

Istanbul Medipol University
School of Engineering and Natural Sciences
Graduation Project
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PROJECT TITLE

Green Agile Sustainable Supplier Selection Problem

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PROJECT OVERVIEW/SUMMARY/ABSTRACT

The textile sector was a large part of the global supply chain and played a key role in global carbon emissions, along with sectors such as agriculture and construction. Green-agile practices to be implemented in this sector played a major role in terms of environmental and social sustainability. With the increasing awareness of today's environmental issues and the criticality of global problems, companies had decided to structure the system by greening it in order to compete and reach their sensitive customers in this regard.

In this project, the supply chain touched not only the product flow but also every aspect of production, from information to money flow of the operation. It facilitated the selection of new suppliers from production to delivery, taking into account criteria such as green design, green packaging, green delivery and the environmental sensitivity of the parties. Thus, the aim of classical supply chain management to provide maximum service at minimum cost was modeled in a way that caused the least damage to the environment.

In this project, using Spherical Fuzzy numbers, data based on linguistic expressions was combined with Spherical Weight Average (SWAM) and the criteria were weighted. The role of experts determined as decision makers were much more important in this method compared to other MCDM techniques used in weighting. Because weighting was created with the SF-SWARA method based on the data to be received from Decision Makers (DM) in order to weight the decision criteria. Then, all decision criterion headings were evaluated to determine the appropriate supplier selection using the SF-EDAS method. In the project, an interface suitable for companies using the mentioned methods was developed. Thanks to this interface, decision makers can quickly weight the criteria and evaluate supplier alternatives.

The competitive environment was changing rapidly with the search for new resources, and quick actions taken against these changes provided an advantage in competition. It was aimed to make it easier with agile steps to be taken for future supply forecasts and plans to meet the demands of the market. This project was to optimize agile, green and sustainability, which was the fast method for companies. The decision support system reduced costs by using resources efficiently and supported sustainable environmental practices in green agile supplier selection.

The textile industry was one of the primary interlocutors on this issue. When we considered carbon emissions in the world, the textile industry was one of the most dangerous polluters. In comparison, case studies on this subject remained limited.

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As a result, since this project, which blends agile and green methods with supplier selection practices, had not been developed before in our country, it contributed to the 12th Development Plan, national knowledge accumulation, contribute to various R&D projects for the development of the decision support system, and will also contributed to our national technological development. In addition, the decision support interface created for this project, together with these methods, has provided organizations with the convenience of digital decision making. These differences highlighted the unique value of the study. If the proposed project was implemented successfully, modernization in supplier selection practices could have become widespread, as the costs of green and agile supplier selection practices were minimized.

Keywords: Green, Agile, Sustainable, SF-SWARA, SF-EDAS

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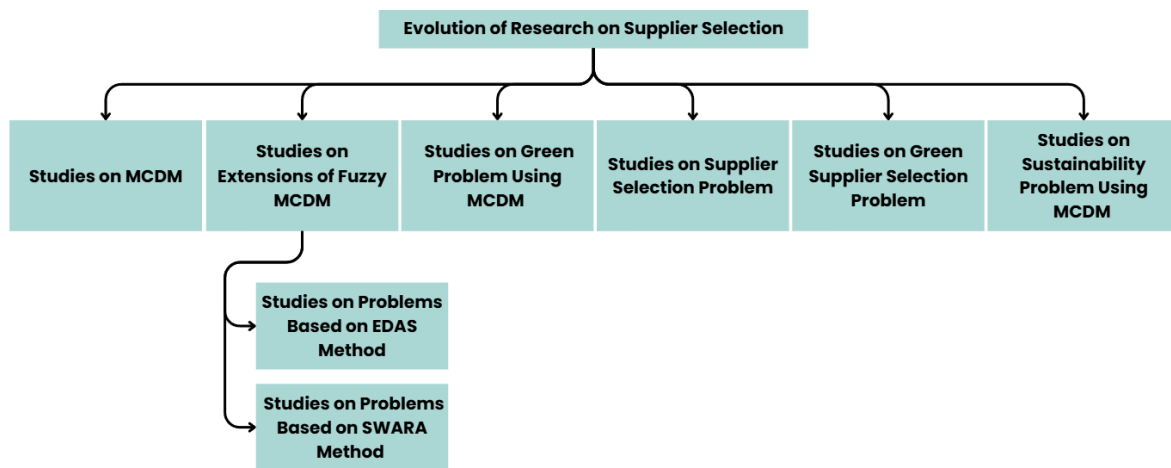
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Manufacturers have started to emphasize the concept of environmental sensitivity in their supplier selection, which has become essential in recent years. Businesses must add ecological value to their activities besides their economic concerns because a new competitive environment has emerged. The articles conducted on the sustainable, green and agile supplier selection issue in the literature can be listed as follows.

