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Green Supplier Selection with Integrated Multi-Criteria Decision Making Techniques

Bütünleşik Çok Kriterli Karar Verme Teknikleri ile Yeşil Tedarikçi Seçimi

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ABSTRACT

The concept of Green Supply Chain Management (GSCM), whose importance has increased in recent years, is considered as a supply chain that prioritizes environmental impacts in all its activities. Nowadays, businesses are considered not only in terms of their economic performance, but also in terms of their environmental performance which makes GSCM important. However, GSCM cannot be conducted without the participation of the suppliers. Due to this fact, correct determination of their suppliers has vital importance in developing a better GSCM performance. While there is a plenty of research in many sectors in GSCM literature, the research in the paint subfield of the chemical sector, which has a great environmental impact, is limited. It is seen that Multi-Criteria Decision Making (MCDM) techniques are frequently used in supplier selection studies, however, there are few studies where the results of different approaches are compared and integrated. In this research, green supplier selection is conducted using different MCDM technics, and the results are compared and combined. In the study, green supplier selection was carried out in the paint sub-branch of the chemical industry with the MOORA-Ratio Method, MOORA-Reference Point Approach, GRA and COPRAS methods, each of which is integrated with the ANP Then, the COPELAND method was used to obtain a general ranking. This research contributes to the literature by proposing a unique model in terms of the applied sector and integrating MCDM method results. The model proposed in this study can help the decision makers in order to build a green supplier selection model.

Keywords: Green Supplier Chain Management (GSCM), MCDM, COPELAND.
Jel Classification: M110.

ÖZ

Önemi son yıllarda daha da artan Yeşil Tedarik Zinciri Yönetimi (YTZY) kavramı, tüm faaliyetlerinde çevresel etkileri ön planda tutan bir tedarik zinciri olarak ele alınmaktadır. Günümüzde işletmeler sadece ekonomik performansları açısından değil aynı zamanda YTZY'yi önemli kılan çevresel performansları açısından da dikkate alınmaktadır. Ancak YTZY, tedarikçilerin katılımı olmadan gerçekleştirilemez. Bu nedenle tedarikçilerinin doğru belirlenmesi, daha iyi bir YTZY performansının geliştirilmesinde hayati önem taşımaktadır. YTZY literatüründe birçok sektörde çok sayıda araştırma bulunurken, çevreye etkisi büyük olan kimya sektörünün boya alt alanındaki araştırmalar sınırlıdır. Tedarikçi seçimi çalışmalarında Çok Kriterli Karar Verme (ÇKKV) tekniklerinin sıklıkla kullanıldığı, ancak farklı yaklaşımların sonuçlarının karşılaştırıldığı ve bütünleştirildiği az sayıda çalışma olduğu görülmektedir. Bu araştırmada, farklı ÇKKV teknikleri kullanılarak yeşil tedarikçi seçimi yapılmakta ve sonuçlar karşılaştırılarak bir araya getirilmektedir. Çalışmada, her biri ANP ile entegre olan MOORA-Oran Yöntemi, MOORA-Referans Noktası Yaklaşımı, GRA ve COPRAS yöntemleri ile kimya endüstrisinin boya alt dalında yeşil tedarikçi seçimi gerçekleştirilmiştir. Daha sonra genel bir sıralama elde etmek için COPELAND yöntemi kullanılmıştır. Bu çalışma uygulanan sektör açısından özgün bir model önermekte ve ÇKKV yöntem sonuçlarını entegre ederek literatüre katkı sağlamaktadır. Çalışmada öne sürülen model, yeşil tedarikçi seçim modelinin oluşturulmasında karar vericilere yardımcı olabilir.

Anahtar Kelimeler: Yeşil Tedarik Zinciri Yönetimi (YTZY), ÇKKV, COPELAND.
Jel Sınıflaması: M110.

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1. Introduction

The concept of supply chain (SC) began to develop as of the 1980s. Supply management (SM) activities are also an important part of supply chain (Cristea and Cristea, 2017:1). SM is defined as a strategic approach to plan and provide the current and future needs of an institution by effectively managing supply base and using a process management together with cross functional teams in order to achieve the organizational mission (Cavinato et al., 2006). Supply chain management (SCM), on the other hand, is a series of approaches that ensure the production of products and their distribution in the correct amount, to the right place, at the correct time by efficiently integrating the suppliers, producers, depots and retailers in order to satisfy customer needs and to minimize the costs within the system (Simchi and Levi, 2004: 2). While there exist many elements in SM activities, supplier selection that involves a series of activities such as identifying, analyzing and selecting the suppliers in order for them to be a layer of SC has an important place in SM.

As supplier selection is based on many criteria, it is not an easy task to select the supplier. Supplier selection includes an extensive comparison of suppliers by using a series of common criteria and measures. Two issues are particularly important in selecting the best supplier or supplier group: which criteria to use, and which method to use in order to compare the suppliers (Alkahtani and Kaid, 2018: 108). Supplier selection used to be considered from an economic point of view. However, in the last twenty years, organizations have been more concerned about environmental protection. In this context, new concepts related to SC have emerged. Environmental problems and related environmental regulations have put businesses under a great pressure in terms of SC practices. At that point where environmental concerns have combined with SCM practices, the concept of green supply chain management (GSCM) has emerged (Gupta, 2019: 663).

GSCM is a construct that requires a successful coordination, integration and management in the face of the members in the supply chain that involves raw material suppliers, producers, distributors, users and recyclers (Tuzkaya et al., 2009: 478). In GSCM practices, green suppliers focus on green production design, green packaging, resource recycling, and continuous green innovation (Wu et al., 2019: 395). Accordingly, green supplier selection has transformed supplier performance into a structure that can be monitored through environmental standards (Mousakhani et al., 2017: 205). Green supplier selection is an important steppingstone in the transition to the design and management of environmentally conscious supply chains. It plays a significant role in sustaining strategic competition (Haeri and Rezaei, 2019: 768) and encouraging corporate development in businesses (Banaeian et al., 2018: 345).

While the criteria used in supplier selection were cost-oriented in the early 1980s, they were considered to be cycling time and the period of recycling back to the customer in the 1990s and afterwards (Kılıç and Yalçın, 2019: 1066). When the most recent literature is considered, various traditional criteria for supplier selection are seen. Among these, the criteria of cost, quality, delivery, flexibility, technological competence, innovation and finance are frequently used (Weber et al., 1991; Yang and Wu, 2007; Chiou et al., 2008; Lee et al., 2009; Ho et al., 2010; Büyüközkan and Çifçi, 2012; Hashemi et al., 2015; Watrobski and Salabun, 2016; Kumar et al., 2017). In addition to the traditional criteria mentioned above, environmental criteria have started to be included in supplier selection processes in recent years. The most frequently used green criteria in supplier selection can be listed as environmental management system, pollution control, green image, green innovation, eco-design, green skills, environmental performance and green product criteria (Tuzkaya et al., 2009; Lee et al., 2009; Tseng, 2011; Hashemi et al., 2015; Govindan et al., 2015; Watrobski and Salabun, 2016).

Identifying the method to be used in supplier selection is as important as identifying the criteria to be used. Determining the decision support management to be created through appropriate methods is

one of the most important steps in supplier selection (Büyüközkan et al., 2011). The methods used in supplier selection with MCDM techniques can be categorized as individual approaches and integrated approaches (Yadav and Sharma, 2014: 220). The most common individual approaches can be listed as Analytic Hierarchy Process (AHP) (Torabi and Boostani 2018), Analytic Network Process (ANP) (Gencer and Gürpınar, 2007), Vise Kriterijumska Optimizacija I Kompromisno Resenje (VIKOR) (Kaya and Kahraman, 2010; Girubha and Vinodh, 2012), Elimination and Choice Translating Reality (ELECTRE) (Girubha and Vinodh, 2012; Peng et al., 2015), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) (Boran et al., 2009; Kamalakannan et al., 2020), Data Envelopment Analysis (DEA) (Dotoli and Falagario, 2012). Commonly used integrated approaches can be listed as AHP-TOPSIS (Taylan et al., 2014), AHP-ANP (Eshtehardian et al., 2013), AHP-DEA (Sevkli et al., 2007) In the literature, there are also some individual and integrated approaches in green supplier selection. These approaches can be listed as The Decision Making Trial and Evaluation Laboratory (DEMATEL) (Hsu et al., 2013), AHP (Kannan et al., 2008; Hruska et al., 2014), ANP (Hashemi et al., 2015), DEMATEL, ANP ve TOPSIS (Büyüközkan and Çifçi 2012), DEA and ANP (Kuo et al., 2010), Artificial Neural Network (ANN) and Fuzzy Analytic Hierarchy Process (FAHP) (Lee et al., 2009), AHP-Entropi-TOPSIS (Freeman and Chen, 2015).

