SUPPLIER SELECTION WITH AN AGILE-SUSTAINABLE APPROACH IN THE AUTOMOTIVE INDUSTRY

(OTOMOTİV SEKTÖRÜNDE ÇEVİK-SÜRDÜRÜLEBİLİRLİK YAKLAŞIMI İLE TEDARİKÇİ SEÇİMİ)

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LIST OF SYMBOLS

SC : Supply Chain
TOPSIS : Technique for Order Preference by Similarity to an Ideal Solution
DEMATEL : The Decision Making Trial and Evaluation Laboratory
BWM : Best-Worst Method
SCM : Supply Chain Management
GSSP : Green Supplier Selection Problem
QFD : Quality Function Deployment
COPRAS : Complex Proportional Assesment
SSC : Sustainable Supply Chain
AHP : Analytical Hierarchy Process
ASSP : Agile Supply Selection Problem
ANP : Analytical Network Process
DEA : Data Envelopment Analysis
SWARA : Step-wise Weight Ratio Analysis
VIKOR : Vise Kriterijumska Optimizacija I Kompromisno Resenje
ISM : Interpretive Structural Model
FANP : Fuzzy Analytical Network Process
FVIKOR : Fuzzy Vise Kriterijumska Optimizacija I Kompromisno Resenje
FBWM : Fuzzy Best-Worst Method
FDEMATEL : Fuzzy The Decision Making Trial and Evaluation Laboratory
OHS : Occupational Health and Safety
DM : Decision Maker
ASC : Agile Supply Chain
PROMETHEE: Preference Ranking Organization Method for Enrichment Evaluations
FAHP : Fuzzy Analytical Hierarchy Process
FTOPSIS : Fuzzy Similarity to Ideal Solution and Sequence Preference Technique

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ABSTRACT

Supplier selection is very important in a competitive market. Determination of supplier selection criteria is as critical as supplier selection. In order to manage this critical process and to find the right supplier, companies have sought different methods than traditional methods.

In recent years, the concept of sustainability has come to the fore in the environmental and social policies implemented by countries. In addition, the agile concept is also taken into account in order to keep up with the dynamics in the market. In the literature, there are many studies on sustainable supplier selection or agile supplier selection. However, as far as we know, the study that took into account the agile-sustainable dimensions and selected suppliers was ignored. In this study, a supplier selection was made in an automotive company considering its agile-sustainable dimensions. For this purpose, Decision Making Trial and Evaluation Laboratory (DEMATEL) and Similarity to Ideal Solution and Sequence Preference Technique (TOPSIS) methods were used. In the study, 8 main criteria, 18 sub-criteria and 3 alternatives were determined. The weights of the criteria are weighted by the DEMATEL method. The ranking of the alternatives was made using the TOPSIS method and the most suitable alternative was determined.

Keywords: Agile, Sustainable, Supplier Selection, Automotive Industry

ÖZET

Rekabetçi bir pazarda tedarikçi seçimi çok önemlidir. Tedarikçi seçim kriterlerinin belirlenmesi, tedarikçi seçimi kadar kritiktir. Bu kritik süreci yönetmek ve doğru tedarikçiyi bulmak için firmalar geleneksel yöntemlerden farklı yöntemler aramışlardır.

Son yıllarda ülkelerin uyguladığı çevresel ve sosyal politikalarda sürdürülebilirlik kavramı ön plana çıkmıştır. Ayrıca pazardaki dinamiklere ayak uydurabilmek için çevik konsept de dikkate alınmaktadır. Literatürde sürdürülebilir tedarikçi seçimi veya çevik tedarikçi seçimi ile ilgili birçok çalışma bulunmaktadır. Ancak bildiğimiz kadarıyla çevik-sürdürülebilirlik boyutlarını dikkate alan ve tedarikçi seçimi çalışması göz ardı edilmiştir. Bu çalışmada bir otomotiv firmasında çevik-sürdürülebilir boyutları dikkate alınarak tedarikçi seçimi yapılmıştır. Bu amaçla Karar Verme Deneme ve Değerlendirme Laboratuvarı (DEMATEL) ile İdeal Çözüme Benzerlik ve Dizi Tercih Tekniği (TOPSIS) yöntemleri kullanılmıştır. Çalışmada 8 ana kriter, 18 alt kriter ve 3 alternatif belirlenmiştir. Kriterlerin ağırlıkları DEMATEL yöntemi ile ağırlıklandırılmıştır. TOPSIS yöntemi kullanılarak alternatiflerin sıralaması yapılmış ve en uygun alternatif belirlenmiştir.

Anahtar Kelimeler : Çevik, Sürdürülebilir, Tedarikçi Seçimi, Otomotiv Endüstrisi

1. INTRODUCTION

Today's companies have realized that in order to compete in the global market, they need to take effective measures to optimize their supply chain and gain more efficiency than their competitors (Amiri et al., 2020). Apart from the measures taken, supplier selection has become just as important. Supplier selection is a critical process as it seriously affects the profitability and production performance of companies, and economic decisions have been at the forefront while making this selection (Memari et al., 2019a). However, the increasing use of outsourcing encourages companies to implement sustainability (economic, environmental and social) supply chain practices (Ghayeblo et al., 2015).

The concept of sustainability does not only consider environmental factors. It plays an important role in the agreement of the relationship between man and nature (Gupta & Barua, 2017). Sustainability integrates the social as well as the economic and environmental dimensions and is an extension of the green supply chain (Mangla et al., 2014). Green supplier and sustainable supplier are terms that can be used interchangeably (Luthra et al., 2017a). Sustainability deals with socio-economic activities from an environmental perspective and is presented as a solution to environmental and social problems that have increased with the industrialization of societies (De Vargas Mores et al., 2018). Therefore combining environmental, economic and social aspects in order to sustain sustainability is very important for organizations aiming to make a profit in recent years (Benn et al. 2014). Suppliers can play an important role in gaining economic, environmental and social dimensions in a Sustainable Supply Chain (SSC) (Shen et al., 2013a). Therefore, sustainable supplier selection in a structure that aims sustainability is a very important strategic move (Amindoust et al., 2012a).

Apart from sustainability, another important feature of Supply Chain (SC) management is agility (Alamroshan et al., 2022a). Agile SC aims to respond faster to ever-changing and dynamic conditions and environments (Alimardani et al., 2013a). Agile SC is to leverage market literature to take advantage of beneficial opportunities in a volatile market (Ciccullo et al., 2018).

A harmonious integration of sustainable and agile SC is recommended because the gains of these two dimensions will streamline operational activities and accelerate adaptability to variability (Alimardani et al., 2013).

In this study, supplier selection was made at Türk Traktör operating in Sakarya with an agile-sustainability (economic-environmental-social) approach. As far as we know, the study that takes this hybrid approach and selects a supplier has been ignored in the literature. 3 alternatives, 8 main criteria and 18 sub-criteria were determined. After a large-scale literature study, it was evaluated by 3 purchasing experts with the determined criteria. Some criteria have been added and some criteria have been removed. The chi-square independence test was performed to measure the dependence of the criteria on each other. Considering the results of the test, the DEMATEL method was used to determine the weights of the criteria. TOPSIS method was used to rank the alternatives after criterion weighting.

The focus of this study is the selection of suppliers by considering sustainable-agile dimensions, which will also create the originality of the study. When the studies in the literature are examined, there are many studies on supplier selection. However, the study that takes into account the sustainable (economic, environmental and social) and agile dimensions has been neglected. In this study, this gap, which has been neglected in the literature, has been tried to be filled.

The remainder of the study is organized as follows: The literature review on supplier selections made with sustainable, green and agile approaches is explained in Section 2. Methods that are used in this study are explained in Section 3.

Proposed model is explained in Section 4. Application and results are explained in Section 5. In the last section concluding remarks and suggestions for future research are explained.

2. LITERATURE REVIEW

This section is divided into 3 parts: Green, sustainable and agile supplier selection studies In the study, 32 articles were analyzed and the literature review summary table is given in Appendix A.

2.1 Supplier Selection

There are many studies in the literature regarding the practices applied in Supply Chain Management (SCM) in supplier selection with a sustainable focus (Luthra et al., 2017b).

2.1.1 Green Supplier Selection

Walton et al. (1998), evaluated 5 furniture companies from a green perspective and environmental aspects were applied during the supplier selection stage. Hsu & Hu (2009), proposed an environmental dimension to avoid dangerous processes in supplier selection processes. Lee et et. (2009) proposed a model that evaluates green aspects to select a supplier that meets green standards and has an environmental perspective. Shaw et al. (2012), proposed a model that observes carbon emissions and analyzes supplier selection in the results of these observations. Shen et al. (2013b), proposed a model that evaluates suppliers according to their environmental and ecological dimensions in the green supplier selection process. Akman (2015), proposed a two-stage supplier evaluation model to evaluate green supplier selection. Mahdiloo et al. (2015), proposed a model to measure and evaluate these standards, taking into account the technical, environmental and ecological efficiency of suppliers. Yazdani et al. (2017), integrated DEMATEL, Quality Function Deployment (QFD), and Complex Proportional Assesment (COPRAS) methods to study green supplier selection problem. Banaeian et al. (2018), investigated Green Supplier Selection Problem (GSSP) in the agri-food industry and developed a new hybrid method in turbid environment to solve the problems there.

Javad et al. (2020), proposed a model on SSC by evaluating green indicators in an iron and steel plant, a new approach was developed in the study by integrating Best-Worst Method (BWM) and fuzzy TOPSIS. Çalık (2021), proposed a new model by integrating Pythagorean Fuzzy Analytical Hierarchy Process (FAHP) and Pythagorean Fuzzy Similarity to Ideal Solution and Sequence Preference Technique (FTOPSIS) methods to investigate GSSP under fuzzy environment in the Industry 4.0 process. The study was carried out in an environment with agricultural machinery.

2.1.2 Sustainable Supplier Selection

Bai & Sarkis (2010) made supplier selection work by integrating sustainability dimensions into their models. Amindoust et al. (2012b), in their proposed model, applied the supplier selection by considering the concept of sustainability, but the selection criteria did not include all of the sustainability criteria. Govindan et al. (2013), proposed a model that includes sustainability in supplier selection. In the proposed model, it is a model in which companies can capture and evaluate the opportunities and possibilities that may occur in SC. Sarkis & Dhavale (2015), stated that supply selection is of critical importance for a sustainable supply management. They proposed a model for sustainability that considers 3 dimensions (economic, environmental and social) and showed that 3 dimensions are critical for the optimization of firms. Jahuar & Pant (2017) addressed the issue of sustainable supplier selection. In the study, DEA, DE algorithm and MODE are integrated. Luthra et al. (2017) proposed a model for sustainable supplier selection by integrating Analytical Hierarchy Process (AHP) and Vise Kriterijumska Optimizacija I Kompromisno Resenje (VIKOR) methods in an automotive company in India. Memari et al. (2019b) addressed the sustainable supplier selection problem with the intuitive FTOPSIS method in an automotive spare part manufacturer. Suraraksa & Shin (2019) presented the AHP method to prioritize and monitor sustainable supplier selection criteria in an automotive company in Thailand.