The methods, which are the main subject of the project, have been used by many authors in different fields in the literature. However, it is worthwhile to indicate that there are no related articles referring to sustainable, agile and green supplier selection in terms of spherical fuzzy decision environments in the current year.

Table 1. Classification of Literature Studies



a. 2.1 Studies on MCDM

This section contains a comprehensive summary of MCDM studies used in supplier selection. There are many examples of supplier selection based on MCDM studies. MCDM methods help choose the best option based on many different criteria. It is frequently used in making strategic decisions such as supplier selection, logistics planning and inventory management in the supply chain. Supplier selection determines the supplier's performance; It was used to evaluate based on criteria such as quality, delivery time, cost and sustainability.

Brewer (2007) investigated how companies perceive psychological distance when entering international markets and how this perception affects which markets they choose and examined the concept consisting of elements such as geographical factors, cultural, economic, psychological distance and language.

Rizaie et al. (2014) evaluated the performances of 27 cement companies traded on the Tehran Stock Exchange between 2008 and 2009 by performing fuzzy Analytical Hierarchy (AHP) and multi-criteria optimization and compromise solution (VlseKriterijumska Optimizacija I Kompromisno Resenje, VIKOR) analysis.

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Erol (2018), a green supplier selection application was made for the purchase of degreaser needed for cleaning the metal sheet surfaces used in the production of a wind turbine tower manufacturing company in Turkey. The study has 4 alternatives consisting of business and environment main criteria, and 8 sub-criteria in which hybrid AHP and TOPSIS methods are used. Distinctively, two of the criteria are the products produced in the final stage are recycled at the end of their life cycle and waste management phase.

Supçiller and Deligöz (2018) solved the problem of choosing the most suitable supplier according to basic decisions for companies that want to improve their supplier chain performance in the textile industry. He identified 8 different MCDM methods. He used more than one method because different rankings could come from each method tried. TOPSIS (Order Preference Technique Based on Similarity to Ideal Solution), AHP (Analytic Hierarchy Process), VIKOR (VlseKriterijumska Optimizacija I Kompromisno. Resenje) method, Simple Additive Weighting (SAW), GIA (Gray Relational Analysis) method, MOORA method, ELECTRE II (Elimination and Choice Translating Reality English) method and M-TOPSIS (Modified Technique for Order Preference by Similarity Ideal Solution) methods were used one by one.

b. 2.2. Studies on Extensions of Fuzzy MCDM

2.2.1. Studies on Problems Based on EDAS Method

In the literature, the related EDAS method was first published by Ghorabae et al. (2015). It was created to make ABC classification of the inventory list. In this study, three criteria were evaluated: average unit price, annual dollar usage, and delivery time. In the study, the author compared it with the 6 methods he had used before and found that EDAS provided the best solution. In other studies, conducted with EDAS, the fuzzy EDAS method was created by combining it with fuzzy logic.

This method was first used by Ghorabae et al. (2016) was used in the problem of determining the most suitable chemical supplier to produce laundry detergent and was evaluated according to 6 basic criteria (Quality, Service, Flexibility, Innovation, Cost and Delivery) by taking the opinions of the expert team.

Yürüyen and Ulutaş (2020) used the fuzzy AHP and fuzzy EDAS method in the selection of the third-party logistics (3PL) company. He argued that companies that want to gain competitive advantage and increase profit margins should work with the right 3PL. In his study, he solved the problem of choosing a company that provides 3PL services to a company that produces military vehicles and machinery in Ankara.

Demirtaş et al. (2020) solved the supplier selection problem using fuzzy EDAS. Instead of only considering quantitative and qualitative criteria during the selection phase, it examined all factors affecting its activities as criteria. The solution was evaluated by 6 alternative suppliers and 5 experts. They chose 16 criteria to determine these alternatives. They tabulated the data obtained and concluded that product quality is the most important criterion, and the appropriate supplier is selected.

Polat and Bayhan (2020) stated that the main causes of greenhouse gases are commercial buildings and energy consumption. Choosing the right supplier is vital for HVAC-AHU system projects to receive

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high scores from green certification systems. Based on this, the problem of supplier selection and HVAC-AHU (Air Handling Units) system for the green and multifunctional shopping mall project in Moscow was solved using the fuzzy EDAS method. Thanks to the method, they identified and ranked the alternatives.

