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-RESEARCH ARTICLE-

GREEN SUPPLIER SELECTION BY USING ISO 14001:2015 CRITERIA

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Abstract

Due to climate change and the necessity of achieving net-zero targets by 2050, sustainability is becoming increasingly important across various sectors. Globally, attention to the environmental sustainability of healthcare institutions is growing exponentially, particularly due to their impact on carbon footprints. ISO 14001 certification stands out as a potent indicator of environmental prowess, influencing the selection of suppliers with a commitment to green practices. Companies holding this certification often enjoy preference in green procurement processes. Conventional ISO 14001 audits predominantly focus on verifying a company's adherence to standard criteria, leaving unaddressed the dimension of "how well" each criterion is satisfied or the relative "importance" of individual criteria.

The aim of this study is to develop an integrated approach to evaluate the green procurement performance of four companies operating in the healthcare sector and to select the best supplier, taking into account the ISO 14001:2015 criteria. The Analytic Hierarchy Process (AHP) was used to prioritize the criteria defined in the ISO 14001:2015 standard, and the Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) was applied to rank the companies based on their compliance with these prioritized criteria. According to the research findings, the most important criteria in the environmental management system are "leadership" and "planning." The most significant sub-criteria were identified as "leadership and commitment" and "actions to address risks and opportunities." It is evident that companies that consider the weighted importance of ISO criteria will gain environmental benefits in terms of quality, cost, and delivery, both for themselves and for the world.

Keywords: *Analytic hierarchy process (AHP), environmental management system, green supplier selection, ISO 14001, preference ranking organization method for enrichment evaluation (PROMETHEE).*

JEL Codes: *C60, Q58.*

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ISO 14001:2015 KRİTERLERİNİ KULLANARAK YEŞİL TEDARİKÇİ SEÇİMİ[3]

Öz

İklim değişikliğine ve 2050 yılına kadar net sıfır hedeflerine ulaşma ihtiyacı nedeniyle sürdürülebilirlik sektörler arasında giderek daha fazla önemli hale gelmektedir. Küresel olarak, sağlık kuruluşlarının çevresel sürdürülebilirliğine yönelik dikkat, özellikle karbon ayak izine etkileri nedeniyle katlanarak artmaktadır. ISO 14001 sertifikası, yeşil uygulamalara bağlılık gösteren tedarikçilerin seçimini etkileyen, çevresel yeteneğin güçlü bir göstergesi olarak öne çıkıyor. Bu sertifikaya sahip şirketler genellikle yeşil tedarikçilerin satın alınmasında tercih edilmektedir. Geleneksel ISO 14001 denetimleri ağırlıklı olarak bir şirketin standart kriterlere bağlılığını doğrulamaya odaklanır ve her bir kriterin "ne kadar iyi" karşılandığı boyutunu veya bireysel kriterlerin göreceli "önemini" ele almaz.

Bu çalışmanın amacı, ISO 14001:2015 kriterlerini dikkate alarak sağlık sektöründe faaliyet gösteren 4 şirketin yeşil tedarik performanslarını değerlendirmek ve en iyi tedarikçiyi seçmek için entegre bir yaklaşım geliştirmektir. ISO 14001:2015 standardında belirtilen kriterleri önceliklendirmek için Analitik Hiyerarşi Süreci (AHP) yöntemini ve şirketleri bu önceliklendirilmiş kriterlere uygunluklarına göre sıralamak için Tercih Sıralaması Organizasyon Yöntemi Zenginleştirme Değerlendirmesi (PROMETHEE) yöntemi uygulanmıştır. Araştırma sonuçlarına göre, çevre yönetim sisteminde en önemli kriter "liderlik" ve "planlama"dır. En önemli alt kriterler ise "liderlik ve bağlılık" ve "risk ve fırsatları ele almak için eylemler" olarak belirlenmiştir. ISO kriterlerinin önem ağırlıklarını dikkate alan şirketlerin, hem kendileri hem de dünya için kalite, maliyet ve teslimat gibi çevresel faydalar elde edecekleri açıktır.

Anahtar Kelimeler: *ISO 14001, Çevre Yönetim Sistemi, Analitik Hiyerarşi Süreci (AHP), Zenginleştirme Değerlendirmesi için Tercih Sıralaması Organizasyon Yöntemi (PROMETHEE), Yeşil Tedarikçi Seçimi.*

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"Bu çalışma Araştırma ve Yayın Etiğine uygun olarak hazırlanmıştır."

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1. INTRODUCTION

Due to climate change and the need to achieve net-zero targets by 2050, sustainability has become increasingly significant across various sectors. Globally, attention to the environmental sustainability of healthcare institutions is rising exponentially, particularly due to their impact on carbon footprints (Salas et al., 2020). Paradoxically, while healthcare promotes health, it also significantly contributes to environmental degradation and is estimated to be responsible for approximately 4–5% of global greenhouse gas emissions (Verdonck and Verniers, 2025).

Aligned with corporate social responsibility, sustainability in hospitals is defined by the integration of social and environmental concerns into business operations (Costa et al., 2022). Healthcare institutions should incorporate sustainability into their strategic planning to reduce environmental impact while maintaining high-quality care. Both academic researchers (Rattan et al., 2022) and international organizations (Pan-European CHSD, 2021) have called on healthcare institutions to develop effective green practices.

Generally, green practices in hospitals consist of waste-reduction-focused initiatives or applications within the hospital supply chain. Messmann et al. (2024) assessed hospitals' environmental and social sustainability, Rodriguez-Gonzalez et al. (2020) evaluated pharmacy performance using the EFQM model, and Orsini et al. (2024) examined the performance of green organizational practices in mitigating climate change in hospitals. These studies emphasize the critical role of green practices in enhancing environmental sustainability, reducing operational costs, and improving patient care quality. Supplier selection is a key decision that influences supply chain efficiency. Green supplier selection has been recognized as a significant factor in enhancing an organization's performance in addressing environmental concerns (Gao et al., 2020). The healthcare supply chain—a specific case of supply chain management—is a critical component of the healthcare delivery system responsible for the continuous flow of goods, information, and finances necessary for quality patient care (Iyengar et al., 2020). The timely and efficient procurement of medical supplies is essential for the continuity of high-quality healthcare services and the satisfaction of patients and staff. Additionally, supply chain expenditures can account for over 40–50% of a hospital's total costs (Gartner Research, 2022). In the literature, green supply chains are also acknowledged as organizational elements supporting the circular economy (Gupta et al., 2019).