Khoshfetrat et al. (2020), developed a multi-objective mathematical model for sustainable supplier selection in a fuzzy environment. The mathematical model developed in this study in the automotive industry aims to purchase optimum products from suppliers in every period. Kannan et al. (2020) proposed BWM and VIKOR methods to make sustainable supplier selection in the closed-loop SC. Tong et al. (2021), using the Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) method in a company operating in the textile and apparel industry, addressed the problem of sustainable supplier selection. Wu et al. (2022), combining VIKOR and DEMATEL methods, proposed a linguistic multi-featured group decision-making method for sustainable supplier selection.

2.1.3 Agile Supplier Selection

Although agility has been popular recently, there are limited studies in the literature.

Hasan et al. (2008) addressed the Agile Supply Selection Problem (ASSP) issue in an Indian company by integrating these two methods, taking into account the Analytical Network Process (ANP) and Data Envelopment Analysis (DEA) methods. Wu & Barnes (2009), proposed a decision-making model to improve feedback in the Agile Supply Chain (ASC). Wu et al. (2009), proposed a new approach to handle co-selection in ASC by integrating the mathematical model and the ANP method. Alimardani et al. (2013b), discussed ASSP in the automotive industry. A new framework was proposed in the study in which Step-wise Weight Ratio Analysis (SWARA) and VIKOR methods were combined. Wu & Barnes (2014) proposed a new perspective by analyzing ASSP under fuzzy conditions. Beikkhakhian et al. (2015), proposed a new framework integrating Interpretive Structural Model (ISM), AHP and TOPSIS methods to examine supplier selection considering agile criteria. Galankashi a & Helmi (2016), addressed the problem of ASSP in a fuzzy environment in the manufacturing industry. They used the Fuzzy AHP method to evaluate the criteria in the agile environment.

Li et al. (2020), addressed the problem of lean and agile in the textile industry. DEMATEL method was used in the study. Göker et al. (2020), proposed a distance-based hierarchical heuristic decision-making procedure to study ASSP. Suppliers are ranked according to their agile performance. Alamroshan et al. (2022b), addressed a hybrid fuzzy approach to the agile and green supplier problem in the medical industry. In the study, they proposed a new approach by integrating Fuzzy The Decision Making Trial and Evaluation Laboratory (FDEMATEL), Fuzzy Best-Worst Method (FBWM), Fuzzy Analytical Network Process (FANP) and Fuzzy Vise Kriterijumska Optimizacija I Kompromisno Resenje (FVIKOR) methods.

3. METHODOLOGY

3.1 Chi-Square Indepedence Test

The chi-square independence test is used to determine whether the relationship between two variables is statistically significant. The difference between the analysis investigating the relationships between the variables in the chi-square test is the type of scale used (Ersöz & Ersöz, 2017a).

In this study, the chi-square independence test was used to determine the dependence relationship between agile-sustainable criteria.

The chi-square test of independence has 5 stages. These stages will be described below.

1) A contingency table is conducted based on the frequency.

Table 3.1 Structure of Contingency

	2. Options of the Variable						
1. Options of Variable	1	2	…	J	…	c	Total
1	n_{11}	n_{12}	…	n_{1j}	…	n_{1c}	n_{1}
2	n_{21}	n_{22}	…	n_{2j}	…	n_{2c}	n_{2c}
.	.	.	…	.	…	.	.
.	.	.	…	.	…	.	.
.	.	.	…	.	…	.	.
I	$n_{\imath 1}$	$n_{\imath 2}$	…	$n_{\imath j}$	…	$n_{\imath c}$	$n_{\imath}$
.	.	.	…	.	…	.	.
.	.	.	…	.	…	.	.
s	n_{s1}	n_{s2}	…	n_{sj}	…	n_{sc}	n_{s}
Total	$n_{.1}$	$n_{.2}$	…	.	…	.	$n_{..} = n$

2) According to the problem, the null hypothesis (H_0) and the alternative hypothesis (H_1) are established.
3) The level of significance (α) is determined.
4) The freedom degree (sd) are determined where r = the row number in the table and c = the number column in the table.

$$sd = (r\text{-}1)\ (c\text{-}1) \tag{3.1}$$

5) From the chi-square table, the chi-square value of the significance level and the freedom degree is found.
6) Chi-square test statistic is calculated. In the Equation, it is expressed as O = "Objective Value" and E = "Expected Value".

$$X_h^2 = \sum \frac{(O - E)2}{E} \tag{3.2}$$

3.2 DEMATEL

The DEMATEL method was introduced by Battelle Memorial between 1972-1976. This method is generally recommended for solving complex and systematically challenging problems (Tzeng et al., 2010a).

DEMATEL, in determining the relations between the criteria determines which ones are affected and which are affecting, and allows a network of relations to be established based on this (Lin et al. 2009). It examines and determines the effect of factors on each other in order to examine the effect of the decision maker on the decision (Rochimah, 2013a). With DEMATEL, it is possible to calculate the weights of the criteria and sort them according to the level of importance (Karaoğlan, 2016).

In this study, DEMATEL method was used to determine the weights of agile-sustainable criteria. The steps required to implement this method are as follows:

Step 1 Determination of direct relation matrix, called the *A* matrix. This matrix is obtained from the expert and the score of each affecting criterion is calculated. The decision maker assigns a score between 0 and 4 to represent the effect of each decision criterion on other decision criteria. The linguistic scale is given in Table 3.2.

Table 3.2 Comparison scale (Tzeng et al., 2010b)

0	No influence
1	Low influence
2	Moderate influence
3	Strong influence
4	Extreme strong influence

Step 2 Direct relation matrix is normalized to obtain the D matrix using the following formula (Hsu et al., 2012).

$$D = s.A, \text{ where} \tag{3.3}$$

$$s = min\left[\frac{1}{max_{1\le i\le n}\sum_{j=1}^{n}|a_{ij}|}, \frac{1}{max_{1\le i\le n}\sum_{i=1}^{n}|a_{ij}|}\right]$$

Step 3 The total relation matrix - *T* is calculated using the following formula (Rochimah, 2013b).

$$T = D(I-D)^{-1} \tag{3.4}$$

Step 4 Cause and effect values, respectively "*D*" and "*R*", are calculated as follows:

$$D = \left[\sum_{i=1}^{n} t_{ij}\right]_{\text{ixn}} = \left[t_j\right]_{\text{nx1}} \tag{3.5}$$

$$R = \left[\sum_{j=1}^{n} t_{ij}\right]_{\text{ixn}} = \left[t_j\right]_{\text{1xn}} \tag{3.6}$$

D+*R* and *D*-*R* vectors are shown in the diagram to be created. *D*+*R* is shown on the horizontal axis and these values are called "significance" while *D*-*R* is shown on the vertical axis and these values are called "relation" (Rochimah, 2013c).

Step 5 The importance weights of each criterion are calculated. The following equation is used for the calculation (Dalalah et al., 2011).

$$W_{\text{i}} = [(D_{\text{i}} + R_{\text{i}})^2 + (D_{\text{i}} - R_{\text{i}})^2]^{1/2} \tag{3.7}$$

Step 6 The weights found in step 5 are normalized using the following formula:

$$w_i = \frac{w_i}{\sum_{i=1}^{n} w_i} \tag{3.8}$$

3.3 TOPSIS

In this study, after the criteria are weighted with DEMATEL, the alternatives will be ranking using TOPSIS. TOPSIS was proposed by Yoon and Hwang (Yoon & Hwang, 1981). The TOPSIS method calculates the relative closeness of the alternatives to the ideal solution using Euclidean distance. In this way, a preference order can be formed by comparing the relative closeness of the alternatives (Cheng & Huang, 2002).

TOPSIS process steps are as follows:

Step 1 Evaluation matrix $(a_{ij})_{mxn}$. It consists of m alternatives and n criteria, and the intersection of each alternative and the given criteria are formed by α_{ij}.

$$A_{ij} = \begin{bmatrix} a_{11} & a_{12} & \ldots & a_{1n} \\ a_{21} & a_{22} & \ldots & a_{2n} \\ . & . & . & . \\ . & . & . & . \\ a_{m1} & a_{m2} & . & a_{mn} \end{bmatrix} \tag{3.9}$$

Step 2 The matrix is normalized using column normalization.

$$r_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{m} a_{ij}^2}} \tag{3.10}$$

$$R_{ij} = \begin{pmatrix} r_{11} & r_{12} & \ldots & r_{1n} \\ r_{21} & r_{22} & \ldots & r_{2n} \\ . & . & . & . \\ r_{m1} & r_{m2} & . & r_{mn} \end{pmatrix}$$

Step 3 Normalized weighted matrix is calculated using the weights w_{ij} found with DEMATEL

$$V_{ij} = \begin{pmatrix} w_1r_{11} & w_2r_{12} & \dots & w_nr_{1n} \\ w_1r_{21} & w_2r_{22} & \dots & w_nr_{2n} \\ . & . & . & . \\ w_1r_{m1} & w_2r_{m2} & \dots & w_nr_{mn} \end{pmatrix} \quad (3.11)$$

Step 4 While the positive ideal solution consists of the best values of the weighted normalization decision matrix, the negative ideal solution consists of the worst values (Shyjith et al., 2008). In both Equations, J represents the benefit type criteria set and J' cost type criteria set (Monjezi et al. 2010a).

$$A^* = \{(max_i v_{ij} | j \in J\ ) min_i v_{ij} | j \in J'\} \quad (3.12)$$

$$A^- = \{(min_i v_{ij} | j \in J\ ) max_i v_{ij} | j \in J'\} \quad (3.13)$$

Step 5 The distance between alternatives is measured. The distance of each alternative from the ideal and negative-ideal solution is calculated (Monjezi et al., 2010b).

$$S_i^+ = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^+)^2} \quad (3.14)$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2} \quad (3.15)$$

Step 6 The relative closeness (*Ci*)* to the ideal solution is calculated using the following equation (Monjezi et al., 2010c).

$$C_i^+ = \frac{S_i^-}{S_i^- + i} \tag{3.16}$$

4. PROPOSED MODEL

This study proposes a new perspective to the literature by selecting suppliers with an agile-sustainable approach. The steps of the model proposed in this study are explained below.