When the studies conducted in the literature are evaluated, it is seen that there are studies related to supplier selection in almost all industries. One of these industries is the chemical industry. There are studies regarding the pharmaceutical industry when the literature related to supplier selection in the chemical industry is considered (Mehralian et al., 2011; Pourghahreman and Qhatari, 2015; Badi and Ballem, 2018;). Research consists in other industries as well, such as; cosmetics industry (Tektaş and Aytekin, 2011), paint industry (Azadi, 2015; Alizadeh and Yousefi, 2019) and chemical material production (Swift, 1995; Pitchipoo et al., 2012). Some studies in the literature suggest that supplier selection studies can be conducted in the different industries where the number of research is limited and chemical industry is one of them (Chiou, 2008; Theiben and Spinler, 2014; Chand et al., 2016; Chan et al., 2018). Especially in the field of the paint industry, there is a gap in terms of supplier selection. Besides, when the literature was examined, it was seen that there was no integrated study which was weighted with ANP and in which selection was made with MOORA-Ratio Method, MOORA-Reference Point Approach, Grey Relational Analysis (GRA) and Complex Proportional Assessment (COPRAS) method, and the results were combined with COPELAND method. There are very few supplier selection studies in the literature in which the results were combined with COPELAND method.

In the study, the basic questions to which answers were sought were: What are the most important criteria that can be used in supplier selection in the industrial paint sector of the chemical industry? What criteria can effectively evaluate green suppliers? How are the suppliers ranked by using hybrid methods? How different will the integrated result that will be obtained be in comparison to the other results? Within the framework of these gaps in the literature and the research questions, the purpose of the study was to make the most appropriate green supplier selection among the raw material suppliers in the field of industrial paints in line with the business policies by using six different methods for external purchase based on the determined criteria.

2. Literature Review

In recent years, increased environmental problems have drawn the attention of the whole world. In the face of these problems, governments are looking for solutions to these problems by means of laws and regulations, while businesses are trying to make a more environmentally sensitive production. In the scientific field, there are ongoing studies to find a solution to these problems. Particularly green supplier selection has been one of the topics studied by researchers in recent years. The studies conducted in this field in the literature can be summarized as follows.

In most of the studies, applications were implemented by creating MCDM models through green criteria. AHP and ANP are widely used in MCDM studies regarding green supplier selection. Handfield (2002) recommended the managers to use a decision support system that will help AHP to understand the balance between environmental dimensions and examined how AHP can be incorporated into a comprehensive information system that supports environmentally sensitive purchase. For instance, Hsu and Hu (2007) applied ANP method to supplier selection in an electronics company in order to determine the criteria for the competence of hazardous material management. For example, Chiou et al. (2008) aimed to solve green supplier selection problem of the American, Japanese and Taiwanese electronic industries in China. In his study, Lee (2009) suggested a model with fuzzy AHP method for the evaluation of green suppliers. They used fuzzy AHP method to designate different weights to various criteria in electronics industry. Lee at al. (2012) evaluated the most important factors in supplier selection in GSC in the economy of Taiwan economy through fuzzy AHP method. Grisi (2009) carried out a supplier performance analysis through AHP method by considering traditional and environmental factors. Çetin and Önder (2015) added environmental criteria in the supplier selection process of a manufacturing company operating in automotive sector. Yu and Hou (2016), on the other hand, analysed green supplier selection problem with AHP method in order to meet the needs of an automotive company consistently. In the literature, some studies were carried out with fuzzy AHP method.

When the studies are examined, it is seen that AHP and ANP methods are used not only individually but also in an integrated way. For example, Wen and Chi (2010) transformed a model integrated with AHP and DEA methods into a practical framework by handling a criteria cluster that involved environmental and traditional criteria for supplier selection problem. Thongchattu and Siripokapirom (2010) contributed to green supplier selection model by weighting company reliability, material quality, material price, environmental project and environmental management system criteria through AHP and ANN. In the study conducted by Jakhar (2014), partner selection and flow allocation decision making model in apparel industry was proposed. In the model, ANN, AHP, and MOLP methods were applied in an integrated way. In the study carried out by Freeman and Chan (2015), it was aimed to develop a green supplier selection model with traditional and environmental supplier selection criteria in Chinese electronics industry. Through AHP and TOPSIS methods, suppliers were ranked. As for the integrated studies with ANP, Kuo and Lin (2012) made a supplier selection that considered green criteria based on environmental protection issues with DEA and ANP methods. Büyüközkan and Çifçi (2012) examined GSCM and GSCM skill dimensions in order to propose an evaluation framework for green suppliers. They created a hybrid model integrated with fuzzy TOPSIS, fuzzy ANP and fuzzy DEMATEL approaches. Govindan et al. (2015) aimed to select the best green production practices based on dimensions and relevant criteria through DEMATEL method on the basis of ANP in the plastics industry in India.

It is also possible to encounter studies in the literature conducted by using different MCDM methods. Fuzzy logic can be counted as one these methods. For example, Humphreys et al. (2006) added environmental criteria to current supplier selection process and applied the model on individual businesses with fuzzy logic system. Yang and Wu (2008) made green supplier selection in an electrical device production business with multilevel extensible synthetic evaluation model based on entropy weight. Chen et al. (2010) aimed to present linguistic preferences to GSCM criteria with missing information in a business that produces electrical appliances. The study focused on developing quantitative evaluations in uncertainty by using fuzzy clustering theory. Mousakhani et al. (2017) suggested a new direction for green supplier selection problems under a new group decision making approach and interval type-2 fuzzy (IT2F) information. Fuzzy Sets theory is not only integrated with AHP and ANP, it is also integrated with several methods. Bali et al. (2013) suggested an MCDM approach integrated with IFS and GRA methods for green supplier selection. In the study conducted by Zhao and Guo (2014), fuzzy entropy-TOPSIS method was used in order to select the best green supplier in Chinese

electrical energy industry. Öztürk and Özçelik (2014) carried out their study in the field of sustainability in energy sector. In the study, they applied fuzzy TOPSIS method for the selection of the best supplier based on sustainability principles for supplier selection operations in supply chain. Kumar et al. (2017) evaluated the performances of suppliers who based on green practices by using fuzzy ELECTRE method in terms of environmental management, pollution control, cost, quality and flexibility. Görener et al. (2017) evaluated the supplier performance in the aviation industry with the hybrid methods of IT2F-AHP and IT2F-TOPSIS.

DEA and GRA are also used in sustainable supplier selection. For instance, Shi et al. (2015) developed a systematic DEA approach to select suppliers in the framework of sustainable supply chain and applied it to an industrial business. Azadi et al. (2015) developed an advanced Russell criterion of DEA in order to select the best sustainable suppliers in the fuzzy context in the field of resin production. Baskaran et al. (2012) evaluated 63 suppliers in textile and apparel industry in India with GRA method within the framework of sustainability criteria. Quan et al. (2018) made the evaluation and selection of green supplier in a chemical processing industry by using weighted GRA model.

When the literature is reviewed, it is observed that various MCDM methods are used in an integrated manner. For example, Kuo et al. (2010) aimed to develop green supplier selection model of a camera manufacturer with ANN and MADA integrated methods. In the study conducted by Sahu (2012), it was aimed to apply decision support tools in supplier selection. In the study, it was suggested to use grey numbers in order to solve the priority weights of subjective performance criteria. Applying grey technique to order preference according to the similarity of TOPSIS and COPRAS-G method solved the supplier selection problem.