Previous studies have shown that supplier selection has often focused solely on economic efficiency, with environmental concerns rarely considered (Kumar et al., 2014). However, environmental degradation, regulatory requirements, and rising consumer awareness have compelled institutions to consider green supplier alternatives. The literature includes numerous criteria for evaluating green supplier selection (Qu et al., 2020; Wei et al., 2021; Yan et al., 2022), though most of these studies are concentrated in sectors such as food, electronics, and automotive (Saputro et al., 2024; Kara et al., 2024). Malik et al. (2016) emphasized that hospitals should pay greater attention to strategies related to supplier selection. Researchers often rely on expert and/or decision-maker opinions when identifying green performance criteria (Tsai et al., 2015; Acar et al., 2016). Balan and Colon (2018) noted that the multiplicity of actors, ambiguity of goals, and the complexity of health systems complicate the evaluation of green initiatives in the supply chain. Some relevant criteria include value creation for stakeholders, speed and accuracy of service, agile transportation methods, risk perception, and the existence of environmental management systems (Nazari-Shirkouhi and Samadi, 2025; Kara et al., 2024).

Several studies have also shown that institutions incorporating social and environmental aspects into procurement procedures—such as those certified with ISO 14001—achieve positive outcomes in meeting sustainable development goals (Walker and Brammer, 2012; Sorooshian and Ting, 2018). This study likewise employs ISO 14001 criteria to evaluate supplier selection in hospitals.

ISO 14001 is an internationally accepted standard that defines the requirements for an environmental management system. It helps organizations to develop their environmental performance through using their resources more efficient, reducing waste, gaining a competitive advantage among others and increasing the trust of stakeholders (ISO, 2015-1).

Environmental Management Systems have positive impact on companies. It increases their performance (Moneva and Ortas, 2010). Moreover, it reduces energy consumption and the attention of environmentally sensitive customers arises (Miles and Covin, 2000). Mohd et. al. (2020) showed that "The quality of environmental information disclosures made by ISO 14001 certified companies is different from non ISO 14001 certified companies and ISO 14001 certified companies show higher disclosure quality".

The ISO 14001 Environmental Management System certificate is one of the strongest indicators of the importance given to the environment. In order to obtain ISO 14001 certification, it is necessary to pass an expert evaluation and to have the criteria of this standard. But during expert assessment, the importance of criteria and how well they are satisfied are not displayed. Only the criterion is assessed as “satisfied” or “not satisfied”. For this reason, it is not possible to compare companies’ environmental management performance with other companies.

Despite the ISO 14001 certification, full compliance with the standards requires follow-up and effort. As a result of a study, it was emphasized that senior management influence plays a key role and the importance of management allocating sufficient time, participation and resources (Chowdhurt et al. 2018). Benefits of an increased level of environmental performance in an ems organization include improved regulatory compliance, increased efficiency in the use of energy and materials, and reduced pollution (Sorooshian and Ting, 2018). Quality management systems are frequently utilized frameworks aimed at enhancing the quality and efficiency of healthcare services.

In a green supplier selection problem, suppliers are evaluated based on their environmental performance. Green criteria considered in the literature include environmental regulation compliance, environmental management systems, product recycling, pollution levels, waste generation and treatment, resource consumption, and eco-design (Saputro et al., 2022).
Supplier selection is generally a multi-criteria decision-making (MCDM) problem that relies on the judgmental evaluation of the decision-maker. MCDM methods supports decision makers in the area of taking the best decision in uncertain, complex, and cases where there are conflicting objectives (Ozdemir et al., 2016). One of the most common used MCDM methods is Analytic Hierarchy Process (AHP). AHP shows the importance of each criterion in the case of multiple criteria. Previous studies on Green Supplier Selection (GSS) practices have demonstrated that multi-criteria decision-making (MCDM) approaches are suitable and applicable techniques in this context (Debnath et al., 2023; Gao et al., 2021).

In the literature, various multi-criteria decision-making (MCDM) methods and a wide range of integrated approaches have been applied to evaluate and select green suppliers. MCDM techniques such as TOPSIS, AHP, and Grey Relational Analysis (GRA) have been widely employed in GSS to incorporate decision-makers' uncertainty. Haeri and Rezaei (2019) addressed GSS using fuzzy GRA, while Dos Santos et al. (2019) implemented fuzzy TOPSIS for green supplier evaluation. Yazdani et al. (2017) proposed an integrated analytical approach combining DEMATEL, QFD, and COPRAS to strategically select green suppliers. One study developed a prioritization model for criteria driving green practices in Fars hospitals using DEMATEL-ANP; here, "management" was identified as the most influential and weighted criterion with respective scores of 1.01 and 1.48 (Norouzi et al., 2019). Another study identified the key green supply chain (GSC) factors in healthcare through 60 interviews with nine French hospitals. Critical factors included regulations, cost reduction, top management commitment, employee training, information technology, and environmental performance (Bentahar et al., 2023). Nazari-Shirkouhi and Samadi (2025) evaluated lean, agile, resilient, and green (LARG) paradigms in healthcare supply chains using an integrated methodology involving Pythagorean Fuzzy-DEMATEL (PF-DEMATEL), Interpretive Structural Modeling (ISM), and Bayesian Networks (BN). Benzidia et al. (2021) assessed the impact of big data analytics and artificial intelligence on green supply chain process integration and environmental performance in hospitals. In a study on the benefits and barriers about ISO 14001 with data that collected through research surveys on 83 companies was determined with 11 barrier parameters and 15 benefit parameters of ISO 14001 and as a result of the most barrier average has been "high cost of implementation" and besides, highest benefit has been "improved corporate image" (Alnavis et al., 2021). Lee et al. (2009) has identified six main criteria and 23 sub-criteria for conventional and green production in technology industry and used fuzzy – extended AHP to prioritize these criteria. Afterwards, 3 different companies were compared with each other with the help of these criteria. Guo et al. (2017) has identified 6 main criteria and 10 sub-criteria for the selection of green supplier. In order to prioritize these criteria Fuzzy MCMD (fuzzy AHP) method was implemented.