Step 1 Determining agile-sustainable criteria

In the first step of the model conducted in this study, the most used agile-sustainable criteria in the determination of agile-sustainable criteria were determined by literature review. In the next stage, the criteria determined in the literature review were evaluated by 3 purchasing specialists working at Türk Traktör in Sakarya. As a result of the evaluation, some criteria were removed and some criteria were added.

Step 2 The Relationship between agile criteria and sustainable criteria

In the second step of the model, we evaluated the relationship between agile dimension sub-criteria and sustainability dimension sub-criteria with the chi-square independence test.

Process steps in The Relationship Between Agile Criteria and Sustainable Criteria:

- Two surveys were directed to experts.
- First of the survey, does agile have a positive effect on the selection of the sustainability sub-criteria?
- In the second of the survey, what is the degree of application of the agile sub-criteria in the suppliers of the automotive sector, where the application is made?
- To perform a chi-square independence test, conducted a hypothesis test.
- According to the results of the survey, determine whether there is a dependence or independence relationship between the sustainability sub-criteria of agile sub-criteria.

- Contingency Coefficient was used to measure the correlation relationship between dependence criteria.

The Chi-Square independence test was performed using the IBM-SPSS program.

Step 3 Weighting of criteria

In the third step of the model, the criteria were weighted using the DEMATEL method.

Step 4 Identifying product and supplier's

One product was determined by taking advantage of expert opinions. After the product was determined, 3 suppliers were determined to supply this product.

Step 5 Ranking of alternatives

In the fourth step of the model, after the criteria were weighted, the TOPSIS method was applied and the best supplier was determined by ranking among the 3 suppliers.

The flow chart of the proposed model for this study is presented in Figure 4.1.

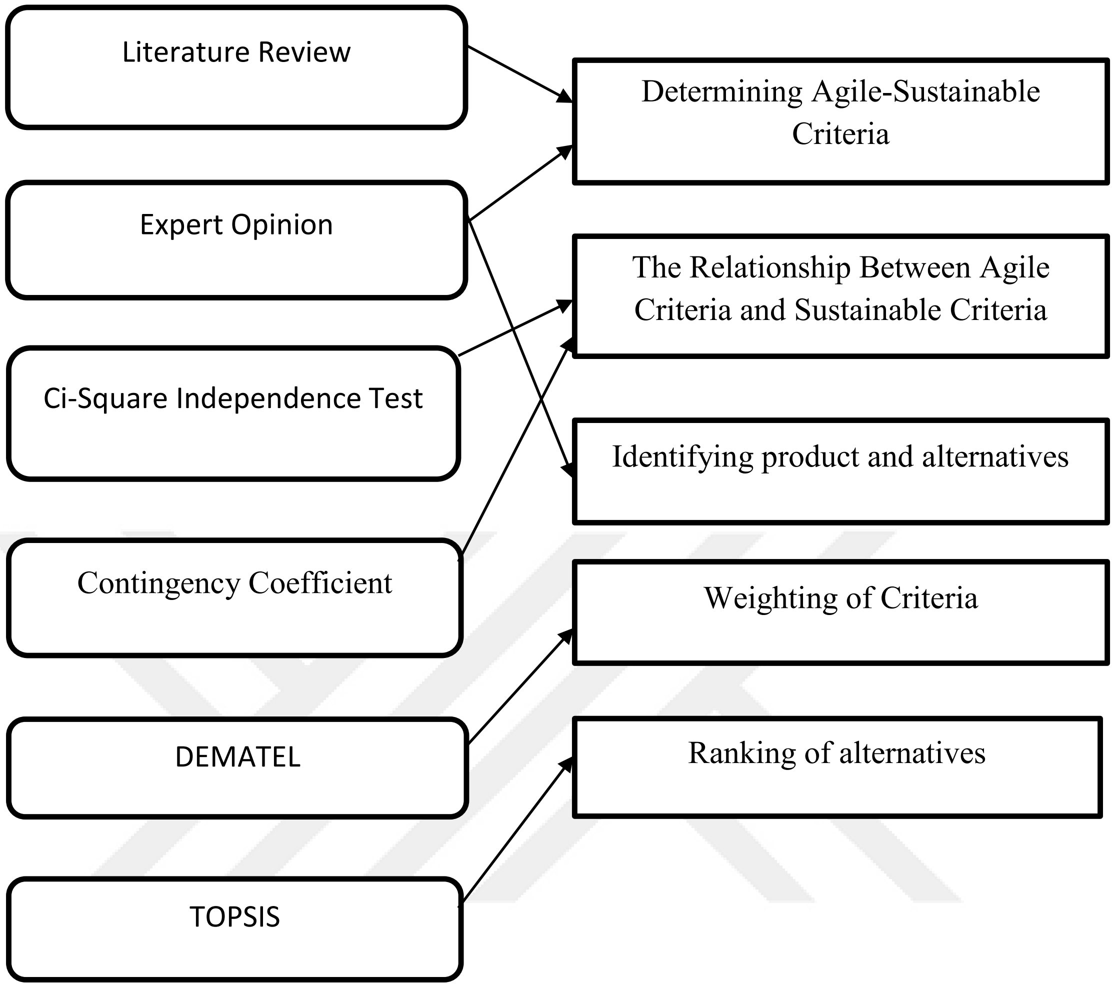

Figure 4.1 Flow chart of proposed model

5. APPLICATION

In this study, when the literature is examined, there is no study on the agile-sustainable approach to supplier selection. For these reasons, the criteria including these dimensions were determined by a literature review. In the next stage, the criteria were evaluated and finalized by 3 purchasing specialists at Türk Traktör, where the application was made. The determined criteria are given below with their definitions.

Table 5.1 Evaluation of criteria

Dimensions	Main Criteria	Sub-Criteria	Definition
Economical	Cost (C_1)	Product Price (C_{11})	This criterion is monetary value of the material purchased or to be received from the supplier is the equivalent.
		Discount (C_{12})	This criterion expresses the price decrease in the product.
		Transportation Cost (C_{13})	This criterion is the sum of the fixed and variable costs in transportation of the material.
	Quality (C_2)	Technical Capability (C_{21})	This criterion expresses the capacity to make the desired product.
		Reputation (C_{22})	This criterion expresses the quality of the product produced by the supplier. If it produces good products, its reputation is just as good.
	Service (C_3)	Delivery Time (C_{31})	This criterion expresses how long it takes for the product to reach the company.
		Geographical Location (C_{32})	This criterion expresses the distance of the supplier to the company.

Environmental	Environmental Management (C_4)	Environmental Certification (C_{41})	This criterion expresses as obtaining certifications by complying with certain standards and rules that monitor and manage the environmental effects of all processes of the supplier company.
		Environmental Protection Policies (C_{42})	This criterion expresses as less use of the products used by the supplier company and the use of recyclable products.
	Pollution Reduction (C_5)	Air Emissions (C_{51})	This criterion expresses as air pollutants emitted into the air by burning fuel and similar derivatives in the manufacturing facility of the supplier company.
		Waste Water (C_{52})	This criterion expresses as the water discharged after being used in the production facility of the supplier company.
		Solid Waste (C_{53})	This criterion expresses as environmentally harmful and non-nature-friendly waste remaining after being used in the production facility of the supplier company.

Social	Safety and Health Management (C_6)	Occupational Health and Safety (OHS) Management (C_{61})	This criterion expresses as the systematic adoption of a continuous improvement approach in line with the occupational health and safety activities of the supplier company.
		Health and Safety Practices (C_{62})	This criterion expresses as the security procedures and activities that the supplier company provides to its employees and customers.
Agile	Technology (C_7)	System Reliability (C_{71})	This criterion expresses as the ERP systems used by the supplier company.
		Future Technology Developments (C_{72})	This criterion expresses the developments that will improve the production system that the supplier company plans to make in the future or is about to put into use.
	Flexibility (C_8)	Production Flexibility (C_{81})	This criterion expresses how well the supplier company can keep up with the order according to the customer.
		Production Volume Flexibility (C_{82})	This criterion expresses how much the supplier company can change its daily production.

After the criteria were determined, two surveys were directed to 33 purchasing experts. First of these surveys, does agile have a positive effect on the selection of each sustainable criterion? For example, "Agile has a positive effect on product price selection" is in the form. The answers were divided into 3 groups by applying a Likert scale (“Disagree” = 1, “I’m undecided” = 3, “I agree” = 5).

In the second survey, what is the degree of application of the agile sub-criteria in the suppliers that the company works with? For example, "What is the degree of application of system reliability in supplier companies?" is in the form. The answers were divided into 3 groups by applying a Likert scale (“Low” = 1, “Medium” = 3, “High” = 5).

In order to test the relationship between the results of these two surveys, the chi-square independence test was conducted. Figure 5.1 shows the relationship between the sub-criteria that depend on the main criteria.