2.2.2. Studies on Problems Based on SWARA Method

Sahin et al. (2022), a case study in the selection of both sustainable and environmentally friendly suppliers. Fuzzy SWARA and Fuzzy COPRAS methods are used to optimize the green lean supplier selection process manufacturing industry. Within the scope of the study, ten different criteria were used while conducting surveys.

Mishra et al. (2023) This study proposes the integration of hesitant fuzzy sets with SWARA and COPRAS methods to optimize the decision-making process for sustainable supplier selection. There is an experimental case study with 5 alternatives was conducted with ABC trading company in India and sensitivity analysis proved that the method can be used safely.

Cakmak (2023), Focusing on the process of creating a sustainable supplier park for a generator manufacturer in the energy sector, the study aims to determine the supplier selection criteria and assign the ranking of suppliers based on the criteria. In the study, Hybrid Interval-Valued Neutrosophic SWARA and Interval-Valued Neutrosophic EDAS methods are applied for solving multi-criteria decision making (MCDM) problems with uncertainty focused on operational, financial, quality technical and sustainability criteria. The findings show that “lead time”, “operations control” and “supplier location” are the most important requirements.

Ziquan et al.(2021), This paper emphasizes the need for effective supply chain management strategies to adapt to the increasing competition and changes in the global shipbuilding industry. The study addresses the supplier selection problem in shipbuilding organizations. It proposes an innovative method to solve the problem by reducing the effects of knowledge conflicts among experts in evaluating the complex intertwined criteria in the industry. This methodology combines the methodologies of intuitionistic fuzzy SWARA and COPRAS.

c. 2.3. Studies on Green Problem Using MCDM

The concept of green emerged in literature in the 1990s. With the development of technology, it has brought many environmental problems. Failure to find solutions to these problems means that future generations will not be safe. Towards the end of the 20th century, this issue became more prominent and as a result, the concept of green management emerged.

Kopicki et al. (1993) presented three types of approaches: reactive, proactive and value-creating. While the reactive approach talks about basic boundary-oriented practices, the proactive approach focuses on preventing environmental problems and providing sustainability and competitive advantage. Finally, the value creation approach involves integrating green activities into business strategies and sharing environmental decisions with all stakeholders.

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Porter and Van Der Linde (1995) stated that greening efforts save resources and increase efficiency in companies. According to this result, it has been revealed that the concept of green is not only for the environment but also for the benefit of companies.

Srivastava (2007) Green supply chain management is defined as integrating environmental thinking into supply chain processes. This scope includes elements such as material supply and selection, product design, production processes, delivery of the product to the customer and management of the product life cycle.

Akandere and Zerenler (2017) determined the effects of internal and external factors and business performance in the green supply chain that put pressure on the green supply chain management decisions of managers in accommodation businesses. In his research, T.C. It carried out its work on 250 green star hotels from 5 different provinces approved by the Ministry of Culture and Tourism. Using correlation analysis, regression analysis, central tendency measurements and descriptive statistics, the impact of selecting appropriate green suppliers on the business was examined.

d. 2.4. Studies on Supplier Selection Problem

Wang et al. (2009) proposed the fuzzy hierarchical TOPSIS method to provide more accurate weights in supplier selection problems. Therefore, this study proposes fuzzy hierarchical TOPSIS, which is well suited to evaluate fuzziness and uncertainty problems and can also provide more objective and accurate criterion weights. For implementation and validation, Wang et al. presents a numerical example for this study and poses a practical supplier selection problem to validate the proposed method and compare it with other methods.

Shemshadi et al. (2011) In this study, the supplier selection problem was addressed within the framework of multi-criteria group decision making (GMCDM) and the opinions of the decision makers were collected as linguistic terms. The VIKOR method was applied by converting linguistic terms into trapezoidal fuzzy numbers. Objective weight measurement based on Shannon entropy is integrated into the method to regulate the subjective weights of decision makers and incorporate end-user opinions. The study presents a solution process based on R, S and Q criteria and is considered as an effective method proposal in supplier selection decisions.