In this study, ISO 14001:2015 criteria were used as indicators of environmental management performance in green supplier selection. These performance indicators are prioritized by 5 experts to reveal their importance levels. To obtain the importance levels of performance indicators, AHP method, which is one of the most common MCDM method, is used. After obtaining criteria prioritization, PROMETHEE method was used to reveal companies' environmental management performance.

The use of AHP provides decision-makers with flexibility in assigning greater or lesser importance weights to criteria, regardless of the number of criteria in each category. This reduces the influence of the number of criteria on the suppliers' preference weights (Hamdan and Cheaitou, 2017). On the other hand, the DEMATEL approach is considered a pragmatic and promising method, capable of developing and analyzing a structural model that incorporates causal relationships among complex factors—thus transforming a qualitative problem into a more analyzable quantitative one (Wang et al., 2024; Zhu and Wang, 2024). Moreover, it can integrate the knowledge and expertise of various specialists to examine the interrelationships and priority levels of all considered criteria (Zhu et al., 2025). DEMATEL facilitates the creation of a causal relationship diagram by classifying the considered criteria into cause and effect groups (Yazdani et al., 2017). Therefore, the DEMATEL method possesses several features that can enhance the efficiency and effectiveness of the GSS process.

The primary objective of this article is to evaluate the green supply chain performance of four companies operating in the healthcare sector, considering the criteria of ISO 14001:2015, and to develop an integrated approach for selecting the best supplier. This study emphasizes the need for a comprehensive approach to sustainability in the healthcare sector. The main contributions of the study and the motivational factors that guided the execution of this research are as follows;

- To demonstrate which ISO criteria have a greater impact on supplier selection in hospitals. In the context of increasingly limited global resources, to indicate which ISO criteria should be prioritized in order to reduce environmental impacts and develop greener supply chain processes.
- To provide valuable insights into the successful implementation of green practices in hospitals. To inform the strategic planning process by providing knowledge for medical and non-medical staff, as well as external stakeholders, in designing and supporting appropriate green initiatives.
- To assess the level of sustainability after ISO certification. To demonstrate the use of ISO criteria as a tool for green supply chain practices and evaluate the relevant factors.
- To provide scientific knowledge that will assist organizations in developing and implementing supply policies. To offer a guide for industry practitioners

and policymakers in promoting sustainable developments within ISO industries.

- To present a methodology that can be easily adjusted to solve decision-making problems involving any number of alternatives and criteria.

2. METHODOLOGY

2.1. ISO 14001:2015 Environmental Management Systems Standard

Companies are required to minimize their environmental impacts in the course of their operations. ISO 14001 Environmental Management System is one of the clean practices pursued by companies to avoid harmful effects on the environment. ISO 14001 is a set of standards that assist companies in improving and implementing environmental management activities. This standard is the only one recognized and applicable worldwide and can be implemented as a potential component of environmental strategies for companies addressing environmental issues (Eksi et al., 2020). Along with top management support, ISO 14001 facilitates the identification of environmental impacts in advance and the implementation of measures accordingly, creation of environmental awareness through environmental training, and greater preservation of nature with environmental objectives.

The consolidation of environmental management systems under a single roof and their publication as a standard occurred in the near past. BS 7750, which forms the basis of ISO 14001 and is a British standard, was first published in 1992 and was implemented experimentally by 200 British companies (Arbor, 1996). In 1993, the International Organization for Standardization (ISO) and the European Committee for Standardization (CEN) entered into an agreement to develop international environmental performance and environmental management standards (Tepedelen and Ozdemir, 2003). The British Standards Institution has published many international standards on behalf of this partnership. One of these standards is ISO 14001.

The ISO 14001 standard was revised in 2015 to adapt to environmental conditions and changing markets, and organizations holding this document were given a period of 3 years to revise themselves. The elements emphasized in the Environmental Management System with the revised regulations are strategic environmental management, leadership, environmental conservation, environmental performance, life cycle perspective, outsourced processes, communication, and documentation.

The final revised standard in 2015 consist of; 10 main criteria, 26 sub-criteria and 16 sub-sub-criteria. ISO 14001:2015 performance indicators are given Table 1 (ISO, 2015-1);

Table 1. ISO 14001:2015 Performance Indicators

1.	Scope	**7.**	Support
2.	Normative References	**7.1.**	Resources
3.	Terms and Definitions	**7.2.**	Competence
4.	Context of the Organization	**7.3.**	Awareness
4.1.	Understanding of the organization and its context	**7.4.**	Communication
4.2.	Understanding of the needs and expectations of interested parties	**7.5.**	Documented information
4.3.	Determining the scope of the environmental managemant system	**8.**	Operation
4.4.	Environmental management system	**8.1.**	Operational planning and control
5.	Leadership	**8.2.**	Emergency preparedness and response
5.1.	Leadership and commitment	**9.**	Performance Evalution
5.2.	Environmental policy	**9.1.**	Monitoring, measurement, analysis and evalution
5.3.	Organizational roles, responsibilities and authorities	**9.2.**	Internal audit
6.	Planning	**9.3.**	Management
6.1.	Actions to address risks and opportunities	**10.**	Improvement
6.2.	Environmental objectives and planning to achieve them	**10.1**	General
		10.2.	Nonconformity and corrective action
		10.3.	Continual Improvement

The first 3 criteria are explanations and definitions. So, they are not used in this research. Also, sub-sub-criteria are assessed inside of the sub-criteria which means only one level sub-criterion is used.

2.2. Analytical Hierarchy Process

Decision-makers then compare the importance of each element against every other element at the same level of the hierarchy. This is done using a scale that reflects the relative importance or preference. To ensure logical and internally consistent comparisons, AHP includes a consistency check. Thomas L. Saaty (1987), introduced a consistency ratio to assess the reliability of these comparisons. The AHP method calculates weights for each element based on the pairwise comparisons, indicating their relative importance in contributing to the overall decision. Finally, the weights are synthesized to make a decision. AHP provides a structured approach for analyzing complex problems and arriving at a rational decision, particularly beneficial when dealing with subjective judgments, offering a way to quantify and prioritize these judgments.