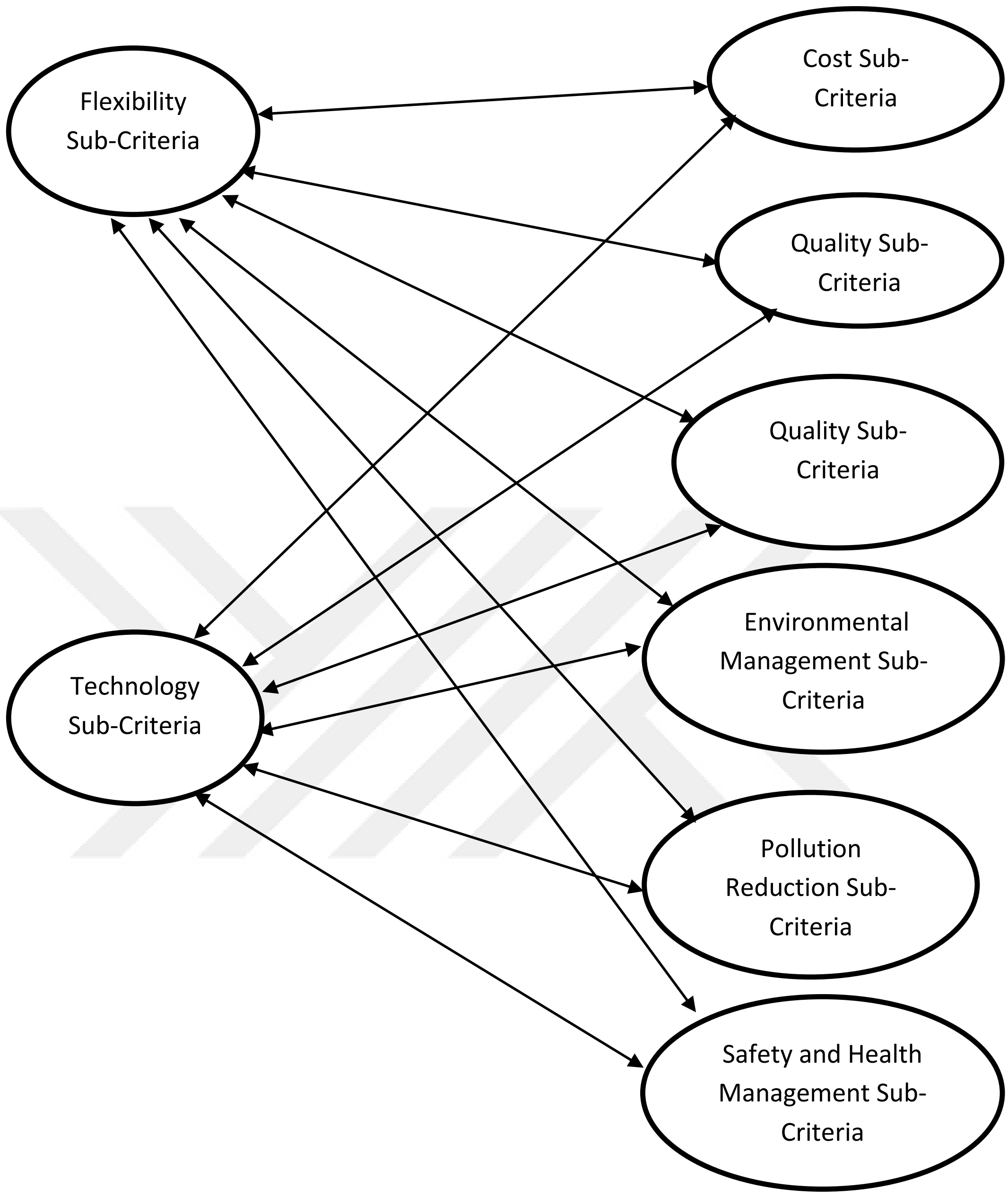

Figure 5.1 Dependence and independence relationship model of sub-criteria

Before the test, a hypothesis test was conducted for each criterion between the sub-criteria of the agile dimension and the sub-criteria of the sustainability dimension. For example,

H_o = “System Reliability and Product Price are independent."

H_1 = “System Reliability and Product Price are dependent.”

Since the agile dimension has 4 sub-criteria and the sustainability dimension has 14 sub-criteria, a total of 14*4 = 56 tests were carried out.

If more than 20% of our groups have expected values less than 5, the Fisher Exact test is used. But the fisher exact test is valid in 2*2 tables. The table of this model is 3*3. That's why Fisher Freeman Halton exact test should be used.

Chi-Square Independence test results are shown in Table 5.2. The "✓" indicates the dependence between the criteria. Contingency Coefficient was used to measure the correlation relationship between dependence criteria. The correlation level of the criteria is shown in Table 5.3. At the relationship level;

"Very Weak" (VW) = (-0.25) - 0 - 0 - 0.25,
"Weak" (W) = (-0.49) - (-0.26) - 0.26 - 0.49,
"Middle" (M) = (-0.69) - (-0.50) - 0.50 - 0.69,
"Strong" (S) = (-0.89) - (-0.70) - 0.70 - 0.89,
"Very Strong" (VS) = (-1.00) - (-0.90) - 0.90 - 1.00
indicated at intervals (Ersöz & Ersöz, 2017b).

Table 5.2 Dependence among sub-criteria according to Chi-Square independence test

		C_7		C_8	
		C_{71}	C_{72}	C_{81}	C_{82}
C_1	C_{11}				
	C_{12}	✓	✓	✓	✓
	C_{13}	✓	✓	✓	
C_2	C_{21}	✓		✓	✓
	C_{22}	✓	✓	✓	✓
C_3	C_{31}	✓	✓	✓	✓
	C_{32}	✓	✓	✓	✓
C_4	C_{41}				
	C_{42}				
C_5	C_{51}				
	C_{52}				
	C_{53}	✓			✓
C_6	C_{61}				
	C_{62}	✓			✓

In the test performed at the 95% confidence level, values with a P value less than 0.05 were found to be significant, so the H_1 hypothesis was accepted. In the criteria with independent relationship, H_o hypothesis test and its derivatives (H_{Oa}, H_{ob} etc.) are rejected and H_1 hypothesis test and its derivatives (H_{1a}, H_{1b}, etc.) are accepted. While 26 H_1 tests and their derivatives were accepted in total, 30 H_o tests and their derivatives were accepted. Looking at Table 5.2, it is seen that agile dimension sub-criteria are in a dependent relationship with economic dimension sub-criteria, apart from the product price criterion. If we look at the relationship between the agile dimension and the environmental dimension; while there is a dependent relationship between solid waste-system reliability and solid waste-production volume flexibility, there is an independent relationship between other sub-criteria. In the relationship between the agile dimension and the social dimension; there is a dependent relationship between safety and health practices-system reliability and safety and health practices-production volume flexibility.

Table 5.3 Level of correlation between dependent criteria

		C7		**C8**	
		C71	**C72**	**C81**	**C82**
C1	**C11**				
	C12	0,573 (M)	0,515 (M)	0,474 (W)	0,582 (M)
	C13	0,657 (M)	0,538 (M)	0,604 (M)	
C2	**C21**	0,536 (M)		0,572 (M)	0,535 (M)
	C22	0,615 (M)	0,541 (M)	0,593 (M)	0,568 (M)
C3	**C31**	0,592 (M)	0,508 (M)	0,565 (M)	0,648 (M)
	C32	0,535 (M)	0,538 (M)	0,626 (M)	0,541 (M)
C4	**C41**				
	C42				
C5	**C51**				
	C52				
	C53	0,441 (W)			0,386 (W)
C6	**C61**				
	C62	0,476 (W)			0,354 (W)

As can be seen in Table 5.3, all sub-criteria except discount-production flexibility, solid waste-system reliability, solid waste-production volume flexibility, safety and health practices-system reliability, safety and health practices-production volume flexibility have a moderate correlation relationship other criteria have a low correlation relationship.

The dependence relationship of the criteria was determined, the DEMATEL was used to determine the weights of criteria. The direct relation matrix is shown below.

Table 5.4 Direct Relation Matrix

		C_1			C_2		C_3		C_4		C_5		C_6			C_7		C_8	
		C_{11}	C_{12}	C_{13}	C_{21}	C_{22}	C_{31}	C_{32}	C_{41}	C_{42}	C_{51}	C_{52}	C_{53}	C_{61}	C_{62}	C_{71}	C_{72}	C_{81}	C_{82}
C_1	C_{11}	0	1	2	1	2	2	2	1	1	1	0	1	0	0	0	0	0	0
	C_{12}	4	0	3	1	2	1	1	0	0	0	0	0	0	0	2	2	1	2
	C_{13}	3	1	0	0	1	3	3	1	1	1	0	0	1	1	2	2	2	0
C_2	C_{21}	3	3	2	0	3	2	1	3	3	3	3	3	2	2	2	0	2	2
	C_{22}	3	2	1	2	0	1	1	2	2	2	2	2	2	2	2	2	2	2
C_3	C_{31}	2	2	3	1	3	0	2	0	0	2	1	1	1	1	2	2	2	2
	C_{32}	4	1	4	1	1	4	0	3	3	3	3	3	2	2	2	2	2	2
C_4	C_{41}	2	0	1	2	3	1	1	0	4	4	4	4	3	4	0	0	0	0
	C_{42}	2	1	2	1	2	1	1	4	0	4	4	4	3	2	0	0	0	0
C_5	C_{51}	1	0	3	1	3	3	2	3	3	0	2	2	3	3	0	0	0	0
	C_{52}	1	0	1	0	3	1	1	3	3	2	0	2	3	3	0	0	0	0
	C_{53}	1	0	1	1	3	1	1	3	3	2	1	0	3	3	1	0	0	1
C_6	C_{61}	1	0	1	1	3	1	0	2	2	2	2	2	0	4	0	0	0	0
	C_{62}	1	0	1	1	3	1	0	2	2	3	3	3	4	0	1	0	0	1
C_7	C_{71}	0	2	2	2	2	2	2	0	0	0	0	1	0	1	0	2	2	2
	C_{72}	0	2	2	0	2	2	2	0	0	0	0	0	0	0	3	0	3	3
C_8	C_{81}	0	1	2	2	2	2	2	0	0	0	0	0	0	0	2	2	0	4
	C_{82}	0	2	0	2	2	2	2	0	0	0	0	1	0	1	2	2	3	0

According to the results obtained in the chi-square independence test, the criteria that do not have a dependent relationship were assigned a value of 0, that is, "no influence", in the DEMATEL. The criteria that are in a dependence relationship with each other are assigned values according to the degree of dependence obtained in the contingency coefficient test.

D matrix is obtained by using Eq. (3.3). The table is shown below.