In the literature, there are some methods that consider green criteria in supplier selection and evaluate these criteria without using MCDM methods. For instance, Min and Galle (1997) applied a questionnaire to businesses which give out heavy scrap and waste material and revealed that the frequency of green purchase practices, the awareness of these practices, and environmental factors were effective in supplier selection decisions. In the survey study they conducted, Varnas et al. (2009) dealt with supplier selection in the service sector. In their study, Bin and Hong-Jun (2010) emphasized that businesses with limited resources and environmental conditions hazardous to human health should improve themselves in terms of the environment in order to increase their competitive power. In the study, a factor analysis was performed, and main factors for green supplier evaluation were identified. Yeh and Chuang (2011) aimed to develop the most appropriate mathematical model for green supplier selection with the criteria of cost, time, product quality, and green evaluation. In their study, Chiou (2011) aimed to improve environmental performances of businesses, encourage green innovation with GSC, and fill the gap by increasing their competitive edge in the global market. In a study conducted by Lee (2015), the structural and relational dimensions of the social capital of a supplier and environmental and operational performance dimensions of a supplier were determined by using factor analysis.

3. Integrated Supplier Selection with Hybrid Methods

Within the framework of the gaps in the literature and the research questions, the purpose of the study was to make the most appropriate green supplier selection among the raw material suppliers in the field of industrial paints in line with the business policies by using six different methods based on the determined criteria.

3.1. Sample of the Study

The study was carried out in the factory which was active in the field of production of industrial paints. Sintaş Paint continues its activities with a wide range of products produced with 100% domestic resources both in domestic and foreign markets. While the most part of the company's production is automobile paint, more than 10 types of paints are produced.

4. Method

The purpose of the study was to make the most appropriate green supplier selection among the raw material suppliers in the field of industrial paints in line with the business polices based on the determined criteria. In line with this purpose, as different results were obtained through different MCDM methods, a method that integrated all these results was also used. In this context, the method of the study is to obtain a hybrid study with MCDM methods ANP, MOORA-Ratio Method, MOORA-Reference Point Approach, GRA and COPRAS methods. The determined methods in the study were brought together and integrated into a new hybrid MCDM model.

4.1. MCDM Methods

4.1.1. ANP Method: ANP method was developed by Thomas L. Saaty and is the generalized form of AHP. Saaty brought ANP, which included AHP, to the literature by using network structure in the model different from AHP. ANP is an approach that takes into consideration the dependencies of the factors in the decision problem on each other. Effect, dependency and feedback are at the focus of ANP. ANP method reveals the problems, relationships between components, and their directions and represents them in the form of a network. Due to this structure, indirect interactions and feedback that may form between main and intermediate structures are calculated (Özdemir et al., 2016: 211). With its framework, ANP is a more flexible decision-making algorithm than AHP. ANP does not require a hierarchical assumption. The network model provides a considerable validity for this algorithm. The steps of ANP method are listed as (Saaty, 2009: 31; Öztürk et al., 2018: 1191-1192):

1. Step: Identifying the Problem and Forming the Decision Model
2. Step: Identifying Dependencies
3. Step: Calculating Priority Vectors
4. Step: Creating the Supermatrix
5. Step: Creating the Limit Supermatrix

4.1.2. MOORA-Ratio Method: This method deals with a matrix that involves m number alternatives and n number criteria. By dividing the square root of the sum of the squares of each alternative by the criteria, normalization is checked. Then, these criteria are determined according to their being maximum and minimum within the framework of the criteria and summed up. The value of the summed up minimum criteria is subtracted from the total criteria value obtained. The results obtained are listed in a descending order, and the process is completed (Brauers and Zavadskas, 2012: 13). MOORA-Ratio method consists of the application steps given below (Brauers and Zavadskas, 2012; Brauers et al., 2015):

1. Step: Creation of the Beginning Matrix
2. Step: Normalization of the Matrix
3. Step: Computing Performance Values
4. Step: Choosing the Most Suitable Alternative

4.1.3. MOORA-Reference Point Approach: In this approach, different from the ratio method, if the purpose of the problem is benefit-oriented, reference points which are maximum points are determined for each criterion and if the purpose is cost-oriented, minimum points are determined as reference points. The distances of these identified points to normalized values are determined. This process is realized by subtracting normalized values from reference points. MOORA-Reference point approach consists of the application steps given below (Brauers et al., 2015):

1. Step: Creation of the Beginning Matrix
2. Step: Normalization of the Matrix
3. Step: Computing Performance Values
4. Step: Choosing the Most Suitable Alternative

4.1.4. COPRAS Method: The method was developed by Zavadskas and Kaklauskas in 1996. COPRAS method can be used for maximum and minimum values in multicriteria evaluation. COPRAS method, which means to complex proportional assessment, can be easily applied to problems with complex criteria and host many alternatives (Sarıçalı and Kundakçı, 2016: 50). Criteria values are used in criteria assessment to maximize benefit-oriented criterion and minimize cost-oriented criteria (Podvezko, 2011: 137). The steps of COPRAS method are listed as follows (Podvezko, 2011: 138-139; Özdağoğlu, 2013b: 235-236):

1. Step: Creation of Decision Matrix
2. Step: Normalizing the Decision Matrix
3. Step: Weighting of the Decision Matrix
4. Step: Calculating Benefit and Cost Criteria
5. Step: Calculating the Relative Importance of the Alternatives
6. Step: Identifying the Benefit Degree of the Alternatives
7. Step: Calculating Performance Index P_I Values for the Alternatives

4.1.5. GRA Method: The method is generally used to exactly reveal the relationships of all situations in some work fields that can emerge in a system (Huang and Lee, 2003: 74). With GRA, simple and comprehensible analyses based on the data that can be accessed in their original form can be performed. This method is among the methods used to enable managers who need to make a decision by evaluating more than one criteria in markets where there is too much competition to make decisions in the most appropriate way. (Wu, 2002: 211). The steps of GRA method are as follows (Wu, 2002: 211; Yıldırım and Önder, 2015: 236; Özbek, 2019: 157):

1. Step: Preparing the Data Set and Creating the Decision Matrix
2. Step: Creating the Reference Series and Comparison Matrix
3. Step: Normalizing the Decision Matrix
4. Step: Creating the Absolute Value Matrix
5. Step: Creating the Grey Relational Coefficient Matrix
6. Step: Calculating Grey Relational Degrees

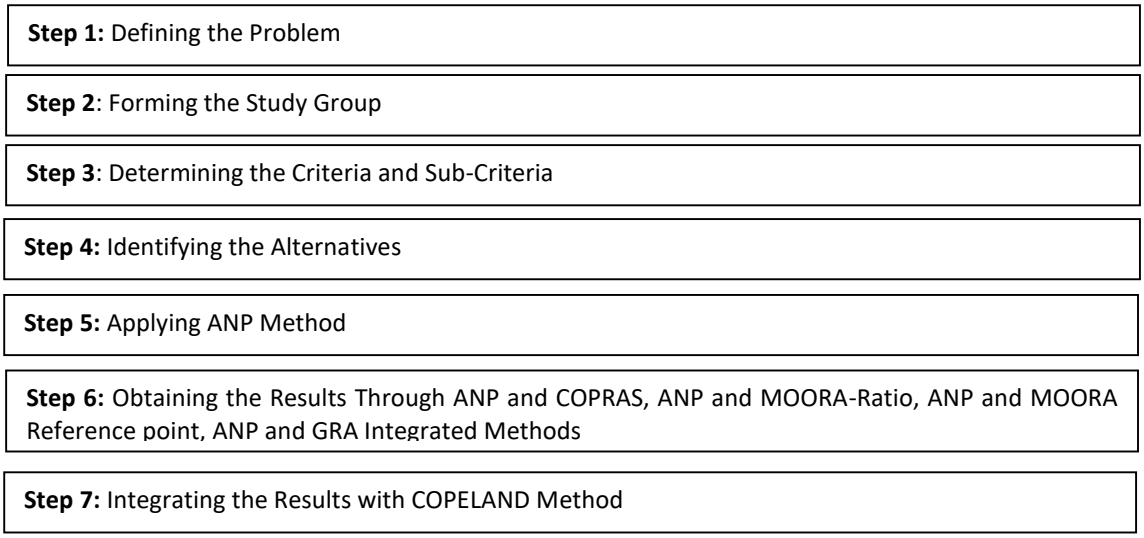
4.1.6. COPELAND Method: COPELAND method, developed by Arrow in 1951, is a technique recognized among alternatives in terms of preference. In COPELAND method, selection is made considering the number of the alternatives worse than themselves and the number of alternatives better than themselves before each alternative is connected to several connections (Caillaux et al., 2011: 357). COPELAND consists of application steps given below (Saari and Merlin, 1996: 5; Çakır, 2017: 48):

1. Step: Making Pairwise Comparisons
2. Step: Calculating Comparison Scores
3. Step: Finding out the Winners
4. Step: Calculating the Winning and Losing Scores
5. Step: Calculating COPELAND Scores

5. Analysis and Findings

In order to demonstrate the suggested method and calculations, four suppliers used in green supplier selection are assessed and ranked. The workflow plan used in the study is presented in Figure 1 below.