The steps of the Analytic Hierarchy Process (AHP) are outlined as follows:

- Problem Identification and Information Gathering
- Formation of Decision-Making Hierarchy
- Pairwise Comparison Matrix Establishment
- Criteria Weighed Determination

In order to make comparisons the scale can be used. It shows how essential an element is compared to the other element. The scale used in AHP can be seen in Table 2 (Saaty, 1987).

Table 2. AHP Scale

Significance of Values	Description of Value
1	Both factors carry equal significance
3	Factor 1 holds a marginal advantage over Factor 2
5	Factor 1 outweighs Factor 2 in importance
7	Factor 1 significantly surpasses Factor 2 in importance
9	Factor 1 exhibits unequivocal superiority over Factor 2

The implementation of AHP in mathematical terms begins with the creation of a comparison matrix, as outlined by Yaralıoğlu (2001). This involves defining and specifying the components and elements (criteria) of the problem. The comparison matrix (K) is then formulated based on these identified parts. In the comparison matrix for "n" elements, there are "n x n" entries, and the values along the diagonal (where i = j) are Equation (2.1).

$$K = \begin{bmatrix} k_{11} & k_{12} & \dots & k_{1n} \\ k_{21} & k_{22} & \dots & k_{2n} \\ . & \cdots & \cdots & . \\ . & \cdots & \cdots & . \\ . & \cdots & \cdots & . \\ k_{n1} & k_{n2} & \dots & k_{nn} \end{bmatrix} \quad (2.1)$$

In Equation (2.2), it can be seen that there is a strong relationship between the elements above the diagonal and the elements below the diagonal. Here k_{ji}, is the j of matrix K line i. represents the column.

$$k_{ji} = \frac{1}{k_{ij}} \quad (2.2)$$

As an illustration, when comparing the importance of the third criterion to the second criterion, the element k_{23} is assigned a value of 5, while the element k_{32} is given a value of 1/5.

While this matrix provides insights into the relative significance of each criterion, it does not offer a comprehensive view of the overall weight of each criterion. To obtain this, column vectors (S_i) need to be derived. Each element is divided by the sum of the values in its respective column. Substituting this value yields n column vectors, each representing the weight of a criterion in aggregate.

When estimating the values of the column vector (s_{ij}), equation (2.3) and equation (2.4) are used:

$$s_{ij} = \frac{k_{ij}}{\sum_{i=1}^{n} k_{ij}} \tag{2.3}$$

$$S_i = \begin{bmatrix} s_{11} \\ s_{21} \\ . \\ . \\ . \\ s_{n1} \end{bmatrix} \tag{2.4}$$

In order to constitute column matrix, n column vectors are are created in a matrix. This matrix (S) is as equation (2.5);

$$S = \begin{bmatrix} s_{11} & s_{12} & \cdots & s_{1n} \\ s_{21} & s_{22} & \cdots & s_{2n} \\ . & \dots & \dots & . \\ . & \dots & \dots & . \\ . & \dots & \dots & . \\ s_{n1} & s_{n2} & \cdots & s_{nn} \end{bmatrix} \tag{2.5}$$

Hence, to determine the percentage of the elements using the S matrix, it is necessary to obtain the weight vector (A). This is achieved by calculating the arithmetic mean of the elements (A_i) within each row of the column matrix. Equation (2.6) is used for this.

$$A_i = \frac{\sum_{j=1}^{n} s_{ij}}{n} \tag{2.6}$$

The summation of the elements of the weight vector is 1. The weight vector is seen as equation (2.7);

$$A = \begin{bmatrix} a_1 \\ a_2 \\ . \\ . \\ . \\ a_n \end{bmatrix} \tag{2.7}$$

The assessment of consistency is employed to gauge the conformity following the determination of weight results. This analysis primarily centers on detecting potential errors in the process or ensuring that the obtained results exhibit internal consistency. Subsequently, the next step in the study involves computing the consistency rate, as outlined by Yaralıoğlu (2001).

To calculate the consistency ratio, the initial step involves the multiplication of the comparison matrix and the weight matrix, resulting in the T column vector. Equation (2.8) is used for this.

$$T = \begin{bmatrix} k_{11} & k_{12} & \dots & k_{1n} \\ k_{21} & k_{22} & \dots & k_{2n} \\ . & \dots & \dots & . \\ . & \dots & \dots & . \\ . & \dots & \dots & . \\ k_{n1} & k_{n2} & \dots & k_{nn} \end{bmatrix} x \begin{bmatrix} a_1 \\ a_2 \\ . \\ . \\ . \\ a_n \end{bmatrix} = \begin{bmatrix} t_1 \\ t_2 \\ . \\ . \\ . \\ t_n \end{bmatrix} \tag{2.8}$$

After getting the T vector, basic value elements (E_i) are obtained by dividing each element of the T vector by the weight vector A of the T vector. Equation (2.9) is used for this.

$$E_i = \frac{t_i}{a_i} \quad i = 1,2,\dots,n \tag{2.9}$$

The average of these elements, computed mathematically, provides the fundamental value for the pairwise comparison in this problem. The symbol λ is determined using the equation (2.10).

$$\lambda = \frac{\sum_{i=1}^{n} E_i}{n} \tag{2.10}$$

After acquaring λ, consistent indicator Cl should be collected. CI is calculated as in equation (2.11).

$$CI = \frac{\lambda - n}{n-1} \tag{2.11}$$

The formula below is employed in the final step to calculate the consistency ratio. CR is calculated as in equation (2.12).

$$CR = \frac{CI}{RI} \tag{2.12}$$

In this context, the RI value serves as a benchmark indicator for standard amendments and is referred to as a coincidental (random) indicator. Table 3 is consulted based on the quantity of elements being compared.