Table 5.5 The D Matrix

		C_1			C_2		C_3		C_4		C_5			C_6		C_7		C_8	
		C_{11}	C_{12}	C_{13}	C_{21}	C_{22}	C_{31}	C_{32}	C_{41}	C_{42}	C_{51}	C_{52}	C_{53}	C_{61}	C_{62}	C_{71}	C_{72}	C_{81}	C_{82}
C_1	C_{11}	0,00	0,03	0,04	0,03	0,04	0,04	0,06	0,03	0,03	0,02	0,01	0,02	0,01	0,00	0,00	0,00	0,00	0,00
	C_{12}	0,10	0,00	0,07	0,03	0,05	0,03	0,03	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,05	0,05	0,03	0,05
	C_{13}	0,09	0,03	0,00	0,01	0,03	0,09	0,07	0,02	0,02	0,03	0,01	0,01	0,02	0,02	0,05	0,05	0,05	0,00
C_2	C_{21}	0,09	0,07	0,04	0,00	0,09	0,06	0,03	0,07	0,07	0,07	0,07	0,07	0,06	0,06	0,05	0,00	0,05	0,05
	C_{22}	0,08	0,06	0,03	0,05	0,00	0,03	0,02	0,04	0,04	0,04	0,04	0,04	0,04	0,04	0,05	0,05	0,05	0,05
C_3	C_{31}	0,06	0,05	0,09	0,03	0,08	0,00	0,04	0,01	0,01	0,04	0,03	0,03	0,02	0,02	0,05	0,05	0,05	0,05
	C_{32}	0,09	0,03	0,10	0,03	0,03	0,10	0,00	0,08	0,07	0,08	0,07	0,07	0,06	0,06	0,05	0,05	0,05	0,05
C_4	C_{41}	0,05	0,01	0,03	0,04	0,09	0,03	0,03	0,00	0,10	0,09	0,09	0,09	0,09	0,09	0,00	0,00	0,00	0,00
	C_{42}	0,06	0,03	0,06	0,03	0,06	0,03	0,03	0,10	0,00	0,09	0,09	0,09	0,08	0,06	0,00	0,00	0,00	0,00
C_5	C_{51}	0,03	0,00	0,08	0,02	0,07	0,07	0,04	0,09	0,09	0,00	0,04	0,04	0,07	0,07	0,00	0,00	0,00	0,00
	C_{52}	0,03	0,01	0,03	0,01	0,07	0,03	0,03	0,09	0,09	0,05	0,00	0,05	0,07	0,07	0,00	0,00	0,00	0,00
	C_{53}	0,03	0,01	0,03	0,02	0,07	0,02	0,03	0,09	0,09	0,05	0,02	0,00	0,07	0,07	0,03	0,00	0,00	0,03
C_6	C_{61}	0,03	0,00	0,02	0,03	0,07	0,03	0,01	0,05	0,06	0,05	0,05	0,04	0,00	0,10	0,01	0,00	0,00	0,01
	C_{62}	0,03	0,00	0,03	0,02	0,07	0,03	0,00	0,06	0,06	0,07	0,07	0,07	0,09	0,00	0,03	0,00	0,00	0,03
C_7	C_{71}	0,00	0,05	0,05	0,05	0,05	0,05	0,05	0,00	0,00	0,00	0,00	0,03	0,00	0,03	0,00	0,06	0,06	0,06
	C_{72}	0,00	0,05	0,05	0,00	0,05	0,05	0,05	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,07	0,00	0,08	0,07
C_8	C_{81}	0,00	0,03	0,05	0,05	0,05	0,05	0,05	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,04	0,04	0,00	0,09
	C_{82}	0,00	0,05	0,00	0,05	0,05	0,05	0,05	0,00	0,00	0,00	0,00	0,03	0,00	0,03	0,05	0,06	0,08	0,00

T matrix is obtained by using the Eq. (3.4). The table is shown below.

Table 5.6 The T Matrix

		C_1			C_2		C_3		C_4		C_5			C_6		C_7		C_8	
		C_{11}	C_{12}	C_{13}	C_{21}	C_{22}	C_{31}	C_{32}	C_{41}	C_{42}	C_{51}	C_{52}	C_{53}	C_{61}	C_{62}	C_{71}	C_{72}	C_{81}	C_{82}
C_1	C_{11}	0,06	0,07	0,10	0,06	0,11	0,10	0,10	0,09	0,09	0,07	0,06	0,07	0,06	0,05	0,04	0,03	0,03	0,04
	C_{12}	0,17	0,05	0,14	0,08	0,13	0,11	0,09	0,07	0,07	0,07	0,06	0,06	0,06	0,06	0,10	0,09	0,08	0,10
	C_{13}	0,16	0,08	0,08	0,06	0,13	0,16	0,13	0,08	0,08	0,10	0,07	0,07	0,08	0,08	0,10	0,10	0,10	0,06
C_2	C_{21}	0,22	0,15	0,17	0,09	0,25	0,18	0,14	0,20	0,20	0,19	0,18	0,19	0,18	0,19	0,13	0,07	0,12	0,13
	C_{22}	0,17	0,12	0,13	0,11	0,13	0,13	0,10	0,14	0,14	0,13	0,12	0,13	0,13	0,13	0,12	0,10	0,11	0,12
C_3	C_{31}	0,15	0,11	0,17	0,08	0,18	0,09	0,12	0,09	0,09	0,12	0,09	0,10	0,09	0,09	0,12	0,11	0,11	0,11
	C_{32}	0,23	0,12	0,24	0,11	0,22	0,23	0,11	0,21	0,20	0,21	0,18	0,19	0,19	0,19	0,14	0,12	0,13	0,14
C_4	C_{41}	0,17	0,07	0,15	0,11	0,24	0,13	0,12	0,14	0,24	0,22	0,20	0,21	0,21	0,22	0,07	0,05	0,05	0,06
	C_{42}	0,18	0,09	0,17	0,10	0,21	0,13	0,11	0,23	0,13	0,21	0,20	0,20	0,20	0,18	0,07	0,05	0,05	0,06
C_5	C_{51}	0,13	0,06	0,17	0,08	0,20	0,16	0,12	0,19	0,19	0,11	0,14	0,14	0,17	0,17	0,06	0,05	0,05	0,06
	C_{52}	0,12	0,06	0,11	0,06	0,18	0,10	0,10	0,18	0,18	0,15	0,09	0,14	0,16	0,17	0,05	0,04	0,04	0,05
	C_{53}	0,13	0,06	0,12	0,08	0,19	0,10	0,10	0,18	0,18	0,15	0,11	0,10	0,16	0,17	0,09	0,04	0,05	0,09
C_6	C_{61}	0,12	0,05	0,09	0,08	0,17	0,10	0,07	0,14	0,15	0,14	0,13	0,13	0,09	0,19	0,06	0,03	0,04	0,05
	C_{62}	0,12	0,05	0,12	0,08	0,19	0,11	0,07	0,16	0,16	0,16	0,15	0,16	0,18	0,10	0,09	0,04	0,04	0,08
C_7	C_{71}	0,07	0,10	0,12	0,10	0,14	0,13	0,11	0,06	0,06	0,06	0,05	0,08	0,05	0,08	0,06	0,11	0,11	0,12
	C_{72}	0,06	0,10	0,11	0,04	0,12	0,12	0,10	0,04	0,04	0,04	0,04	0,04	0,04	0,04	0,12	0,05	0,13	0,12
C_8	C_{81}	0,06	0,08	0,11	0,09	0,13	0,12	0,10	0,05	0,05	0,05	0,04	0,05	0,04	0,05	0,10	0,09	0,05	0,14
	C_{82}	0,07	0,10	0,07	0,10	0,13	0,12	0,10	0,05	0,05	0,05	0,05	0,08	0,05	0,08	0,11	0,10	0,13	0,06

D and *R* parameters is obtained using Eqs. (3.5-3.6). The table is shown below.

Table 5.7 The Table of D and R Parameters

	D	R	D+R	D-R
C_{11}	1,241	2,371	3,611	-1,130
C_{12}	1,580	1,185	2,765	0,395
C_{13}	1,726	1,930	3,656	-0,204
C_{21}	2,980	1,276	4,256	1,704
C_{22}	2,259	2,556	4,815	-0,297
C_{31}	2,011	1,911	3,922	0,100
C_{32}	3,177	1,126	4,303	2,051
C_{41}	2,689	1,962	4,651	0,727
C_{42}	2,554	1,985	4,539	0,569
C_{51}	2,241	2,011	4,252	0,230
C_{52}	1,988	1,785	3,773	0,202
C_{53}	2,084	1,867	3,951	0,217
C_{61}	1,820	2,033	3,853	-0,214
C_{62}	2,046	2,016	4,062	0,030
C_{71}	1,617	1,242	2,860	0,375
C_{72}	1,354	1,787	3,142	-0,433
C_{81}	1,406	1,640	3,046	-0,235
C_{82}	1,502	1,598	3,100	-0,095

The affected and affecting diagram is shown in such a way that the $D + R$ x axis forms the $D - R$ y axis. While creating the diagram, the value of 0.08, which is the average of the values of the total relationship matrix, was taken as the threshold value. The affected-affecting diagram is shown below.

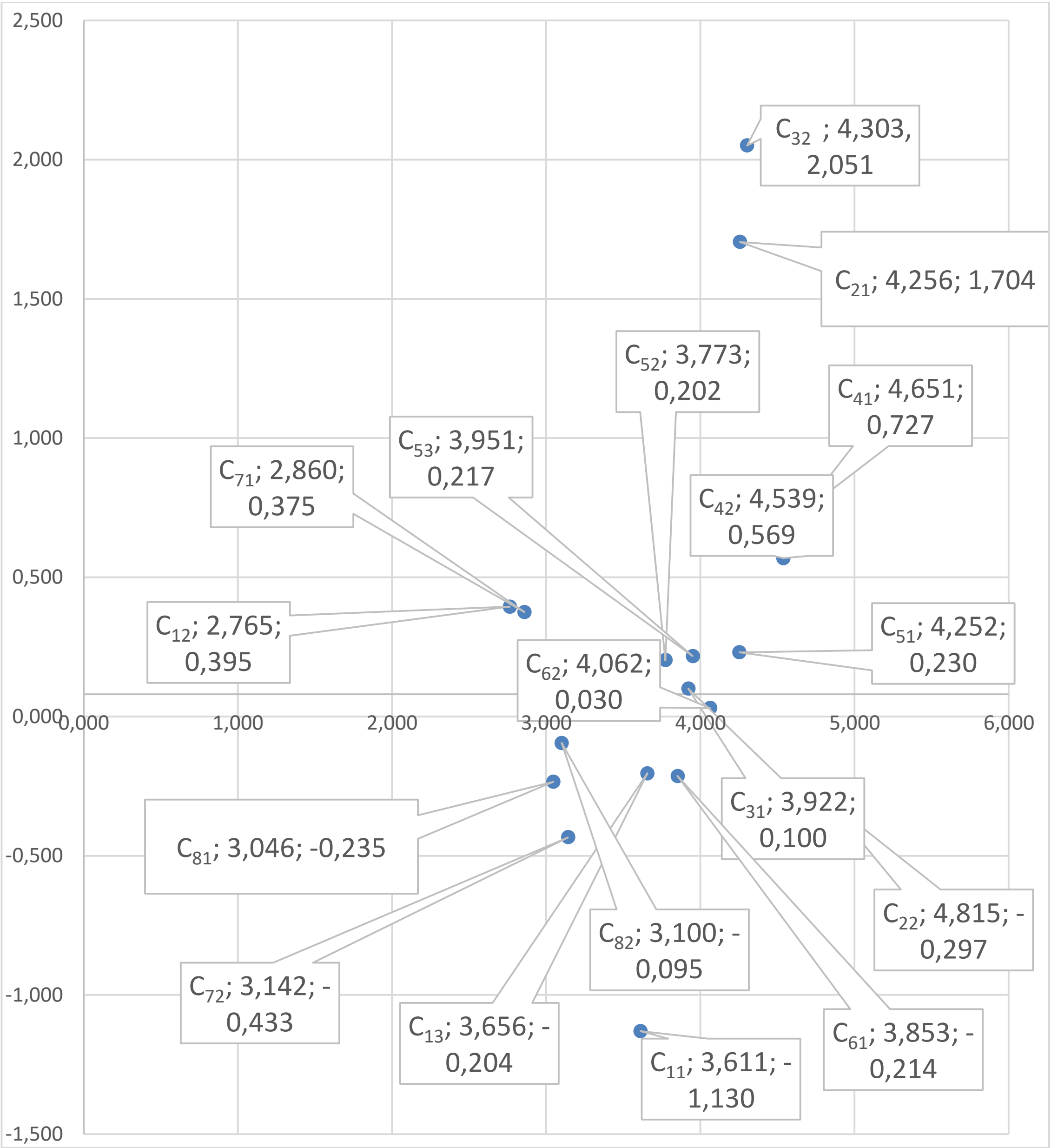

Figure 5.2 Affected-Affecting Diagram

It is seen that geographical location (C_{32}), technical capability (C_{21}), system reliability (C_{71}), solid waste (C_{53}), environmental certifications (C_{41}) environmental protection policies (C_{42}), discount (C_{12}), waste water (C_{52}), delivery time (C_{31}), air emissions (C_{51}) criteria are in the influencing group. When choosing a supplier, the company should pay more attention to these criteria compared to other criteria.