Figure 1: Workflow Plan



6.1. Identifying the Problem:

The most commonly used 50 criteria used in the literature and determined within the scope of the literature review were evaluated, first interview was held with the business, and the criteria were presented to the expert team. 50 criteria were score by the expert team between 1 and 10. The arithmetic mean of the criteria scored was taken. 26 criteria which were above the mean score constituted the basic criteria of the study. These criteria obtained were distributed among themselves under five main criteria, and the study problem and the model of the study were formed.

6.2. Forming the Study Group:

Following the interviews with the business, the study group was formed. The study group consisted of one certified environmental engineer, two chemists, one accounting and purchasing manager, one marketing manager, and one academician experienced in the industry.

6.3. Determining the Criteria and Sub-Criteria

The criteria in Table 1 used to evaluate the suppliers were obtained from the literature review of the current literature.

Table 1: Criteria and Descriptions

CRITERION	DESCRIPTION
QUALITY	It provides information about the compliance of the products and services provided by the business with expected standards.
Defect Ratio	The percentage of the products that do not meet the determined quality standard.
Improvement	Increasing the capability of meeting quality standards
Quality control system	Having a quality control system and team
Refusal ratio	The number of materials that are refused and returned during quality control
Process improvement	Applying process improvement activities
Total Quality Management	A management approach that is quality-oriented, emphasizes customer satisfaction, and benefits the society.
COST	It provides information about the costs of the supplier such as raw material, processing, transportation and waste disposal.
Processing cost	The cost of producing, storing and selling one unit

Transportation cost	The cost of transporting the product from production unit to distribution center
Energy cost	The cost of total energy used in manufacturing the product
Raw material cost	The cost of total raw materials used in manufacturing the product
Chemical waste disposal cost	The cost of purification for the destruction of toxic chemical materials
Solid waste disposal cost	Costs related to the transportation of solid waste for disposal
SOCIAL CRITERIA	It gives information about the attitude of the supplier towards the stakeholders.
Relations with stakeholders	The existence of behaviour rules in the relations with customers, suppliers, or distributors.
Social responsibility	Supporting community projects and educational institutions, grants and donations
Knowledge level	The knowledge level of the business in its field
Safety and health practices	Compliance with safety and health requirements
Employee rights	Business relations, human rights and employee interests
GREEN MANAGEMENT	It gives information about the works of the supplier in the field of green management.
Environmental management system	It includes the supplier's controlling and applying environmental policies and related certification.
Environmental performance	It is related with the measurement and analysis of the production process of the supplier in terms of environment with a green perspective.
Waste management	It includes the disposal of annual solid waste going to storage area and hazardous materials.
Hazardous material management	Compliance with the minimum legal requirements related to the processing of chemicals and other toxic substances
GREEN PRODUCTION	It shows the supplier's service design and production capacity with low environmental impact.
Reproduction	Reproduction of a worn-out, defective or discarded product
Green package	The level of the environmentally sensitive materials used in packaging
Solid wastes	The amount control of solid wastes and what procedures to be followed with these
Redesign	Redesigning the product in a way to be dismantled easily or to use less material in its production
Energy consumption	The amount of energy consumption

6.4. Identifying the Alternatives

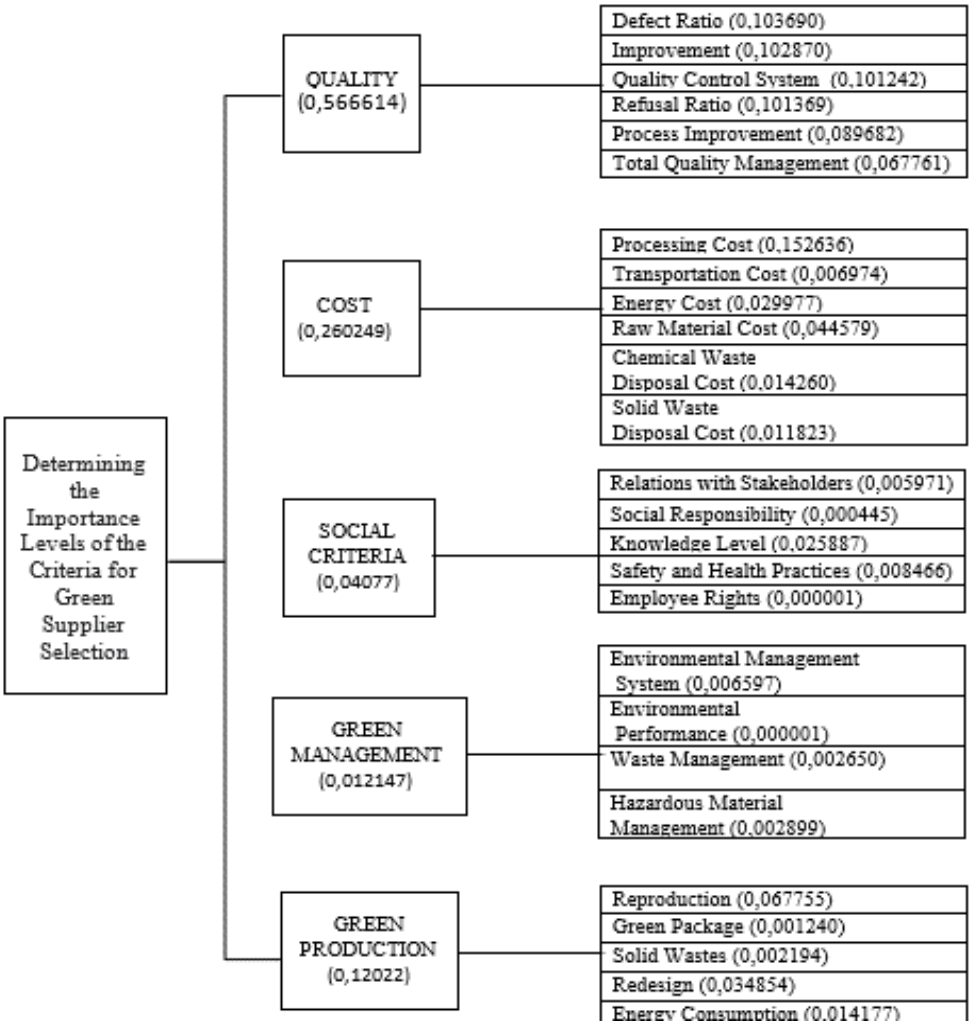
An alternative set consisting of the company from which the business was currently supplying basic raw materials and the four companies which the business could evaluate as alternatives in the supply process was formed. In order to keep the information about the determined alternative supplier companies confidential, their names were not clearly provided. Alternative suppliers were coded as S1, S2, S3, and S4 respectively, and these codes were used at every stage of the study.

6.5. Implementation of ANP Method

In ANP method, firstly, the impacts among the criteria were determined by a group decision which involved the whole study group. After that, this impact matrix was entered into SuperDecision software, and network structure was formed. Based on this network structure, the questionnaire form was prepared. The questionnaire form was administered to each member of the 6-person expert team. In the process of transforming the evaluations obtained into a single group decision, geometrical mean method

was used for the question group where the criteria were weighted. The group decision formed here was entered into SuperDecision software, and the criteria weightings were determined through ANP method.