Table 3. Coincidental Indicator Values

N	1	2	3	4	5	6	8	9
RI	0.0	0.0	0.6	1.0	1.1	1.2	1.4	1.5

2.3. PROMETHEE Method

PROMETHEE algorithm consists of 7 stages. In the first stage; alternatives, criteria and criteria weights are determined and a data table is created. In PROMETHEE method, criteria weight and criteria values are given as input to the system. Alternatives indicate the options that can be the solution to the problem, the criteria indicate the properties of the alternatives, and the weight of the criteria indicate the degree of importance of each criterion. The PROMETHEE data table is shown in Table 4.

Table 4. PROMETHEE Data Table

Data Table		**Criteria**				**Weights**
		a	b	c	...	W
Alternatives	f_1	$f_1(a)$	$f_1(b)$	$f_1(c)$	...	w_1
	f_2	$f_2(a)$	$f_2(b)$	$f_2(c)$	...	w_2
	…	...	....	....	...	...
	f_k	$f_k(a)$	$f_k(b)$	$f_k(c)$	...	w_k

In the second stage, the preference functions, to be used for the evaluation of the criteria, are determined. There are 6 different preference functions. Preference functions and their parameters are determined by the decision maker based on the type of criteria. Preference functions can be seen in Table 4.

In the third stage, the criteria values of each alternative are compared in duplicate and common preference functions ($P(a,b)$) are created. Common preference functions are done in two ways for all criteria. Where alternatives are a and b, the common preference function is given in equation (2.13).

$$P(a,b) = \begin{cases} 0, & f(a) \leq f(b) \\ p[f(a) - f(b)], & f(a) > f(b) \end{cases} \tag{2.13}$$

In the fourth stage, preference indices ($\pi(a,b)$) are determined by using common preference functions for each alternative pair. At this stage, criterion weights are needed. The number of criteria is indicated by the k value. Preference index function is shown in equation (2.14).

$$\pi(a,b) = \frac{\sum_{i=1}^{k} w_i P_i(a,b)}{\sum_{i=1}^{k} w_i} \tag{2.14}$$

In the fifth stage, positive and negative superiority values are determined for each alternative. Positive superiority ($\emptyset^+$) takes positive value when it is superior to other alternatives. Negative superiority ($\emptyset^-$) takes positive value in case of weakness than other alternatives. These values are calculated and summed for each alternative. The formula for superiority values is given in equation (2.15) and equation (2.16).

$$\emptyset^+ = \sum \pi(a,x)\,, x = (b,c,d\ldots) \tag{2.15}$$

$$\emptyset^- = \sum \pi(x,a)\,, x = (b,c,d\ldots) \tag{2.16}$$

In the sixth stage, the superiority of the alternatives is examined. There are 3 situations at this stage; one alternative is superior to another, one alternative and the other are no different and one alternative cannot be compared with another.

In cases of equations (2.17), (2.18) and (2.19), alternative a is superior to alternative b.

$$\emptyset^+(a) > \emptyset^+(b)\ ve\ \emptyset^-(a) < \emptyset^-(b) \tag{2.17}$$

$$\emptyset^+(a) > \emptyset^+(b)\ ve\ \emptyset^-(a) = \emptyset^-(b) \tag{2.18}$$

$$\emptyset^+(a) = \emptyset^+(b)\ ve\ \emptyset^-(a) < \emptyset^-(b) \tag{2.19}$$

In case of equation (2.20), there is no difference between alternative a and alternative b.

$$\emptyset^+(a) = \emptyset^+(b)\ ve\ \emptyset^-(a) = \emptyset^-(b) \tag{2.20}$$

In cases of equation (2.21) and (2.22), alternative a cannot be compared with alternative b.

$$\emptyset^+(a) > \emptyset^+(b)\ ve\ \emptyset^-(a) > \emptyset^-(b) \tag{2.21}$$

$$\emptyset^+(a) < \emptyset^+(b)\ ve\ \emptyset^-(a) < \emptyset^-(b) \tag{2.22}$$

At the last stage, definite priorities are determined for alternatives and alternatives are ranked according to their index values. The index values of alternatives are obtained by subtracting negative superiority values from positive superiority values, as seen in equation (2.23).

$$\emptyset^+(a) = \emptyset^+(a) - \emptyset^-(a) \tag{2.23}$$

Index values take values from -1 to 1. When sorting, it is sorted from the alternative with high index value to the alternative with low index value.

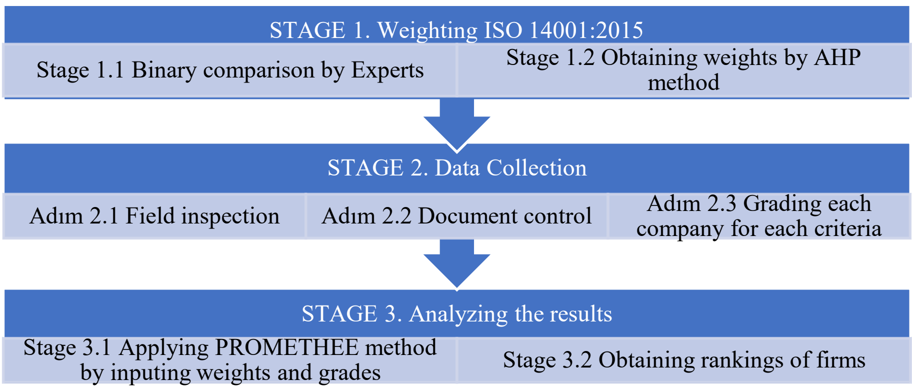
Table 5. PROMETHEE Preference Functions

Type	Parameters	Function
First Type (Usual)	-	$p(x) = \begin{cases} 0, & x \leq 0 \\ 1, & x > 0 \end{cases}$
Second Type (U-Shape)	q	$p(x) = \begin{cases} 0, & x \leq q \\ 1, & x > q \end{cases}$
Third Type (V- Shape)	q	$p(x) = \begin{cases} x/q, & x \leq q \\ 1, & x > q \end{cases}$
Fourth Type (Level)	p, q	$p(x) = \begin{cases} 0, & x \leq q \\ 1/2, & q < x \leq q + p \\ 1, & x > q + p \end{cases}$
Fifth Type (Linear)	p, q	$p(x) = \begin{cases} 0, & x \leq q \\ (x - q)/p, & q < x \leq q + p \\ 1, & x > q + p \end{cases}$
Sixth Type (Gaussian)	σ	$p(x) = \begin{cases} 0, & x \leq 0 \\ 1 - \mathbf{e}^{-x^2/2\sigma^2}, & x > 0 \end{cases}$