First calculated weights and normalized weights of each criterion are obtained by using Eqs. (3.7-(3.8).

Table 5.8 The Weight of Criteria

	Wi	**wi**
C_{11}	3,78	0,054
C_{12}	2,79	0,040
C_{13}	3,66	0,053
C_{21}	4,58	0,066
C_{22}	4,82	0,069
C_{31}	3,92	0,056
C_{32}	4,77	0,068
C_{41}	4,71	0,067
C_{42}	4,57	0,066
C_{51}	4,26	0,061
C_{52}	3,78	0,054
C_{53}	3,96	0,057
C_{61}	3,86	0,055
C_{62}	4,06	0,058
C_{71}	2,88	0,041
C_{72}	3,17	0,045
C_{81}	3,05	0,044
C_{82}	3,10	0,044

The weights of the criteria were determined and TOPSIS was used for alternative ranking.

In the first stage, a common product was determined. The specified product is the fuel tank. The 3 suppliers supplying this product were determined by 3 purchasing experts. Suppliers; EMPO Automotive (A_1), Floteks (A_2) and Cornaglia TR (A_3).

Actual data were found for some criteria in supplier evaluations. Experts were asked to evaluate the criteria for which real data could not be found. The criteria evaluated with 3 purchasing experts were evaluated according to the scale in table 5.9. This scale is a linguistic scale from 0-4. The linguistic scale is as follows:

Table 5.9 Evaluation Scale

Very Bad	0
Bad	1
Medium	2
Good	3
Very Good	4

The decision matrix is shown below.

Table 5.10 Decision Matrix

	0,05	**0,04**	**0,05**	**0,07**	**0,07**	**0,06**	**0,07**	**0,07**	**0,07**	**0,06**	**0,05**	**0,06**	**0,06**	**0,06**	**0,04**	**0,05**	**0,04**	**0,04**
	C	**B**	**C**	**B**	**B**	**C**	**C**	**B**	**B**	**C**	**C**	**C**	**B**	**B**	**B**	**B**	**B**	**B**
	C_{11} €	**C_{12} %**	**C_{13} ₺**	**C_{21}**	**C_{22}**	**C_{31}**	**C_{32} km**	**C_{41}**	**C_{42}**	**C_{51}**	**C_{52}**	**C_{53}**	**C_{61}**	**C_{62}**	**C_{71}**	**C_{72}**	**C_{81}**	**C_{82}**
A1	335	5	8000	3	2	2	187	2	2	2	2	2	3	3	3	3	3	3
A2	339	7	7850	3	3	3	177	3	2	2	2	2	2	3	3	2	3	3
A3	341	10	8200	2	3	2	187	3	3	3	3	3	3	3	4	4	3	3

The normalized matrix is obtained by using Eq. (3.10). The table is shown below.

Table 5.11 Normalized Matrix

	C_{11} €	**C_{12} %**	**C_{13} ₺**	**C_{21}**	**C_{22}**	**C_{31}**	**C_{32} km**	**C_{41}**	**C_{42}**	**C_{51}**	**C_{52}**	**C_{53}**	**C_{61}**	**C_{62}**	**C_{71}**	**C_{72}**	**C_{81}**	**C_{82}**
A1	0,6	0,4	0,6	0,6	0,5	0,5	0,6	0,5	0,5	0,5	0,5	0,5	0,6	0,5	0,5	0,6	0,5	0,5
A2	0,6	0,5	0,6	0,6	0,6	0,7	0,6	0,6	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,4	0,6	0,5
A3	0,6	0,8	0,6	0,5	0,6	0,5	0,6	0,7	0,7	0,7	0,7	0,7	0,7	0,7	0,7	0,7	0,6	0,7

The weighted normalized matrix is obtained by using Eq. (3.11). The table is shown below.

Table 5.12 Weighted Normalize Matrix

	C_{11} €	**C_{12} %**	**C_{13} ₺**	**C_{21}**	**C_{22}**	**C_{31}**	**C_{32} km**	**C_{41}**	**C_{42}**	**C_{51}**	**C_{52}**	**C_{53}**	**C_{61}**	**C_{62}**	**C_{71}**	**C_{72}**	**C_{81}**	**C_{82}**
A1	0,03	0,02	0,03	0,04	0,03	0,03	0,04	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,02	0,03	0,02	0,02
A2	0,03	0,02	0,03	0,04	0,04	0,04	0,04	0,04	0,03	0,03	0,03	0,03	0,03	0,03	0,02	0,02	0,03	0,02
A3	0,03	0,03	0,03	0,03	0,04	0,03	0,04	0,04	0,05	0,04	0,04	0,04	0,04	0,04	0,03	0,03	0,03	0,03

Ideal and ideal negative solutions are obtained by using Eqs. (3.12-3.13). The table is shown below.

Table 5.13 Ideal and ideal negative solutions

	C_{11} €	**C_{12} %**	**C_{13} ₺**	**C_{21}**	**C_{22}**	**C_{31}**	**C_{32} km**	**C_{41}**	**C_{42}**	**C_{51}**	**C_{52}**	**C_{53}**	**C_{61}**	**C_{62}**	**C_{71}**	**C_{72}**	**C_{81}**	**C_{82}**
A^*	0,03	0,03	0,03	0,04	0,04	0,03	0,04	0,04	0,05	0,03	0,03	0,03	0,04	0,04	0,03	0,03	0,03	0,03
A^-	0,03	0,02	0,03	0,03	0,03	0,04	0,04	0,03	0,03	0,04	0,04	0,04	0,03	0,03	0,02	0,02	0,02	0,02

The euclidean distance is obtained by using Eqs. (3.14-3.15). The euclidean distance is given below.

$$S_i^+ = \{0{,}0295;\ 0{,}0305;\ 0{,}0260\}$$

$$S_i^- = \{0{,}0301;\ 0{,}0277;\ 0{,}0350\}$$

Relative closeness measures for alternatives is obtained by using Eq. (3.16). Proximity ranking and alternatives according to the optimal results are shown in Table 5.14.

Table 5.14 Ranking by supplier score

Alternatives	**Relative Closeness to the Ideal Solution**	**Rank**
EMPO AUTOMOTIVE (A1)	0,50	2
FLOTEKS (A2)	0,48	3
CORNAGLIA TR (A3)	0,57	1

6. CONCLUSION

The constant change in the SC and the increase in responsiveness cause companies to attach importance to criteria in supplier selection. The concepts of agile and sustainability have come to the fore in recent years due to the social and environmental policies implemented by countries and their rapid response to them.

In this study, supplier selection was made considering the agile-sustainable dimensions. The place where the study was applied is Türk Traktör operating in Sakarya province. Although there are many studies on supplier selection in the literature, the study that considers agile-sustainable dimensions and selects suppliers has been ignored in the literature.

First stage of the study, a large scale literature review was conducted and agile-sustainable criteria were determined. After the criteria were determined, the criteria were evaluated with 3 purchasing experts. While the criteria that are suitable for the supplier selection policy of the company were added to the list, unsuitable criteria were removed. After all evaluations regarding the criteria were made, 8 main criteria and 18 sub-criteria were determined.

In the second stage of the study, two surveys were directed to 33 purchasing specialists. While the first of these surveys is selecting sustainable criteria, does agile have a positive effect on these criteria. The other survey is what is the degree of application of the criteria belonging to the agile dimension in the supplier companies where the company works. The answers given to the survey questions were grouped according to the Likert scale.

Chi-square independence test and correlation test were performed. Considering the findings, while the agile dimension's dependence to the environment and social dimension is low, the economic dimension's dependence is quite high.

In the correlation between agile and sustainable sub-criteria, while the relationship between solid waste-system reliability, solid waste-production volume flexibility, safety health practices-system reliability, safety health practices-production volume flexibility and discount-production flexibility sub-criteria was weak, the relationship level of the remaining sub-criteria was tested as medium.

In the third stage of the study, the DEMATEL was used to determine the weights of the criteria. DEMATEL takes into account bilateral relations and gives more efficient results in complex problems. Considering the results of the chi-square independence test, the degree of influence of the criteria that are not related to each other is given as low.

In the last stage, the ranking of the alternatives was made using the TOPSIS. First, a common product is determined. The name of the designated product is the fuel tank. 3 suppliers have been determined to supply this product. These suppliers are; EMPO Automotive, Floteks and Cornaglia TR. After the TOPSIS process steps were applied, it was determined that ideal supplier for the company was Cornaglia TR.

In future research, this model could be applied in different fields and according to the data obtained, evaluations can be made according to research in other fields. By using the DEMATEL-ANP, the study supplier can be selected and the study can be advanced. As long as appropriate data are provided, supplier selection can be made in a fuzzy environment.

REFERENCES

Akman, G., (2015). Evaluating suppliers to include green supplier development programs via fuzzy c-means and VIKOR methods. *Computers & Industrial Engineering*: 86: 69-82.

Alamroshan, F., La'li, M., Yahyaei, M., (2022). The green supplier selection problem for the medical devices: a hybrid fuzzy decision making approach. *Environmental Science and Pollution Research*: 29: 6793-6811.

Alimardani, M., Hashemkhani, S., Aghdaie MH., Tamosaitiene J., (2013). A novel hybrid SWARA and VIKOR methodology for supplier selection in an agile environment. *Technological and Economic Development of Economy:* 19(3): 533-548.