Ayhan (2013) presents an application of the Fuzzy AHP methodology in a gear motor company in order to determine the supplier that best suits the selected criteria according to supplier selection problems and offers a solution that supports the decision-making process, especially in cases of uncertainty. The study includes a multi-criteria structure, determination of basic criteria such as quality, cost, delivery, origin and after sales evaluation of alternative suppliers. It has also been stated that this methodology can be easily applied to other decision problems.

e. 2.5. Studies on Green Supplier Selection Problem

Adamides et al. (2024) examined supplier evaluation and selection processes based on environmental performance in terms of whether they differ across industries. They considered green supplier evaluation and selection processes as a sub-process of a broader procurement process and modeled these

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processes with activity theory. The research was conducted with the participation of 80 companies from five industries in Greece (pharmaceutical, food processing, aquaculture, construction materials, waste management). Findings indicate that there are different practices across industries and that cultural and historical contexts influence these processes.

Jianhua Wang and Nan An (2024) proposed a model based on Pythagorean fuzzy sets and the TOPSIS method to solve the problem of green supplier evaluation and selection by considering uncertain expert opinions. The model calculates the criterion weights using the entropy weighting method in a fuzzy environment and ranks alternative suppliers. The applicability and effectiveness of the model was confirmed by a case study analysis conducted on a business and a comparison with existing models. This approach aims to provide more accurate evaluation and selection results in green supply chain management.

Qian Yu and Fujun Hou (2016) proposed the Modified Multiplicative Analytic Hierarchy Process (MMAHP) method for the green supplier selection problem. MMAHP is integrated into multi-criteria decision making (MCDM) processes where both qualitative and quantitative factors are evaluated. Application through an automobile manufacturer in Qingdao has demonstrated the effectiveness of MMAHP and its capacity to prevent sequence reversals. The study finds that MMAHP provides more consistent results compared to traditional AHP, and the ranking does not change when a new supplier is added.

This study investigates how Khouzestan Steel Company (KSC) might choose more sustainable suppliers. The organisation used approaches such as the Best-Worst Method (BWM) and Fuzzy TOPSIS to assess suppliers based on their commitment to eco-friendly activities including green production and environmental initiatives. The results showed that Supplier 2 had the best performance. The report emphasises the need to help suppliers improve their environmental efforts and include explicit sustainability requirements in the supplier selection process to ensure a greener supply chain.

This review examines effective strategies for evaluating and selecting green suppliers, emphasizing methods like AHP, DEA, and TOPSIS. By reviewing 1,098 studies from 1990 to 2020, it identifies these three approaches as the most widely used for addressing sustainability challenges in supplier selection. These techniques enable businesses to choose environmentally responsible suppliers and pave the way for further advancements in sustainable supply chains.

f. 2.6. Studies on Sustainability Problem Using MCDM

Raghunathan Krishankumar (2021) The aim of this paper is to prioritize zero-carbon initiatives to address the issue of sustainable urban mobility. In addition, a decision-making model that integrates the EDAS approach with dual hierarchy fuzzy language terms (DHHFL) is developed in this paper. The results of the model, which effectively manages uncertainties and proposes both individual and aggregate rankings, provide a roadmap to support sustainable city development in line with zero carbon targets.

Rahman et al. (2022), The article decides on the selection of a sustainable supplier company in the textile dyeing industry using hybrid SWARA and WASPAS methods. After weighing through

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SWARA, "chemical quality" was selected as the most important among 15 criteria. A global chemical supplier in Singapore was selected as the best alternative through the WASPAS method. After sensitivity analysis, the decision was found to have a valid lambda value among other MCDM methods.

Jain et al. (2020) combines the FIS (Fuzzy Inference System) approaches as well as the crux of MCDM for supplier selection. Methodology has been applied as a real-life case study at a steel and iron company in India.

Reema Agarwall · Anil Kumar Nishad (2023) In this paper, using the "Fuzzy EDAS" (F-EDAS) method, a multi-criteria decision making (MCDM) method was used to identify the best supplier based on social, environmental, economic and flexibility criteria. The focus of the article is on the importance of sustainable supplier selection, however, the article evaluates flexible and sustainable suppliers. The three-dimensional idea of sustainability, considering social, economic and environmental ideologies, is integrated into a fuzzy mathematical model. At the end of the studies, it was concluded that 'SRS3' is the best supplier and 'SRS1' is the worst supplier.

Hezam et al. (2024) The article proposes to select WELS using hybrid SF-SWARA and SF-Weighted Euclidean Distance Based Approach (WEDBA) methods to utilize the wave, which can generate many times more electricity than air, as an alternative to energy lost over long distances.

g. 2.7. Contribution

As can be observed in the reviewed literature, there is no comprehensive review on Green-Agile supplier selection or studies combining these two frameworks. This study examines Green Agile methodologies for supplier selection in a fuzzy environment. This one of the first studies to contribute to green agile applied.