Figure 2: ANP Weighting Values of the Main Criterion and the Sub-Criteria



Then, decision matrix was formed in order to make the best supplier selection. The criteria values to be used in the decision matrix were obtained through the scoring of the criteria by the expert team between 1-10. The arithmetic mean of the scores obtained was taken, and the decision matrix values were formed as in Table 2.

Table 2: Decision Matrix

	Min	Max	Max	Min	Max	Max	Min	Min	Min	Min	Min	Min	Max
SUPPLIERS	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**S1**
S1	7,53	6,15	5,93	7,79	5,71	6,15	5,77	5,21	5,26	6,90	8,37	8,14	6,52
S2	7,95	7,53	6,35	7,19	7,16	7,38	6,03	6,88	5,62	7,46	4,48	4,48	6,72
S3	8,77	8,12	7,00	7,69	7,29	7,19	6,17	6,03	6,03	7,72	8,56	8,56	6,72
S4	4,64	7,41	7,69	4,04	8,14	8,14	5,14	8,14	6,31	4,58	3,32	3,32	7,38
	Max	Max	Max	Max	Max	Max	Max	Max	Max	Max	Min	Max	Min
SUPPLIERS	**S2**	**S3**	**S4**	**S5**	**GM1**	**GM2**	**GM3**	**GM4**	**GP1**	**GP2**	**GP3**	**GP4**	**GP5**
S1	6,72	7,38	7,38	6,72	8,37	8,56	8,37	8,37	8,56	3,25	8,37	2,93	5,88

S2	6,72	6,72	6,72	6,72	7,55	6,52	6,26	6,88	4,28	8,56	3,52	8,37	5,49
S3	6,72	7,38	7,38	6,72	8,56	8,56	8,56	8,56	7,26	3,39	8,37	2,86	5,49
S4	7,38	7,38	6,72	6,72	6,17	5,90	5,37	6,17	2,22	3,25	2,55	2,55	7,22

In Table 2, there are 4 alternatives and 26 evaluation criteria. In the table, quality sub-criteria were coded as "Q", cost sub-criteria as "C", social sub-criteria as "S", green management sub-criteria as "GM", and green production sub-criteria as "GP". The values obtained after the average score of the expert evaluations was taken were analysed in Microsoft Excel software without any rounding. However, the representation here was arranged as two digits in the decimal part.

6.6. Obtaining the Results Through ANP and COPRAS, ANP and MOORA-Ratio, ANP and MOORA Reference Point, ANP and GRA Integrated Methods

The ranking results were obtained by using the weightings determined with ANP method in integration with the relevant methods. The ranking results obtained through ANP and COPRAS, ANP and MOORA-Ratio, ANP and MOORA Reference Point Approach, and ANP and GRA Integrated Methods are presented in Table 3, 4, 5 and 6, respectively.

Table 3: Relative Importance and Performance Index Values

SUPPLIERS	Q_i	P_i	RANKING
S1	0,235	0,841	**4**
S2	0,247	0,883	**2**
S3	0,241	0,862	**3**
S4	0,279	1,000	**1**

According to the results of ANP and COPRAS integrated method, S1 alternative is in the most important supplier position for the business. The ranking was as S4>S2>S3>S1.

Table 4: Performance Values and Ranking

SUPPLIERS	yi*	RANKING
S1	-0,0048	**4**
S2	0,0166	**2**
S3	0,0064	**3**
S4	0,0678	**1**

According to the results of ANP and MOORA-Ratio integrated method, S4 alternative is in the most important supplier position for the business. The ranking was as S4>S2>S3>S1.

Table 5: Performance Values and Ranking

SUPPLIERS	yi*	RANKING
S1	0,0277	**2**
S2	0,0237	**1**
S3	0,0289	**3**
S4	0,0352	**4**

According to the results of ANP and MOORA-Reference Point approach integrated method, S2 alternative is in the most important supplier position for the business. The ranking was as S2>S1>S3>S4.

Table 6: Grey Relational Degrees and Ranking

SUPPLIERS	DEGREES	RANKING
S1	0,456	**3**
S2	0,455	**4**
S3	0,520	**2**
S4	0,828	**1**

According to the results of ANP and GRA integrated method, S4 alternative is in the most important supplier position for the business. The ranking was as S4>S3>S1>S2.

6.7. Integration of the Results with COPELAND Method

It was seen that there were differences in the selection processes of the supplier businesses that were analyzed through the integration of ANP with four different MCDM methods. The ranking results obtained from four methods were integrated to be as one ranking by using COPELAND method.

Table 7: COPRAS, MOORA-Ratio Method, MOORA-Reference Point Approach, GRA and COPELAND Supplier Evaluation Results

	COPRAS		MOORA- Ratio		MOORA-Reference Point		GRA		COPELAND	
SUPPLIERS	**P_i**	**RANKING**	**y_i***	**RANKING**	**y_i***	**RANKING**	**$Ґ_i$**	**RANKING**	***CP_i***	**RANKING**
S1	0,841	4	-0,0048	4	0,0277	2	0,456	3	-3	4
S2	0,883	2	0,0166	2	0,0237	1	0,455	4	1	2
S3	0,862	3	0,0064	3	0,0289	3	0,520	2	-1	3
S4	1,000	1	0,0678	1	0,0352	4	0,828	1	3	1

When the ranking results obtained from COPELAND method are compared with the results obtained from the other methods, it is seen that the ranking results obtained from COPRAS and MOORA-Ratio methods are the same as the ranking obtained from COPELAND method.

7. Discussion, Conclusion, and Suggestions for Future Research

In the study, among MCDM methods, ANP, MOORA-Ratio Method, MOORA-Reference Point Approach, GRA, COPRAS, and COPELAND methods were used for the solution of supplier selection problem. The methods chosen were appropriate for the solution of multicriteria decision making problem, and it was possible to analyse the data through these methods. The methods were integrated with each other to minimize the inadequacies that may form when each method was used on its own. The rankings obtained from different methods were integrated to form a single ranking.

In the study, it is seen that according to the weighted criterion obtained through ANP method, the most important criterion in the main criteria group is the quality criterion. The least important main criterion is the green management criterion. In the interviews held with the business, the issue that the experts emphasized the most was that the quality criterion was very important for them. In fact, when

the criteria weighting results are considered, it is seen that the main criterion of quality was in the first place among the other criteria with a considerable difference. This situation proves that expert opinions were correctly conveyed to the study results. When the sub-criteria are considered, it is observed that the most important criterion was the processing cost, and the least important criterion was the environmental performance.

Although the cost criterion was important for the customers when purchasing a product, the quality of the product purchased outranked its cost. As a matter of fact, when the weighting results in the traditional supplier selection criteria are considered, the weighting value of the quality criterion is higher than that of the cost criterion. When the products produced in the paint sector of the chemical industry are considered, it is seen that the same raw material has been used for years, and there has been no improvement based on innovation. This situation shows that supplier selection in the field of paint industry is based on quality and cost. Today, customers gaining awareness and evaluating more than one criteria in preferring a product have led to an increase in conscious consumption. At this point, customers pay attention not only to the product purchased, but also to the company where the product is produced, the compatibility of the product with the environment or the social responsibility projects of the company. However, although the customers evaluate the products in different dimensions, it is observed that none of these dimensions can outrank the quality criterion. The increase in competition in paint industry, new laws and regulations on the environment, and increase in social responsibility projects drive the businesses to produce by considering all these criteria with a green management approach. The business where the study was conducted continues its production with optimum price, high quality and environmental sensitivity.

When the sub-criteria under the main criterion of social criteria are examined, it is seen that knowledge level criterion is the most important one. This situation indicates that the business where the study was conducted wants its suppliers to be well equipped in terms of sectoral knowledge. As paint production is made based on formulas, the high knowledge level of the supplier leads to forming good formulas, which is reflected in the quality of the product. When the sub-criteria under the main criterion of social criteria are examined, it is also seen that employee rights criterion has the lowest weighting value. This situation can be expressed as follows: In a country, employee rights in a business are supervised or examined through the laws of that state. Therefore, it is difficult for these rights to be supervised by customers, and it can be perceived as intervening. Also, when a business located in Turkey requests information about such rights, it can be perceived as a negative request in terms of culture and trade. In this context, a low value of this criterion does not reflect an adversity for the business.