Amindoust, A., Ahmed, S., Saghafinia, A., Bahreininejad, A., (2012). Sustainable supplier selections: a ranking model based on fuzzy inference system. *Applied Soft Computing:*12(6): 1668-1677.

Amiri, M., Hashemi-Tabatabaei, M., Ghahremanloo, M., Keshavarz-Ghorabaee, M., Zavadskas, E., Banait, A., (2020). A new fuzzy BWM approach for evaluating and selecting a sustainable supplier in supply chain management. *International Journal of Sustainable Development & World Ecology:* 28(2): 125-142.

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

Bai, C.A., Sarkis, J., (2010). Integrating sustainability into supplier selection with grey system and rough set methodologies. *International Journal of Production Economics*: 124(1): 252-264.

Beikkhakhian, Y., Javanmardi M., Karbasian, M., Khayambashi, B., (2015). The application of ISM model in evaluating agile suppliers selection criteria and ranking suppliers using fuzzy TOPSIS-AHP methods. *Expert Systems with Applications*: 42: 6224-6236.

Benn, S., Edwards, M., Williams, T., (2014). Organizational Change for Corporate Sustainability, third edn, Routledge Publication.

Chen, C.T., Lin, C.T., Huang, S.F., (2002). A fuzzy approach for supplier evaluation and selection in supply chain management. *International Journal of Production Economics*: 102: 289-301.

Ciccullo, F., Pero, M., Caridi, M., Gosling, J., Purvis, L., (2018). Integrating the environmental and social sustainability pillars into the lean and agile supply chain management paradigms: a literature review and future research directions. *Journal of Cleaner Production:* 172: 2336-2350.

Çalık, A., (2021). A novel Pythagorean fuzzy AHP and fuzzy TOPSIS methodology for green supplier selection in the industry 4.0 era. *Soft Computing*: 25: 2253-2265.

Dalalah, D., Hajahneh, M., Batieha, F. (2011). A fuzzy multi-criteria decision making model for supplier selection. *Expert Systems with Applications*: 38: 8384-8391.

De Vargas Mores, G., Finocchio, CPS., Barichello R., Pedrozo, EA., (2018). Sustainability and innovation in the Brazilian supply chain of green plastic. *Journal of Cleaner Production:* 177: 12-18.

Ersöz, F., Ersöz, T., (2017). Uygulamalı istatistik yöntemler II, first edn, 72 Tasarım ltd,şti.

Galankashi, M.R., Helmi, S.A., (2016). Assessment of hybrid lean-agile (Leagile) supply chain strategies. *Journal of Manufacturing Technology Management*: 27(4): 470-482.

Ghayeblo, S., Tarokh, MJ., Venkatadri, U., Diallo, C., (2015). Developing a bi-objective model of the closed-loop supply chain network with green supplier selection and disassembly of products: the impact of parts reliability and product greenness on the recovery network. *Journal of Manufacturing Systems:* 36: 76-86.

Goker, N., Dursun, M., Cedolin, M., (2020). A novel IFCM integrated distance based hierarchical intuitionistic decision making procedure for agile supplier selection. *Journal of Intelligent & Fuzzy Systems*: 38(1): 653-662.

Govindan, K., Khodaverdi, R., Jafarian, A., (2013). A fuzzy multi criteria approach for measuring sustainability performance of a supplier based on triple bottom line approach. *Journal of Cleaner Production*: 47: 345-354.

Gupta, H., Barua, MK., (2017). Supplier selection among SMEs on the basis of their green innovation ability using BWM and fuzzy TOPSIS. *Journal of Cleaner Production:* 152: 242-258.

Hasan, M.A., Shankar, R., Sarkis, J., (2008). Supplier selection in an agile manufacturing environment using data envelopment analysis and analytical network process. *International Journal Logistics Systems and Management*: 4(5): 523-550.

Hsu, C. C. (2012). Evaluation criteria for blog design and analysis of causal relationships using factor analysis and DEMATEL. *Expert Systems with Applications*: 39(1): 187-193.

Hsu, C.W., Hu, A.H., (2009). Applying hazardous substance management to supplier selection using analytic network process. *Journal of Cleaner Production*: 17(2):255-264.

Hwang, C., Lai, Y., Liu, T., (1993). A new approach for multiple objective decision making. *Computer Operations Research*: 20(8): 889-899.

Hwang, C., Yoon, K., (1981). Multiple Attribute Decision Making: Methods and Applications. *A State-of-The-Art Survey, Springer-Verlag*: 20(3): 1145-1145.

Jahuar, S., Pant, M., (2017). Integrating DEA with DE and MODE for sustainable supplier selection. *Journal of Computational Science*: 21: 299-306.

Javad, M.O.M., Darvishi, M., Javad, A.O.M., (2020). Green supplier selection for the steel industry using BWM and fuzzy TOPSIS: a case study of Khouzestan steel company. *Sustainable Futures*: 2: 100012.

Kannan, D., Mina, H., Abarghooee, S., Khosrojerdi, G., (2020). Sustainable circular supplier selection. *A novel hybrid approach. Science of The Total Environment*: 722: 137936.

Karaoğlan, S., (2016). DEMATEL ve VIKOR yööntemleriyle dış kaynak seçimi: Otel işletmesi örneği. *Akademik Bakış Uluslararası Hakemli Sosyal Bilimler Dergisi*: 55: 9-24.

Khoshfetrat, S., Galanakashi, M.R., Almasi, M., (2020). Ssutainable supplier selection and order allocation: a fuzzy approach. *Engineering Optimization*: 52(9): 1494-1507.

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

Li, Y., Diabat, A., Lu, C-C., (2020). Leagile supplier selection in Chinese textile industries: a DEMATEL approach. *Annals of Operations Research*: 287: 303-322.

Lin, C.W., Chen, S.H., Tzeng, G.H., (2009). Constructing a cognition map of alternative fuel vehicles using the DEMATEL method. *Journal of Multi-Criteria Decision Analysis*: 16: 5-19.

Luthra, S., Govindan, K., Kannan, D., Mangla, S., Garg, C., (2017). An integrated framework for sustainable supplier selection and evaluation in supply chains. *Journal of*

Cleaner Production: 140(3):1686-1698.

Mahdiloo, M., Saen, R.F., Lee, K.H., (2015). Technical, environmental and eco-efficiency measurement for supplier selection: an extension and application of data envelopment analysis. *International Journal of Production Economics*: 168: 279-289.

Mangla, S.K., Kumar, P., Barua, M.K., (2014). Flexible decision approach for analyzing performance of sustainable supply chains under risks/uncertainty. *Global Journal of Flexible Systems Management*: 15(2): 113-130.

Memari, A., Dargi, A., Jokar, M., Ahmad, R., Rahim, A., (2019). Sustainable supplier selection: A multi-criteria intuitionistic fuzzy TOPSIS method. *Journal of Manufacturing Systems:* 50: 9-24.

Monjezi, M., Dehghani, H., Singh, T.N., Sayadi, A.R., Gholinejad, A., (2010). Application of TOPSIS method for selecting the most appropriate blast design. *Arabian Journal of Geosciences*: 1: 19-34.

Rochimah, S. (2013). Integration of DEMATEL and ANP methods for calculate the weight of characteristics software quality based model ISO 9126. *In 2013 International Conference on Information Technology and Electrical Engineering* (ICITEE), pp. 143-148.

Sarkis, J., Dhavale, D.G., (2015). Supplier selection for sustainable operations: a triple-bottom-line approach using a Bayesian framework. *International Journal of Production Economics*: 166: 177-191.

Shaw, K, Shankar, R., Yadav, S.S., Thakur, L.S., (2012). Supplier selection using fuzzy AHP and fuzzy multi-objective linear programming for developing low carbon supply chain. *Expert Systems With Applications*: 39(9): 8182-8192.

Shen, L., Olfat, L., Govindan, K., Khodaverdi, R., Diabat, A., (2013). A fuzzy multi criteria approach for evaluating green supplier's performance in green supply chain with linguistic preferences. *Resources, Conservation and Recycling:* 74: 170-179.

Shyjith, K., Ilangkumaran, M., Kumanan, S., (2008). Multi-criteria decision making approach to evaluate optimum maintenance strategy in textile industry. *Journal of Quality in Maintenance Engineering*: 14(4): 375-386.

Suraraksa, J., Shin, K.S., (2019). Comparative analysis of factors for supplier selection and monitoring: the case of the automotive in Thailand. *Sustainablity*: 11(4): 981.

Tong, L., Wang, J., Yi, J., (2021). Sustainable textile and apparel enterprise supplier selection research. *AATCC Journal of Research*: 8(1): 46-53.

Tzeng, G.H., Chen, W.H., Yu, R., & Shih, M.L. (2010). Fuzzy decision maps: a generalization of the DEMATEL methods. *Soft Computing*: 14(11): 1141-1150.

Yazdani, M., Chatterjee, P., Zavadskas, E.K., Zolfani, S.H., (2017). Integrated QFD-MCDM framework for green supplier selection. *Journal of Cleaner Production*: 142: 3728-3740.

Walton, S.V., Handfield, R.B., Melnyk, S.A., (1998). The green supply chain: integrating suppliers into environmental management processes. *International Journal of Purchasing and Materials Management*: 34(2): 2-11.

Wu, C., Barnes, D., (2009). A model for continuous improvement in supplier selection in agile supply chains. *Knowledge and Process Management*: 16: 85-110.

Wu, C., Barnes, D., (2014). Partner selection in agile supply chains: a fuzzy intelligent approach. *Production Planning & Control*: 25: 821-839.

Wu, C., Barnes, D., Rosenberg, D., Luo, X., (2009). An analytic network process-mixed integer multi-objective programming model for partner selection in agile supply chains. *Production Planning & Control*: 20: 2.

Wu, J., Jin, Y., Zhou, M., Cao, M., Liu, (2022). A group consensus decision making based sustainable supplier selection method by combing DEMATEL and VIKOR. *Journal of Intelligent & Fuzzy Systems*: 42(3): 2595-2613.