Theoretical Contributions

- This research introduces the innovative combination of Spherical Fuzzy EDAS and Spherical Fuzzy SWARA methodologies for the selection of both green-environmental and agile suppliers to present a unique decision-making methodology.
- By extending the use of spherical fuzzy sets, it provides a sophisticated method to address uncertainties and interdependencies among green to agile indicators.
- The study advances literature by integrating sustainability (green) and flexibility (agile), two key elements in contemporary supply chain management.
- It presents a comprehensive and systematic methodology, providing an innovative and environmental perspective on multi-criteria decision-making (MCDM) frameworks in a fuzzy context.

Practical Contributions

- Recognizes and ranks key green-agile factors, benefiting decision makers to make more informed and efficient supplier selection.

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- Demonstrates the practical use of the methodology in a global world perspective, improving supplier selection outcomes by incorporating sustainability and agility into supply chain processes.
- This study provides a comprehensive framework that reduces computational complexity while increasing result reliability.
- It provides useful and usable information for supply chain managers to comply with environmental rules and increase resilience in volatile and competitive industries.

3. ORIGINALITY

The unique value of this research lies in the fact that it aims to develop an MCDM framework to address the Green-Agile Supplier Selection Problem, considering both environmental sustainability and operational agility. Within the framework of the proposed evaluation, the importance of the criteria will be determined by the SWARA method, while the EDAS method will be used for the selection and ranking of suppliers. While the SWARA method performs a step-by-step ratio analysis, the decision criteria are evaluated by calculating the distances between positive and negative solutions with the EDAS method, which is a reliable distance-based method. In this way, a simpler and more effective solution is achieved by skipping unnecessary steps. This study is designed as research that has not been done before in the field of green and agile supplier selection in the existing literature.

After decision makers weigh the criteria according to their importance using SF-SWARA, the ranking of these weightings will be obtained with the SF-EDAS method. Thanks to the two MCDM methods to be used, it will be possible to adapt and respond to demand changes more quickly. With the flexibility that can be provided and the agile method obtained, the margin of error in the procurement process can be minimized in cases of emergency. In addition, companies will be quickly evaluated by data analysis, considering their commitment to green and agile practices. Companies will increase their business performance and become better prepared for possible crises by establishing stronger ties with customers who care about sustainability and social responsibility. As a result, organizations will achieve more stable growth, providing financial security in the long term.

As seen in the literature review, there are a few studies that include the integration of Spherical Fuzzy number-based SWARA and EDAS methods, but there is no integration of the two methods for the concept of green agile sustainable supplier selection. In addition, although there are many scientific studies in the existing literature on the supplier selection problem, no study has been found that addresses the green and agile criteria together. Therefore, this study aimed to put forward a model for green and agile supplier selection in the textile industry through MCDM methods, which is an innovative approach.

4. METHOD

WP 1: Selection of the MCDM method and determination of the Competent Decision Maker group.

The criteria that should be considered in supplier selection often contradict each other and cause difficulties in decision-making.[1] At this point, MCDM methods can be used. These methods help evaluate alternatives using criteria with different characteristics.[2] It is also appropriate to use Spherical Fuzzy Sets (SFS) for the uncertain statements of decision-makers. [3]

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In this study, Stepwise Weight Assessment Ratio Analysis (SWARA) and Evaluation Based on Distance from Average Solution (EDAS) are combined with Spherical Fuzzy Sets (SFS) for fuzzy MCDM problems. Additionally, the proposed method examined the green and agile supplier selection situation.

In 2018, Spherical Fuzzy Sets (SFS) were introduced as an extension of fuzzy sets.[4] These fuzzy sets differ from others in that they are three-dimensional. “In Spherical Fuzzy Sets, the sum of the squares of Membership, Non-membership and Neutrality parameters can be between 0 and 1, or each of them can be independently defined between 0 and 1 so that the sum of their squares is at most equal to 1.” [5]

$$\tilde{A}_s = \{ \langle x, \mu_{\tilde{A}_s}(x), v_{\tilde{A}_s}(x), \pi_{\tilde{A}_s}(x) \mid x \in X \rangle \} \quad (1)$$

Definition 1: The following is the fuzzy set \tilde{A}_s on the discourse universe X: [1]