3. RESULTS

For the application part, five experts in the field helped this research. First, they filled a survey of binary comparison of each sub-criterion in ISO 14000:2015. Then, these surveys were used to find the weights of each criterion by using AHP method. AHP application was done by using Superdecisions program. SuperDecisions is a free educational decision support software that applies AHP methodologies. The 'SuperDecisions' software is a package for constructing an AHP model for decision-making with dependence and feedback, and for computing results using a pairwise comparison matrix (Adams and Saaty, 2003). It is a frequently used software package in the literature for AHP applications (Cenani and Can, 2025; Malbila et al., 2024; Patil et al., 2024). Afterwards, experts audited 4 companies in the health-care sector in order to understand how good they satisfy each sub-criterion. The audit contained field inspection and documentation control. Each company has already certified with ISO 14001 certificate, so they have already satisfied each criterion. In this audit, each company was graded in the scale of 1 to 5, according to how good they satisfy each sub-criteria (very good, good, normal, limited, very limited) by five experts. As a result, the weights and grades of each sub-criterion were obtained. By using PROMETHEE method, companies were ranked according to their performance. PROMETHEE application was done by using PROMETHEE-GAIA program. The validity of the program's use is well-established in the literature (Brans and Mareschal, 1994; Glavinovic and Luka, 2023; Zorlu and Dede, 2023). The application methodology is presented in Figure 1.

Figure 1. Application Methodology



First, the main and sub-criteria were weighted using the AHP procedure given in section 2.2. Consistency ratio (CR) for 7 main criteria and 22 sub-criteria was found to be 0.07. In this case, results are consistent (<0.01). Ranks and weights of each criterion can be seen in in Table 6. Due to the length of the sub-item names, they are not included in Table 6. They can be accessed from Table 1.

Table 6. Ranks and Weight of Each Criterion

Criteria	Weighting	Ranking	Criteria	Weighting	Ranking
4. Context of the Organization	0.0113	7	**7. Support**	0.0138	6
4.1.	0.0038	13	**7.1.**	0.0018	20
4.2.	0.0047	12	**7.2.**	0.0032	15
4.3.	0.0018	19	**7.3.**	0.0030	17
4.4.	0.0010	22	**7.4.**	0.0032	14
5. Leadership	0.1454	1	**7.5.**	0.0026	18
5.1.	0.0800	1	**8. Operation**	0.0418	3
5.2.	0.0305	5	**8.1.**	0.0334	4
5.3.	0.0349	3	**8.2.**	0.0084	10
6. Planning	0.0569	2	**9. Performance Evaluation**	0.0313	5
6.1.	0.0455	2	**9.1.**	0.0031	16
6.2.	0.0114	8	**9.2.**	0.0104	9
			9.3.	0.0179	7
			10. Improvement	0.0329	4
			10.1.	0.0017	21
			10.2.	0.0079	11
			10.3.	0.0232	6

The degree of compliance of the companies evaluated with criteria can be seen in Table 7. Each company was graded for each criterion, according to how good they satisfy that sub-criterion. Experts used their experience to companies for each criterion. These grades and weights obtained as a result of the AHP procedure of each criterion were inputs of the PROMETHEE model.

Table 7. Grades of each company in each criterion

	4. Context of the Organization				**5. Leadership**		
Criteria	4.1.	4.2.	4.3.	4.4.	5.1.	5.2.	5.3.
Weights	0.0038	0.0047	0.0018	0.0010	0.0800	0.0305	0.0349
Company A	4	4	3	4	4	3	3
Company B	4	4	5	3	3	3	3
Company C	2	2	2	3	4	4	3
Company D	3	3	3	3	3	3	3

	6. Planning		**7. Support**				
Criteria	6.1.	6.2.	7.1.	7.2.	7.3.	7.4.	7.5.
Weights	0.0455	0.0114	0.0018	0.0032	0.0030	0.0032	0.0026
Company A	3	2	2	3	2	2	3
Company B	4	4	2	3	3	2	1
Company C	3	3	3	3	2	3	2
Company D	4	3	3	2	2	3	2

	8. Operation		**9. Performance Evaluation**			**10. Improvement**		
Criteria	8.1.	8.2.	9.1.	9.2.	9.3.	10.1.	10.2.	10.3.
Weights	0.0334	0.0084	0.0031	0.0104	0.0179	0.0017	0.0079	0.0232
Company A	2	2	2	2	2	4	3	4
Company B	2	2	2	2	2	3	2	3
Company C	4	3	4	3	4	4	3	4
Company D	3	2	3	3	3	4	4	3

After obtaining the importance of the criteria, the values given in Table 7 were processed according to the PROMETHEE procedure outlined in section 2.3, and the ranking of each company was obtained. The PROMETHEE scores of the companies can be seen in Table 8.

Table 8. Grades of Each Company in Each Criterion

Rank	**Company**	**PROMETHEE Score**
1	Company C	0.41

2	Company D	-0.07
3	Company B	-0.14
4	Company A	-0.21

4. DISCUSSION

According to research results, the most important criterion in environmental management system is “leadership” and “planning”. The most important sub-criteria were identified as “leadership and commitment” and “actions to address risk and opportunities”. As expected, employers’ concern for environment increases when leaders and managers courage them. When planning works properly and risks and opportunities are identified in a timely manner, appropriate actions are taken to reduce environmental damage. Then it follows “operation”, “improvement”, “performance evaluation”, “support” and “context of the organization”. The findings obtained were found to align with the results of similar studies conducted in Iran and France using different sets of evaluation criteria (Norouzi et al., 2019; Bentahar et al., 2023).

According to the company evaluation results made after criterion weighting, Company C gives the most satisfactory result for ISO 14001 standard criterion. After that Company D, Company B and Company A follows.