When the sub-criteria under the main criterion of green management were examined, EMS criterion was found to be the most important one. As EMS requires businesses to control and implement environmental policies and involves certification, it is the natural right of the business to demand information of certification about these issues. Since this situation can be proved or documented, it does not lead to a problem between the supplier and the business. Besides, as the suppliers having these certificates indicates that they are supervised by certain institutions in that country, it indirectly shows that these suppliers make green production. It is also perceived indirectly that suppliers with these certificates make quality production. In this main criteria group, the sub-criteria of environmental performance has the lowest value. As the environmental performance is related to the measurement and analysis of whether the production process of the suppliers is "green" in terms of environment, it is difficult to obtain this information. This situation causes businesses to focus on EMS rather than on the environmental performance in evaluating their suppliers.

When the results obtained from the current study are compared with the results of the literature, there exist similarities and differences in terms of criteria and methods. In their study, Govindan et al. (2015) emphasized that implementation of green issues in supplier selection process was limited. They

put forth that the criterion that was considered the most in green supplier selection was EMS, and that the most commonly used MCDM method was AHP. In the present study, EMS criterion was found to be the most important sub-criteria under the main criterion of green management. Nevertheless, although AHP is the most commonly used method, ANP method was used in the study, as the relations between the criteria formed a network structure. In their study, Kumar et al. (2017) evaluated the performances of suppliers based on green practices by using fuzzy ELECTRE method in terms of environmental management, pollution control, cost, quality and flexibility. When compared with the current study, it is seen that the criteria of cost and quality are common. Besides, among the criteria they suggested for future studies on supplier selection, they emphasized that criteria such as solid waste, chemical waste, energy, product redesign and reproduction could be used. It is seen that the said criteria are among the criteria obtained as a result of the scoring by the expert team. In the study carried out by Freeman and Chan (2015), it was aimed to develop a green supplier selection model with traditional and environmental supplier selection criteria. As a result, they suggested that traditional criteria were more important than environmental criteria. When the results obtained from the current study are considered, it is seen that the weighting values of quality and cost criteria among supplier selection criteria are more important than environmental supplier selection criteria and in upper ranks in terms of scores. In this case, it can be said that though there may be differences on a sectoral basis, green criteria are generally not adopted, are not frequently used in the literature, and mostly traditional criteria are used more. The study conducted by Govindan et al. (2015), in which implementation of green issues in supplier selection process was limited, verifies this situation. In the study conducted by Jabbor (2009), it was emphasized that businesses still used traditional criteria such as quality and cost in selecting suppliers, and that they did not fully adopt environmental requirements in supplier selection process.

In the evaluation process of the alternatives according to the degree of importance of the determined criteria, as a result of the analysis performed with ANP+COPRAS integrated method, the alternatives were ranked as S4>S2>S3>S1, as a result of the analysis with ANP+MOORA-Ratio integrated method, the alternatives were ranked as S4>S2>S3>S1, as a result of the analysis with ANP+MOORA-Reference Point approach integrated method, the alternatives were ranked as S2>S1>S3>S4, and as a result of the analysis with ANP+GRA integrated method, the alternatives were ranked as S4>S3>S1>S2. The results obtained through these four methods were integrated by using COPELAND method, which yielded the ranking of the alternatives as S4>S2>S3>S1.

Considering the analysis results, it is seen that the results obtained with each pairwise integrated method are consistent. As a result, it was seen that ANP+ MOORA-Ratio Method, ANP+MOORA-Reference Point Approach, ANP+GRA, and ANP+COPRAS methods produced easy and fast results and could successfully be implemented in the supplier selection decision problem. In future studies, the framework of the suggested criteria for the chemical industry in the study can be compared with the results to be obtained by using other MCDM methods. The results can be compared by using different decision makers and different industries. In future research, different green criteria can be added, and the effects of these criteria on supplier selection can be investigated.

The results obtained in this study can be extended by attempting to exceed the limitations of the current study. In the study, a business in a specific region was examined. Therefore, new studies can be conducted by considering different geographical regions and industries. It can be revealed what criteria stand out in shaping the businesses' attitudes towards green practices in supplier selection in different regions and more businesses.

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References

Alizadeh, A., and Yousefi, S. (2019). An integrated taguchi loss function–fuzzy cognitive map –mcgp with utility function approach for supplier selection problem. *Neural Computing and Applications*, *31*(11), 7595-7614.

Alkahtani, M. and Kaid, H. (2018). Supplier selection in supply chain management: A review study. *International Journal of Business Performance and Supply Chain Modelling*, 10(2), 107–130.

Azadi, M., Jafarian, M., Saen, R. F. and Mirhedayatian, S. M. (2015). A new fuzzy DEA model for evaluation of efficiency and effectiveness of suppliers in sustainable supply chain management context. *Computers and Operations Research*, 54, 274–285.

Badi, I. and Ballem, M. (2018). Supplier selection using the rough BWM-MAIRCA model: A case study in pharmaceutical supplying in Libya. *Decision making: Applications in Management and Engineering, 1(2), 16-33.*

Bali, Ö., Köse, E. and Gümüş, S. (2013). Green supplier selection based on IFS and GRA. *Grey Systems: Theory and Application*, 3(2), 158-176.

Banaeian, N., Mobli, H., Fahimnia, B., Nielsen, I. E. and Omid, M. (2018). Green supplier selection using fuzzy group decision making methods: A case study from the agri-food industry. *Computers and Operations Research* 89, 337–347.

Baskaran, V., Nachiappan, S. and Rahman, S. (2012). Indian textile suppliers' sustainability evaluation using the grey approach. *International Journal of Production Economics*, 135, 647–658.

Bin, L. and Hong-Jun, L. (2010). Research on supplier assessment indices system of green purchasing. *International Conference on Measuring Technology and Mechatronics Automation*, 314-317.

Boran, F. E., Genç, S., Kurt, M., ve Akay, D. (2009). A multi-criteria intuitionistic fuzzy group decision making for supplier selection with TOPSIS method. *Expert systems with applications*, *36*(8), 11363-11368.

Brauers, W. K. M., Ginevičius, R. and Podvezko, V. (2010). Regional development in Lithuania considering multiple objectives by the MOORA method. *Technological and Economic Development of Economy*, *16*(4), 613-640.

Brauers, W. K. M. and Zavadskas, E. K. (2012). Robustness of MULTIMOORA: A method for multi-objective optimization. *Informatica*, 23(1), 1–25.

Brauers, W. K. M., Zavadskas, E. K. and Ginevicius, R. (2015). Multi-objective decision making in macro and microeconomics with application of the MULTIMOORA method. *International Journal Applied Nonlinear Science*, 2(1/2), 75–99.

Büyüközkan, G., Çifçi, G. and Güleryüz, S. (2011). Strategic analysis of healthcare service quality using fuzzy AHP methodology. *Expert Systems with Applications*, 38(8), 9407-9424.

Büyüközkan, G., ve Çifçi, G. (2012). A novel hybrid MCDM approach based on fuzzy DEMATEL, fuzzy ANP and fuzzy TOPSIS to evaluate green suppliers. *Expert Systems with Applications*, 39(3), 3000–3011.

Caillaux, M. A. (2011). Container logistics in Mercosur: Choice of a transhipment port using the ordinal COPELAND method, data envelopment analysis and probabilistic composition. *Maritime Economics and Logistics*, 13, 355–370.

Cavinato, J. L., Flynn, A., and Kauffman, R. (2006). *The supply management handbook*, New York: McGraw-Hill, pp. 643–675.

Chand, M., Bhatia, N. and Singh, R. K. (2016). ANP-MOORA-based approach for the analysis of selected issues of green supply chain management. *An International Journal,* 25(2), 642-659.

Chen, C. C., Tseng, M. L., Lin, Y. H. and Lin, Z. S. (2010). Implementation of green supply chain management in uncertainty. *International Conference on Industrial Engineering and Engineering Management*, Macao, December, 7–10.

