperation contract. Sustainability, 11(20), 5584.

[21] Khanra, S., Kaur, P., Joseph, R. P., Malik, A., & Dhir, A. (2022). A resource-based view of green innovation as a strategic firm resource: Present status and future directions. Business Strategy and the Environment, 31(4), 1395-1413.

[22] Arfi, W. B., Hikkerova, L., & Sahut, J. M. (2018). External knowledge sources, green innovation and performance. Technological Forecasting and Social Change, 129, 210-220.

[23] Seman, N. A. A., Govindan, K., Mardani, A., Zakuan, N., Saman, M. Z. M., Hooker, R. E., & Ozkul, S. (2019). The mediating effect of green innovation on the relationship between green supply chain management and environmental performance. Journal of cleaner production, 229, 115-127.

[24] Singh, S. K., Del Giudice, M., Chierici, R., & Graziano, D. (2020). Green innovation and environmental performance: The role of green transformational leadership and green human resource management. Technological Forecasting and Social Change, 150, 119762.

[25] Seyhan, M. (2021). Yönetsel bağlamda yeşil inovasyonun evriminin bibliyometrik analizi. Gaziantep University Journal of Social Sciences, 20(2), 611-625.

[26] Le, T. T., Vo, X. V., & Venkatesh, V. G. (2022). Role of green innovation and supply chain management in driving sustainable corporate performance. Journal of Cleaner Production, 374, 133875.

[27] Schiederig, T., Tietze, F., & Herstatt, C. (2012). Green innovation in technology and innovation management – an exploratory literature review. R&D Management, 42(2), 180–192.

[28] Pereira, R. M., MacLennan, M. L. F., & Tiago, E. F. (2020). Interorganizational cooperation and

eco-innovation: A literature review. International Journal of Innovation Science, 12(5), 477–493.
[29] Takalo, S. K., Tooranloo, H. S., & Parizi, Z. S. (2021). Green innovation: A systematic literature review. Journal of Cleaner Production, 279, 122474.
[30] Avunduk, Z. B. (2021). Üretim yönetiminde yeşil inovasyon:(s) SCI dergilerinde yayımlanan makalelerin içerik analizi. Yönetim Bilimleri Dergisi, 19(Özel Sayı), 187-210.
[31] Arici, H.E., & Uysal, M. (2022). Leadership, green innovation, and green creativity: A systematic review. The Service Industries Journal, 42(5-6), 280-320.
[32] Saaty, T. L. (1988). What is the analytic hierarchy process?. In Mathematical models for decision support (pp. 109-121). Springer, Berlin, Heidelberg.
[33] Oral, N., Yumuşak, R., & Eren, T. (2021). AHP ve ANP yöntemleri kullanılarak tehlikeli madde depo yeri seçimi: Kırıkkale ilinde bir uygulama. Niğde Ömer Halisdemir Üniversitesi Mühendislik Bilimleri Dergisi, 10(1), 115-124.
[34] Sarikale, H., & Kandemir, T. (2022). Bankalarda uzaktan ve yerinde şube denetimlerinin AHP yöntemiyle değerlendirilmesi. Karamanoğlu Mehmetbey Üniversitesi Sosyal ve Ekonomik Araştırmalar Dergisi, 24(42), 125-143.
[35] Ersoy, Y. (2021). AHP ve TOPSIS yöntemleri kullanılarak tekstil sektöründe personel seçimi. Kafdağı, 6(1), 60-78.
[36] Akdeniz, E. (2021). Bireysel otomobil satın alma problemi için AHP yöntemi ile karar verme: Bir otomobil firması bazında inceleme. Yaşar Üniversitesi E-Dergisi, 16(64), 1551-1574.
[37] Yıldız, A., Ayyıldız, E., Gümüş, A. T., & Özkan, C. (2019). Ülkelerin yaşam kalitelerine göre değerlendirilmesi için hibrit pisagor bulanık AHP-TOPSIS metodolojisi: Avrupa Birliği örneği. Avrupa Bilim ve Teknoloji Dergisi, (17), 1383-1391.
[38] Ayyildiz, E., & Taskin Gumus, A. (2021). Pythagorean fuzzy AHP based risk assessment methodology for hazardous material transportation: an application in Istanbul. Environmental Science and Pollution Research, 28(27), 35798-35810.
[39] Yılmaz, M., & Yıldız, A. (2022). Prioritization of R&D Project Evaluation Criteria Using Pythagorean Fuzzy AHP Method. Academic Perspective Procedia, 5(3), 443-455.
[40] Yucesan, M., & Gul, M. (2020). Hospital service quality evaluation: an integrated model based on Pythagorean fuzzy AHP and fuzzy TOPSIS. Soft Computing, 24(5), 3237-3255.
[41] Shete, P. C., Ansari, Z. N., & Kant, R. (2020). A Pythagorean fuzzy AHP approach and its application to evaluate the enablers of sustainable supply chain innovation. Sustainable Production and Consumption, 23, 77-93.
[42] Karasan, A., Ilbahar, E., & Kahraman, C. (2019). A novel pythagorean fuzzy AHP and its application to landfill site selection problem. Soft Computing, 23(21), 10953-10968.