CONCLUSION

This research was conducted to find a novel and applicable method in order to measure green suppliers operating in the healtcare sector environmental performance. It conducts what businesses need, for green practices investment in new manufacturing technologies, Environmental Management Systems (EMS) and information technology systems (IT) training processes which will enable their employees to adapt to these innovations.

Green supplier selection is the process of choosing suppliers in supply chains who have low environmental impacts, prioritize social and environmental responsibilities, with the aim of reducing environmental impacts and achieving sustainability goals while continuing the operations of companies and organizations. Green supplier selection not only aims to reduce environmental impacts but also helps companies take responsibility for a more sustainable future economically and socially. Therefore, by collaborating with suppliers who prioritize environmental and social responsibilities, companies not only achieve their sustainability goals but also contribute to creating a better world overall.

Green supply chain management has recently gained importance for organizations and become a significant competitive issue. As environmental awareness increases, customers' demands have also changed in this direction. Therefore, implementing green supply chain management enhances both the efficiency of organizations and their preference rates. It is important for organizations implementing green supply chain management to assess their current status and determine when they will reach the desired level.

To analyze this complex structure, AHP and PROMETHEE methods have been utilized. We used ISO 14001 standard criteria were used to measure environmental performance of the companies. First, we prioritize them by using AHP method and then we graded 4 companies according to how good they satisfy each criterion, by using help from 5 environmental experts. Afterwards, we ranked 4 companies by using weights and grades of each criterion When looking at the results of AHP, the criteria that have been most influential in green supplier selection are the sub-criteria under the main criteria of leadership and planning. Therefore, businesses prefer to work with suppliers who meet these criteria in order to maintain their profitability ratios. The opinions obtained from five experts in the field also confirm this idea. Many companies have ISO 14001 certificate; however, it is unclear to select the best supplier in terms of green production.

The high costs of innovations required for green practices in suppliers. The thought will cause problems and it will take a long time to adapt to new applications. It may cause them to act reluctantly about green supply chain practices. Training and financing are necessary for businesses to transition of green practices for their suppliers to provide their support which will encourage suppliers to switch to green practices.

This study provides quantitative information on the successful implementation of green practices in hospitals. It has laid the foundation for the development of strategic plans by medical and non-medical staff, as well as external stakeholders, in designing and supporting appropriate green initiatives. One of the most important aspects of this study is the weighting of ISO 14001:2015 criteria by the healthcare organizations participating in the research, and the evaluation of these organizations based on the weighted criteria. Another significant point is that with this study, the healthcare sector can identify its shortcomings in green procurement and address them. It is evident that companies that consider the importance weights of ISO criteria in the study will gain benefits in terms of quality, cost, and delivery, as well as environmental benefits for both themselves and the world.

Recommendations for future studies:

- This study can be conducted in different industries outside the healthcare sector. Particularly, when applied in sectors engaged in manufacturing activities, it is believed that very successful results can be achieved.
- Deficiencies observed in the healthcare sector can be addressed by companies based on the ISO 14001:2015 criteria included in the study.
- The number of companies can be increased, allowing for a broader examination of the healthcare sector.
- The number of criteria can be increased, and other multi-criteria decision-making methods can be used.

ISO 14001:2015 KRİTERLERİNİ KULLANARAK YEŞİL TEDARİKÇİ SEÇİMİ

1. GİRİŞ

ISO 14001 Çevre Yönetim Sistemi sertifikası, çevre yönetim sistemleri için gereklilikleri tanımlayan uluslararası kabul görmüş bir standarttır. Çevreye verilen önemin en güçlü göstergelerinden biridir. Kuruluşların kaynaklarını daha verimli kullanması ve atıklarını azaltması ile diğer kuruluşlara karşı rekabet avantajı elde etmesine ve paydaşların güvenini artırarak çevresel performanslarını geliştirmesine yardımcı olur (ISO, 2015-1). Son yıllarda, dünyada yeşil üretim eğilimi oldukça yaygın görünüyor.

ISO 14001 sertifikası almak için uzman değerlendirmesinden geçmek ve bu standardın kriterlerine sahip olmak gerekir. Ancak uzman değerlendirmesi sırasında kriterlerin önemi ve ne kadar karşılandığı gösterilmez. Sadece kriter "karşılandı" veya "karşılanmadı" olarak değerlendirilir. Bu nedenle şirketlerin çevre yönetimi performansını diğer şirketlerle karşılaştırmak mümkün değildir.

Çevre yönetim sisteminin başarısının üst yönetimin liderliğine ve kuruluşun tüm seviye ve işlevlerindeki emirlere bağlıdır (ISO, 2015-2). ISO 14001, standartlara tam uyum, takip ve çaba gerektirir. Yapılan bir araştırmada, üst düzey yönetim etkisinin önemli bir rol oynadığı ve yönetimin yeterli zaman, katılım ve kaynak ayırmasının önemi vurgulanmıştır (Chowdhurt vd. 2018).

2. YÖNTEM

Çalışmanın amacı sağlık sektöründe faaliyet gösteren 4 şirketin yeşil tedarik performanslarını değerlendirmektir. Ayrıca bu çalışma ile farklı sektörlerde ve farklı kalite göstergeleri ile değerlendirme yapacak çalışmalar için bir metodoloji sunulmuştur. Bu çalışmada çevre yönetimi performansının göstergesi olarak ISO 14001:2015 kriterleri kullanılmıştır. Bu performans göstergeleri 5 uzman tarafından önceliklendirilerek önem düzeyleri ortaya konulmuştur. Performans göstergelerinin önem düzeyleri elde etmek için en yaygın MCDM yöntemlerinden biri olan AHP yöntemi kullanılmıştır. Kriter önceliklendirmesi elde edildikten sonra şirketlerin çevre yönetimi performansı PROMETHEE yöntemi ile ortaya konulmuştur. AHP uygulaması Superdecisions programı, PROMETHEE uygulaması ise PROMETHEE-GAIA programı kullanılarak yapılmıştır.

“Bu çalışma Araştırma ve Yayın Etiğine uygun olarak hazırlanmıştır.”