APPENDICES

Appendix A. (Literature Review)

Table AA.1 Literature Review Summary

Authors	DIMENSIONS			
	Economical	Environmental	Social	Agile
Walton et al. (1998)		X		
Hasan et al. (2008)	X			X
Hsu & Hu (2009)	X	X		
Lee et al. (2009)	X	X		
Wu et al. (2009)	X			X
Bai & Sarkis (2010)	X	X	X	
Shaw et al. (2012)	X	X	X	
Amindoust et al (2012)	X	X	X	
Shen et al. (2013)		X		
Govindan et al. (2013)	X	X	X	

Alimardani et al. (2013)	X			X
Wu & Barnes (2014)	X			X
Akman (2015)	X	X		
Sarkis & Dhavale (2015)	X	X	X	
Mahdiloo et al. (2015)		X		
Beikkhakhian et al. (2015)	X			X
Galankashi & Helmi (2016)	X			X
Jahuar & Pant (2017)	X	X	X	
Yazdani et al. (2017)	X	X		
Luthra et al. (2017)	X	X	X	
Banaeian et al. (2018)	X	X		
Memari et al. (2019)	X	X	X	
Suraraksa & Shin (2019)	X	X	X	
Javad et al. (2020)	X	X		
Khoshfetrat et al. (2020)	X	X	X	
Kannan et al. (2020)	X	X	X	

Li et al. (2020)	X			X
Göker et al. (2020)	X			X
Çalık (2021)	X	X		
Tong et al. (2021)	X	X	X	
Alamroshan et al. (2022)	X	X		X
Wu et al. (2022)	X	X	X	

Appendix B. (DEMATEL)

Table AB.1 DM1's direct relation matrix

		C_1			C_2		C_3		C_4		C_5			C_6		C_7		C_8	
		C_{11}	C_{12}	C_{13}	C_{21}	C_{22}	C_{31}	C_{32}	C_{41}	C_{42}	C_{51}	C_{52}	C_{53}	C_{61}	C_{62}	C_{71}	C_{72}	C_{81}	C_{82}
C_1	C_{11}	0	0	2	1	1	3	2	2	2	2	1	2	1	0	0	0	0	0
	C_{12}	4	0	2	1	1	3	2	1	1	1	1	1	1	1	2	2	1	2
	C_{13}	4	2	0	1	1	4	4	2	2	4	1	1	2	2	2	2	2	0
C_2	C_{21}	2	1	1	0	3	1	1	1	1	1	1	1	1	1	2	0	2	2
	C_{22}	3	1	1	2	0	1	1	3	3	3	3	3	3	3	2	2	2	2
C_3	C_{31}	3	1	4	1	3	0	4	1	1	2	1	1	1	1	2	2	2	2
	C_{32}	3	1	4	0	1	4	0	1	1	2	2	2	2	2	2	2	2	2
C_4	C_{41}	1	0	3	2	3	2	1	0	4	3	3	3	2	3	0	0	0	0
	C_{42}	1	1	2	1	2	2	1	4	0	3	3	3	2	2	0	0	0	0
C_5	C_{51}	1	0	3	1	2	3	2	3	3	0	1	1	2	2	0	0	0	0
	C_{52}	1	1	1	1	2	1	1	3	3	3	0	2	2	2	0	0	0	0
	C_{53}	1	1	1	2	2	1	1	3	3	3	2	0	2	2	2	0	0	2
C_6	C_{61}	1	0	1	1	2	1	1	2	3	2	2	1	0	4	0	0	0	0
	C_{62}	1	0	1	1	2	1	0	2	2	3	3	3	4	0	2	0	0	2
C_7	C_{71}	0	2	2	2	2	2	2	0	0	0	0	1	0	1	0	3	2	2
	C_{72}	0	2	2	0	2	2	2	0	0	0	0	0	0	0	3	0	2	1
C_8	C_{81}	0	1	2	2	2	2	2	0	0	0	0	0	0	0	2	3	0	3
	C_{82}	0	2	0	2	2	2	2	0	0	0	0	1	0	1	2	3	2	0

Table AB.2 DM2's direct relation matrix

		C1			**C2**		**C3**		**C4**		**C5**			**C6**		**C7**		**C8**	
		C11	C12	C13	C21	C22	C31	C32	C41	C42	C51	C52	C53	C61	C62	C71	C72	C81	C82
C1	C11	0	0	0	2	3	1	4	2	2	0	0	0	0	0	0	0	0	0
	C12	4	0	3	3	4	0	0	0	0	0	0	0	0	0	2	2	1	2
	C13	4	0	0	0	3	4	4	0	0	0	0	0	0	0	2	2	2	0
C2	C21	4	4	3	0	3	2	1	3	3	3	3	3	2	2	2	0	2	2
	C22	3	2	0	3	0	1	0	0	0	0	0	0	0	0	2	2	2	2
C3	C31	1	2	4	0	3	0	0	0	0	3	2	2	0	0	2	2	2	2
	C32	4	0	4	2	2	4	0	4	3	3	2	2	2	2	2	2	2	2
C4	C41	1	0	0	1	3	0	0	0	4	4	4	4	4	4	0	0	0	0
	C42	2	0	3	2	2	1	0	4	0	4	4	4	3	3	0	0	0	0
C5	C51	1	0	3	0	3	2	1	4	4	0	3	3	3	3	0	0	0	0
	C52	1	0	2	0	3	2	1	4	4	3	0	3	3	3	0	0	0	0
	C53	2	0	2	0	3	1	1	4	4	3	0	0	3	3	1	0	0	1
C6	C61	2	0	0	2	4	1	0	3	3	2	2	2	0	4	1	0	0	1
	C62	1	0	2	0	4	1	0	4	4	3	3	3	3	0	1	0	0	1
C7	C71	0	2	2	2	2	2	2	0	0	0	0	1	0	1	0	3	3	3
	C72	0	2	2	0	2	2	2	0	0	0	0	0	0	0	2	0	4	4
C8	C81	0	1	2	2	2	2	2	0	0	0	0	0	0	0	2	0	0	4
	C82	0	2	0	2	2	2	2	0	0	0	0	1	0	1	3	2	3	0

Table AA.3 DM3's direct relation matrix

		C_1			C_2		C_3		C_4		C_5			C_6		C_7		C_8	
		C_{11}	C_{12}	C_{13}	C_{21}	C_{22}	C_{31}	C_{32}	C_{41}	C_{42}	C_{51}	C_{52}	C_{53}	C_{61}	C_{62}	C_{71}	C_{72}	C_{81}	C_{82}
C_1	C_{11}	0	4	3	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0
	C_{12}	4	0	3	0	1	1	1	0	0	0	0	0	0	0	2	2	1	2
	C_{13}	2	1	0	0	0	2	0	0	0	0	0	0	0	0	2	2	2	0
C_2	C_{21}	4	3	1	0	4	4	2	4	4	4	4	4	4	4	2	0	2	2
	C_{22}	3	4	2	1	0	2	1	2	2	2	2	2	2	2	2	2	2	2
C_3	C_{31}	3	3	2	2	3	0	1	0	0	0	0	0	1	1	2	2	2	2
	C_{32}	4	3	4	1	1	4	0	4	4	4	4	4	3	3	2	2	2	2
C_4	C_{41}	4	1	1	2	4	1	3	0	4	4	4	4	4	4	0	0	0	0
	C_{42}	4	2	2	1	3	0	2	4	0	4	4	4	4	2	0	0	0	0
C_5	C_{51}	1	0	3	1	3	3	2	3	3	0	1	1	3	3	0	0	0	0
	C_{52}	1	0	0	0	3	0	2	3	3	0	0	1	3	3	0	0	0	0
	C_{53}	1	0	0	0	3	0	2	3	3	0	0	0	3	3	1	0	0	1
C_6	C_{61}	1	0	1	1	2	1	0	1	1	2	2	2	0	4	0	0	0	0
	C_{62}	1	0	1	1	2	1	0	1	1	2	2	2	4	0	1	0	0	1
C_7	C_{71}	0	2	2	2	2	2	2	0	0	0	0	1	0	1	0	1	2	2
	C_{72}	0	2	2	0	2	2	2	0	0	0	0	0	0	0	3	0	3	3
C_8	C_{81}	0	1	2	2	2	2	2	0	0	0	0	0	0	0	1	2	0	4
	C_{82}	0	2	0	2	2	2	2	0	0	0	0	1	0	1	1	2	4	0

Appendix C. (TOPSIS)

Table AC.1 DM1's decision matrix

	0,05	0,04	0,05	0,07	0,07	0,06	0,07	0,07	0,07	0,06	0,05	0,06	0,06	0,06	0,04	0,05	0,04	0,04
	C	B	C	B	B	C	C	B	B	C	C	C	B	B	B	B	B	B
	C_{11} €	C_{12} %	C_{13} ₺	C_{21}	C_{22}	C_{31}	C_{32} km	C_{41}	C_{42}	C_{51}	C_{52}	C_{53}	C_{61}	C_{62}	C_{71}	C_{72}	C_{81}	C_{82}
A1	335	5	8000	3	2	2	187	2	2	2	2	2	2	2	2	2	3	3
A2	339	7	7850	3	3	3	177	3	2	2	2	2	2	2	2	2	3	3
A3	341	10	8200	2	3	2	187	2	3	3	3	3	3	3	4	4	4	4

Table AC.2 DM2's decision matrix

	0,05	0,04	0,05	0,07	0,07	0,06	0,07	0,07	0,07	0,06	0,05	0,06	0,06	0,06	0,04	0,05	0,04	0,04
	C	B	C	B	B	C	C	B	B	C	C	C	B	B	B	B	B	B
	C_{11} €	C_{12} %	C_{13} ₺	C_{21}	C_{22}	C_{31}	C_{32} km	C_{41}	C_{42}	C_{51}	C_{52}	C_{53}	C_{61}	C_{62}	C_{71}	C_{72}	C_{81}	C_{82}
A1	335	5	8000	3	2	2	187	2	2	2	2	2	3	3	3	4	2	2
A2	339	7	7850	2	2	3	177	2	2	2	2	2	2	3	3	2	3	3
A3	341	10	8200	2	3	2	187	3	3	3	3	3	3	3	3	3	3	3

Table AC.3 DM3's decision matrix

	0,05	0,04	0,05	0,07	0,07	0,06	0,07	0,07	0,07	0,06	0,05	0,06	0,06	0,06	0,04	0,05	0,04	0,04
	C	B	C	B	B	C	C	B	B	C	C	C	B	B	B	B	B	B
	C_{11} €	C_{12} %	C_{13} ₺	C_{21}	C_{22}	C_{31}	C_{32} km	C_{41}	C_{42}	C_{51}	C_{52}	C_{53}	C_{61}	C_{62}	C_{71}	C_{72}	C_{81}	C_{82}
A1	335	5	8000	3	3	2	187	3	3	2	2	2	3	3	3	3	3	3
A2	339	7	7850	3	4	3	177	3	3	2	2	2	3	3	3	3	3	2
A3	341	10	8200	3	3	2	187	4	4	3	3	3	4	4	4	4	2	3

BIOGRAPHICAL SKETCH