Chiou, C. Y., Hsu, C. W. and Hwang, W. Y. (2008). Comparative investigation on green supplier selection of the American, Japanese and Taiwanese electronics industry in China. *International Conference On IE&EM, IEEE*, 8(11), 1909-1914.

Chiou, T. Y., Chan, H. K., Lettice, F. and Chung, S. H. (2011). The influence of greening the suppliers and green innovation on environmental performance and competitive advantage in Taiwan. *Transportation Research Part E: Logistics and Transportation Review*, *47*(6), 822-836.

Cristea, C. and Cristea, M. (2017). A multi-criteria decision-making approach for supplier selection in the flexible packaging industry. *MATEC Web of Conferences 94*, EDP Sciences.

Çakır, E. (2017). Kriter ağırlıklarının SWARA–COPELAND yöntemi ile belirlenmesi: Bir üretim işletmesinde uygulama. *Adnan Menderes Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, 4(1), 42-56.

Çetin, O, Önder, E. (2015). Cetin, O., & Önder, E. (2015). Tedarikçi Seçiminde Analitik Ağ Süreci Yönteminin Kullanilmasi (Using Analytic Network Process Method for Supplier Selection). The Journal of KAU IIBF, 6(10), 335-354.

Dotoli, M. and Falagario, M. (2012). A hierarchical model for optimal supplier selection in multiple sourcing contexts. *International Journal of Production Research*, *50*(11), 2953-2967.

Eshtehardian, E., Ghodousi, P. and Bejanpour, A. (2013). Using ANP and AHP for the supplier selection in the construction and civil engineering companies; case study of Iranian company. *KSCE Journal of Civil Engineering,* 17 (2): 262–70.

Freeman, J. and Chen, T. (2015). Green supplier selection using an AHP-Entropy-TOPSIS framework. *Supply Chain Management: An International Journal*, 20(3), 327-340.

Gencer, C. ve Gürpinar, D. (2007). "Analytic network process in supplier selection: A case study in an electronic firm. *Applied Mathematical Modelling*, *31*(11), 2475-2486.

Girubha, R. J. and Vinodh, S. (2012). Application of fuzzy VIKOR and environmental impact analysis for material selection of an automotive component. *Materials and Design*, 37, 478 - 486.

Govindan, K. Kannan, D. and Shankar, M. (2015). Evaluation of green manufacturing practices using a hybrid MCDM model combining DANP with PROMETHEE. *International Journal of Production Research*, 53(21), 6344-6371.

Govindan, K., Rajendran, S., Sarkis, J. and Murugesan, P. (2015). Multi criteria decision making approaches for green supplier evaluation and selection: A literature review. *Journal of Cleaner Production*, 98, 66-83.

Görener, A., Ayvaz, B., Kuşakcı, A. O., and Altınok, E. (2017). A hybrid type-2 fuzzy based supplier performance evaluation methodology: The Turkish Airlines technic case", *Applied Soft Computing*, *56*, 436-445.

Grisi, R. M., Guerra, L. and Naviglio, G. (2009). Supplier performance evaluation for green supply chain management. içinde Taticchi, P. (Ed.), *Business Performance Measurement and Management* (s.149-163).

Gupta, S., Soni, U. and Kumar, G. (2019). Green supplier selection using multi-criterion decision making under fuzzy environment: A case study in automotive industry. *Computers and Industrial Engineering*, 136, 663–680.

Haeri, S., Amin, S. and Rezaei, J. (2019). A grey-based green supplier selection model for uncertain environments. *Journal of Cleaner Production*, 221, 768-784.

Handfield, R., Walton, S. V., Sroufe, R. and Melnyk, S. A. (2002). Applying environmental criteria to supplier assessment: A study in the application of the AHP. *European Journal of Operational Research*, 141, 70-87.

Hashemi, S. H., Karimi, A. and Tavana, M. (2015). An integrated green supplier selection approach with analytic network process and improved grey relational analysis. *International Journal of Production Economics,* 159, 178-191.

Ho, W., Xu, X., and Dey, P. K. (2010). Multi-criteria decision-making approaches for supplier evaluation and selection: A literature review. *European Journal of Operational Research*, *202*(1), 16-24.

Hruska, R., Průša, P. and Babić, D. (2014). The use of AHP method for selection of supplier. *Transport*, *29*(2), 195-203.

Hsu, C. W. and Hu, A. H. (2007). Application of analytic network process on supplier selection to hazardous substance management in green supply chain management. *International Conference on Industrial Engineering and Engineering Management*, 1362-1368.

Hsu, C. W., Kuo, T. C., Chen, S. H. and Hu, A. H. (2013). Using DEMATEL to develop a carbon management model of supplier selection in green supply chain management. *Journal of cleaner production*, *56*, 164-172.

Huang, C. C. and Lee, H. M. (2003). A novel partial-memory learning algorithm based on grey relational structure. içinde *Advances in Intelligent Data Analysis V*, August 28-30, 68-75.

Humphreys, P., McCloskey, A., McIvor, R., Maguire, L. and Glackin, C. (2006). Employing dynamic fuzzy membership functions to assess environmental performance in the supplier selection process. *International Journal of Production Research*, 44(12), 2379-2419.

Jabbour, A. B. L. S. and Jabbour, C. J. C. (2009). Are supplier selection criteria going green? Case studies of companies in Brazil. *Industrial Management and Data Systems*, 109(4) 477-495.

Jakhar, S. K. (2014). Designing the green supply chain performance optimisation model. *Global Journal of Flexible Systems Management*, 15(3), 235–259.

Kamalakannan, R., Ramesh, C., Shunmugasundaram, M., Sivakumar, P., and Mohamed, A. (2020). Evaluvation and selection of suppliers using TOPSIS. *Materials Today: Proceedings*, *33*, 2771-2773.

Kannan, G., Haq, A. N., Sasikumar, P., and Arunachalam, S. (2008). Analysis and Selection of green suppliers using interpretative structural modelling and AHP. *International Journal of Management and Decision Making*, *9*(2), 163-182.

Kaya, T. ve Kahraman, C. (2010). Entegre bir bulanik VIKOR ve AHP metodolojisi kullanarak çok kriterli yenilenebilir enerji planlamasi: İstanbul örneği. *Enerji*, *35*(6), 2517-2527.

Kılıç, H. S. ve Yalçın, A. S. (2019). Green supplier selection via an integrated multi-attribute decision making approach. *Sakarya Üniversitesi Fen Bilimleri Enstitüsü Dergisi*, 23(6), 1066-1079.

Kumar, P., Singh, R. K. and Vaish, A. (2017). Suppliers' green performance evaluation using fuzzy extended ELECTRE approach. *Clean Technology Environment*, 19(3), 809-821.

Kuo, R. J., Wang, Y. C. and Tien, F. C. (2010). Integration of artificial neural network and mada methods for green supplier selection. *Journal of Cleaner Production*, 18, 1161-1170.

Kuo, R. J. and Lin Y. J. (2012). Supplier selection using analytic network process and data envelopment analysis. *International Journal of Production Research*, 50(11), 2852-2863.

Lee, A. H. I., Kang, H. Y., Hsu, C. F. and Hung, H. C. (2009). A green supplier selection model for high-tech industry. *Expert Systems with Applications*, 36(4), 7917-7927.

Lee, T. (J)., Phuong Nha Le, T., Genovese, A. and Koh, L. S. C. (2012). Using FAHP to determine the criteria for partner's selection within a green supply chain the case of hand tool industry in Taiwan. *Journal of Manufacturing Technology Management* , 23(1), 25-55.

Lee, S. Y. (2015). The effects of green supply chain management on the supplier's performance through social capital accumulation. *Supply Chain Management: An International Journal*, 20(1), 42-55.

Mehralian, G., Gatari, A. R., Morakabati, M. and Vatanpour, H. (2011). Developing a suitable model for supplier selection based on supply chain risks: An empirical study from Iranian pharmaceutical companies. *Journal of Pharmaceutical Research*, 11(1), 209-219.

Min, H. and Galle, W. P. (1997). Green purchasing strategies: Trends and implications. *International Journal of Purchasing and Materials Management*, Summer, 10-17.