3. BULGULAR

Alanında uzman 5 araştırmacı, ISO 14000:2015'teki her alt kriterin ikili karşılaştırmasını içeren bir anket doldurmuşlardır. AHP yöntemi kullanılarak her kriterin ağırlıkları bulunmuştur. Ayrıca uzmanlar sağlık sektöründe faaliyet gösteren

4 şirketi denetleyerek her bir alt kriteri ne kadar iyi karşıladıklarını anlamaya değerlendirmiştir.

Öncelikle, ana ve alt kriterler, 2.2. bölümde verilen AHP prosedürü kullanılarak ağırlıklandırıldı. 7 ana kriter ve 22 alt kriter için tutarlılık oranı (CR) 0,07 olarak bulundu. Her kriterin sıralaması ve ağırlıkları Tablo 6'da görülebilir.

Kriterlere göre değerlendirilen şirketlerin uyum derecesi Tablo 7'de görülebilir. Her şirket, ilgili alt kriteri ne kadar iyi karşıladıklarına göre her kriter için derecelendirildi. Her kriterin AHP prosedürü sonucunda elde edilen bu dereceler ve ağırlıklar, PROMETHEE modelinin girdileriydi.

Kriterlerin önemi elde edildikten sonra, Tablo 7'de verilen değerler, 2.3. bölümde özetlenen PROMETHEE prosedürüne göre işlendi ve her şirketin sıralaması elde edildi. Şirketlerin PROMETHEE puanları Tablo 8'de görülmektedir.

4. TARTIŞMA

Araştırma sonuçlarına göre çevre yönetim sisteminde en önemli kriter "liderlik" ve "planlama"dır. En önemli alt kriterler ise "liderlik ve bağlılık" ve "risk ve fırsatları ele almak için eylemler" olarak belirlenmiştir. Beklendiği üzere, liderler ve yöneticiler onları cesaretlendirdiğinde işverenlerin çevreye olan ilgisi artmaktadır. Planlama düzgün çalıştığında ve riskler ve fırsatlar zamanında belirlendiğinde, çevresel hasarı azaltmak için uygun eylemler gerçekleştirilir. Daha sonra "işletme", "iyileştirme", "performans değerlendirmesi", "destek" ve "kuruluşun bağlamı" gelir.

Kriter ağırlıklandırması sonrasında yapılan şirket değerlendirme sonuçlarına göre, Şirket C, ISO 14001 standardı kriteri için en tatmin edici sonucu vermektedir. Bunu Şirket D, Şirket B ve Şirket A takip etmektedir.

SONUÇ

Bu araştırma, sağlık sektöründe faaliyet gösteren yeşil tedarikçilerin çevresel performansını ölçmek için yeni ve uygulanabilir bir yöntem bulmak amacıyla yürütülmüştür. Yeşil tedarikçi seçimi, tedarik zincirlerinde düşük çevresel etkilere sahip, sosyal ve çevresel sorumlulukları önceliklendiren, çevresel etkileri azaltma ve sürdürülebilirlik hedeflerine ulaşma amacıyla şirketlerin ve kuruluşların faaliyetlerini sürdürme sürecidir. Yeşil tedarikçi seçimi yalnızca çevresel etkileri azaltmayı değil, aynı zamanda şirketlerin ekonomik ve sosyal olarak daha sürdürülebilir bir gelecek için sorumluluk almalarına yardımcı olur. Bu nedenle, çevresel ve sosyal sorumlulukları önceliklendiren tedarikçilerle iş birliği yaparak, şirketler yalnızca sürdürülebilirlik hedeflerine ulaşmakla kalmaz, aynı zamanda genel olarak daha iyi bir dünya yaratmaya da katkıda bulunurlar.

Çevresel farkındalık arttıkça, müşterilerin talepleri de bu yönde değişmiştir. Bu nedenle, yeşil tedarik zinciri yönetiminin uygulanması hem kuruluşların verimliliğini

hem de tercih oranlarını artırmaktadır. Yeşil tedarik zinciri yönetimi uygulayan kuruluşlar için mevcut durumlarını değerlendirmek ve istenilen seviyeye ne zaman ulaşacaklarını belirlemek önemlidir.
Birçok şirketin ISO 14001 sertifikası bulunmaktadır; ancak yeşil üretim açısından en iyi tedarikçiyi seçmek belirsizdir.

Bu çalışma ile hastanelerde yeşil uygulamaların başarılı bir şekilde uygulanmasına ilişkin nicel bilgiler sunulmuştur. Uygun yeşil girişim tasarlama ve desteklemede tıbbi ve tıbbi olmayan personelin, dış paydaşların stratejik planları oluşturulmasına bir zemin sağlanmıştır. Çalışmanın en önemli yönlerinden biri, araştırmaya katılan sağlık kuruluşları tarafından ISO 14001:2015 kriterlerinin ağırlıklandırılması ve bu kuruluşların ağırlıklandırılmış kriterlere göre değerlendirilmesidir. Bir diğer önemli nokta ise, bu çalışma ile sağlık sektörünün yeşil tedarik konusundaki eksikliklerini belirleyip bunları giderebilmesidir. Çalışmada ISO kriterlerinin önem ağırlıklarını dikkate alan şirketlerin, hem kendileri hem de dünya için kalite, maliyet ve teslimat açısından faydalar elde edecekleri ve çevresel faydalar elde edecekleri açıktır.

Gelecekteki çalışmalar için öneriler:
• Bu çalışma sağlık sektörü dışındaki farklı endüstrilerde de yapılabilir. Özellikle üretim faaliyetlerinde bulunan sektörlerde uygulandığında çok başarılı sonuçlar elde edilebileceği düşünülmektedir.
• Sağlık sektöründe gözlemlenen eksiklikler, çalışmada yer alan ISO 14001:2015 kriterlerine göre şirketler tarafından giderilebilir.
• Şirket sayısı artırılarak sağlık sektörünün daha geniş bir şekilde incelenmesi sağlanabilir.
• Kriter sayısı artırılabilir ve diğer çok kriterli karar verme yöntemleri kullanılabilir.

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