Mousakhani, S., Nazari-Shirkouhi, S., and Bozorgi-Amiri, A. (2017). A novel interval type-2 fuzzy evaluation model-based group decision analysis for green supplier selection problems: A case study of battery industry. *Journal of Cleaner Production*, *168*, 205-218.

Özbek, A. (2019). Çok *kriterli karar verme yöntemleri ve excel ile problem çözümü,* 2. Baskı, Ankara, Seçkin Yayıncılık.

Özdağoğlu, A. (2013b). Çok ölçütlü karar verme modellerinde normalizasyon tekniklerinin sonuçlara etkisi: COPRAS örneği. *Eskişehir Osmangazi Üniversitesi İ.İ.B.F. Dergisi*, 8(2), 229-252.

Özdemir, Y., Tüysüz, S. ve Başlıgil, H. (2016). Nükleer enerji santralleri için AHP ve ANP yöntemi kullanılarak risklerin ağirliklandirilması. *Sigma Journal of Engineering and Natural Sciences*, 7(2), 207-217.

Öztürk, B. A. ve Özçelik, F. (2014). Üçlü kar payına dayali bulanik çok kriterli karar verme yöntemiyle sürdürülebilir tedarikçi seçimi. *İşletme ve Ekonomi Araştırma Dergisi*, *5*(3), 129.

Öztürk, H., Pekel, E. and Elevli, B. (2018). Using ANP and ELECTRE methods for supplier selection: Cable industry application. *Journal of Science*, 22(5), 1190-1198.

Podvezko, V. (2011). The comparative analysis of MCDA methods SAW and COPRAS. *Inzinerine Ekonomika-Engineering Economics*, 22(2), 134-146.

Peng, J. J., Wang, J. Q., Wang, J., Yang, L. J., and Chen, X. H. (2015). An extension of ELECTRE to multi-criteria decision-making problems with multi-hesitant fuzzy sets. *Information Sciences*, *307*, 113-126.

Pitchipoo, P., Venkumar, P. and Rajakarunakaran, S. (2012). A distinct decision model for the evaluation and selection of a supplier for a chemical processing industry. *International Journal of Production Research*, 50(16), 4635-4648.

Pourghahreman, N. and Qhatari, A. N. (2015). Supplier selection in an agent based pharmaceutical supply chain: An application of TOPSIS and PROMETHEE. *Uncertain Supply Chain Management,* 3, 231–240.

Qin, J., Liu, X., and Pedrycz, W. (2017). An extended TODIM multi-criteria group decision making method for green supplier selection in interval type-2 fuzzy environment. *European Journal of Operational Research*, *258*(2), 626-638.

Quan, J., Zeng, B. and Liu, D. (2018). Green supplier selection for process industries using weighted grey incidence decision model. *Complexity*, 1-12.

Saari, D. G. and Merlin, V. R. (1996). The copeland method relationships and the dictionary. *Economie Theory*, 8, 51-76.

Saaty, T. L. (2009). *Theory and applications of the analytic network process: Decision making with benefits, opportunities, costs, and risk.* RWS Publications. Pittsburgh.

Sahu, N. K., Datta, S. and Mahapatra, S. S. (2012). Establishing green supplier appraisement platform using grey concepts. *Grey Systems: Theory and Application*, 2(3), 395–418.

Sarıçalı, G. ve Kundakçı, N. (2016). AHP ve COPRAS yöntemleri ile otel alternatiflerinin değerlendirilmesi. *International Review of Economics and Management*, 4(1), 45-66.

Sevkli, M., Lenny Koh, S.C., Zaim, S., Demirbag, M. ve Tatoglu, E. (2007). Tedarikçi seçimi için bir veri zarflama analitik hiyerarşi süreci uygulamasi: Türkiye'de Beko'nun bir vaka çalişmasi. *Uluslararası Üretim Araştırmaları Dergisi*, *45* (9), 1973-2003.

Shi, P., Yan, B., Shi, S., and Ke, C. (2015). A decision support system to select suppliers for a sustainable supply chain based on a systematic DEA approach. *Information Technology and Management*, *16*(1), 39-49.

Simchi, D. and Levi, P. K. (2004). *Managing the supply chain the definitive guide for the business.* McGraw-Hill, USA.

Swift, C. O. (1995). Preferences for single sourcing and supplier selection criteria. *Journal of Business Research*, 23, 105-111.

Taylan, O., Bafail, A.O., Abdulaal, R.M. and Kabli, M.R. (2014). Bulanık AHP ve bulanık TOPSIS metodolojileri ile inşaat projeleri seçimi ve risk değerlendirmesi. *Uygulamalı Yumuşak Hesaplama*, *17*, 105-116.

Tektaş, A. ve Aytekin, A. (2011). Supplier selection in the international environment: A comparative case of a Turkish and an Australian company. *IBIMA Business Review,* 1-15.

Theiben, S. and Spinler, S. (2014). Strategic analysis of manufacturer-supplier partnerships: An ANP model for collaborative CO2 reduction management. *European Journal of Operational Research*, 233(2), 383-397.

Thongchattu, C. and Siripokapirom, S. (2010). Green supplier selection consensus by neural network. *2nd International Conference on Mechanical and Electronics Engineering*, 313-316.

Torabi, S. A., and Boostani, A. (2018). Supplier selection and order allocation under risk: Iranian oil and gas drilling companies. *International Journal of Industrial Engineering & Production Research*, *29*(1), 35-52.

Tseng, M. L. (2011). Green supply chain management with linguistic preferences and incomplete information. *Apply Soft Computing*, 11(8), 4894-4903.

Tuzkaya, G., Özgen, A., Özgen, D. and Tuzkaya, U. R. (2009). Environmental performance evaluation of suppliers: A hybrid fuzzy multi-criteria decision Approach. *International Journal of Environmantel Science and Technology,* 6(3), 477-490.

Varnas, A., Balfors, B. and Faith-Ell, C. (2009). Environmental consideration in procurement of construction contracts: Current practice, problems and opportunities in green procurement in the Swedish construction industry. *Journal of Cleaner Production*, 17, 1214–1222.

Watrobski, J. ve Salabun, W. (2016). Green supplier selection framework based on multi-criteria decision-analysis approach. *Sustainable Design and Manufacturing*, (361-371). Springer, Cham.

Weber, C. A. Current, J. R. and Benton, W. C. (1991). Vendor selection criteria and methods. *European Journal of Operational Research*, 50(1), 2–18.

Wen, U. P. and Chi, J. M. (2010). Developing green supplier selection procedure: A DEA approach. *International Conference on IEEM, IEEE*, 29-31 Oct., 74-79.

Wu, H. H. (2002). A comparative study of using grey relational analysis in multiple attribute decision making problems. *Quality Engineering*, 15(2), 209-217.

Wu, Q., Zhou, L., Chen, Y. and Chen, H. (2019). An integrated approach to green supplier selection based on the interval type-2 fuzzy best-worst and extended VIKOR methods. *Information Sciences*, 502, 394–417.

Yadav, V. and Sharma, M. K. (2014). An application of hybrid data envelopment analytical hierarchy process approach for supplier selection. *Journal of Enterprise Information Management*, 28(2), 218-242.

Yang, Y. and Wu, L. (2007). Grey entropy method for green supplier selection. *International Conference on Wireless Communications*, *Networking and Mobile Computing,* Shanghai, 4682-4685.

Yang, Y. Z. and Wu, L. Y. (2008). Extension method for green supplier selection. *International Conference on Wireless Communications, Networking and Mobile Computing*, 1-4.

Yeh, W. C. and Chuang, M. C. (2011). Using multi-objective genetic algorithm for partner selection in green supply chain problems. *Expert Systems with Applications*, 38, 4244–4253.

Yıldırım, B. F. ve Önder, E. (2015). *Çok kriterli karar verme yöntemleri*. Dora Yayıncılık, Bursa.

Yu, Q. and Hou, F. (2016). An Approach for green supplier selection in the automobile manufacturing industry. *Kybernetes*, 45(4), 571-588.

Zhao, H. and Guo, S. (2014). Selecting green supplier of thermal power equipment by using a hybrid MCDM method for sustainability. *Sustainability,* 6, 217-235.