$\mu_{\tilde{A}_s}(x)$, $v_{\tilde{A}_s}(x)$, and $\pi_{\tilde{A}_s}(x)$ represent the Membership degree, Non-membership degree, and Neutrality degree of x in \tilde{A} , respectively, and they satisfy the $\mu_{\tilde{A}_s}(x): X \rightarrow [0,1]$, $v_{\tilde{A}_s}(x): X \rightarrow [0,1]$, $\pi_{\tilde{A}_s}(x): X \rightarrow [0,1]$ condition.

$$0 \leq \mu_{\tilde{A}_s}^2(x) + v_{\tilde{A}_s}^2(x) + \pi_{\tilde{A}_s}^2(x) \leq 1, \forall x \in X \quad (2)$$

$\pi_{\tilde{A}}(x) = \sqrt{1 - \mu_{\tilde{A}}^2(x) - v_{\tilde{A}}^2(x) - \eta_{\tilde{A}}^2(x)}$ is the expression for the hesitation parameter of \tilde{A} . Just called a Spherical Fuzzy Number (SFN), the phrase. $(\mu_{\tilde{A}_s}(x), v_{\tilde{A}_s}(x), \pi_{\tilde{A}_s}(x))$ can be expressed as $\alpha = (\mu, \nu, \pi)$.

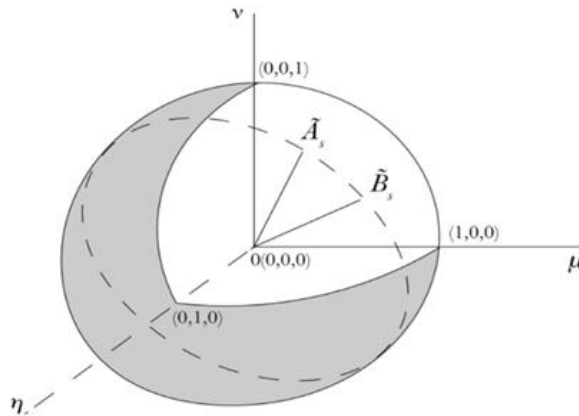


Figure 3: Geometric representation of SFS (Gündoğdu and Kahraman, 2019b)

Definition 2: Let $\tilde{A}_s = (\mu_{\tilde{A}_s}, v_{\tilde{A}_s}, \pi_{\tilde{A}_s})$ and $\tilde{B}_s = (\mu_{\tilde{B}_s}, v_{\tilde{B}_s}, \pi_{\tilde{B}_s})$ be two Spherical Fuzzy Numbers (SFNs) and let λ be a positive real number. Then:

$$\tilde{A}_s \oplus \tilde{B}_s = \left\{ \left(\mu_{\tilde{A}_s}^2 + \mu_{\tilde{B}_s}^2 - \mu_{\tilde{A}_s}^2 \mu_{\tilde{B}_s}^2 \right)^{\frac{1}{2}}, v_{\tilde{A}_s} v_{\tilde{B}_s}, \left((1 - \mu_{\tilde{B}_s}^2) \pi_{\tilde{A}_s}^2, (1 - \mu_{\tilde{A}_s}^2) \pi_{\tilde{B}_s}^2 - \pi_{\tilde{A}_s}^2 \pi_{\tilde{B}_s}^2 \right)^{1/2} \right\} \quad (3)$$

$$\tilde{A}_s \otimes \tilde{B}_s = \left\{ \mu_{\tilde{A}_s} \mu_{\tilde{B}_s}, \left(v_{\tilde{A}_s}^2 + v_{\tilde{B}_s}^2 - v_{\tilde{A}_s}^2 v_{\tilde{B}_s}^2 \right)^{\frac{1}{2}}, \left((1 - v_{\tilde{B}_s}^2) \pi_{\tilde{A}_s}^2, (1 - v_{\tilde{A}_s}^2) \pi_{\tilde{B}_s}^2 - \pi_{\tilde{A}_s}^2 \pi_{\tilde{B}_s}^2 \right)^{1/2} \right\} \quad (4)$$

Multiplying by a scalar ($\lambda > 0$):

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$$\lambda * \tilde{A}_s = \{(1 - (1 - \mu_{\tilde{A}_s}^2)^\lambda)^{1/2}, v_{\tilde{A}_s}^\lambda, ((1 - \mu_{\tilde{A}_s}^2)^\lambda - (1 - \mu_{\tilde{A}_s}^2 - \pi_{\tilde{A}_s}^2)^\lambda)^{\frac{1}{2}}\} \quad (5)$$

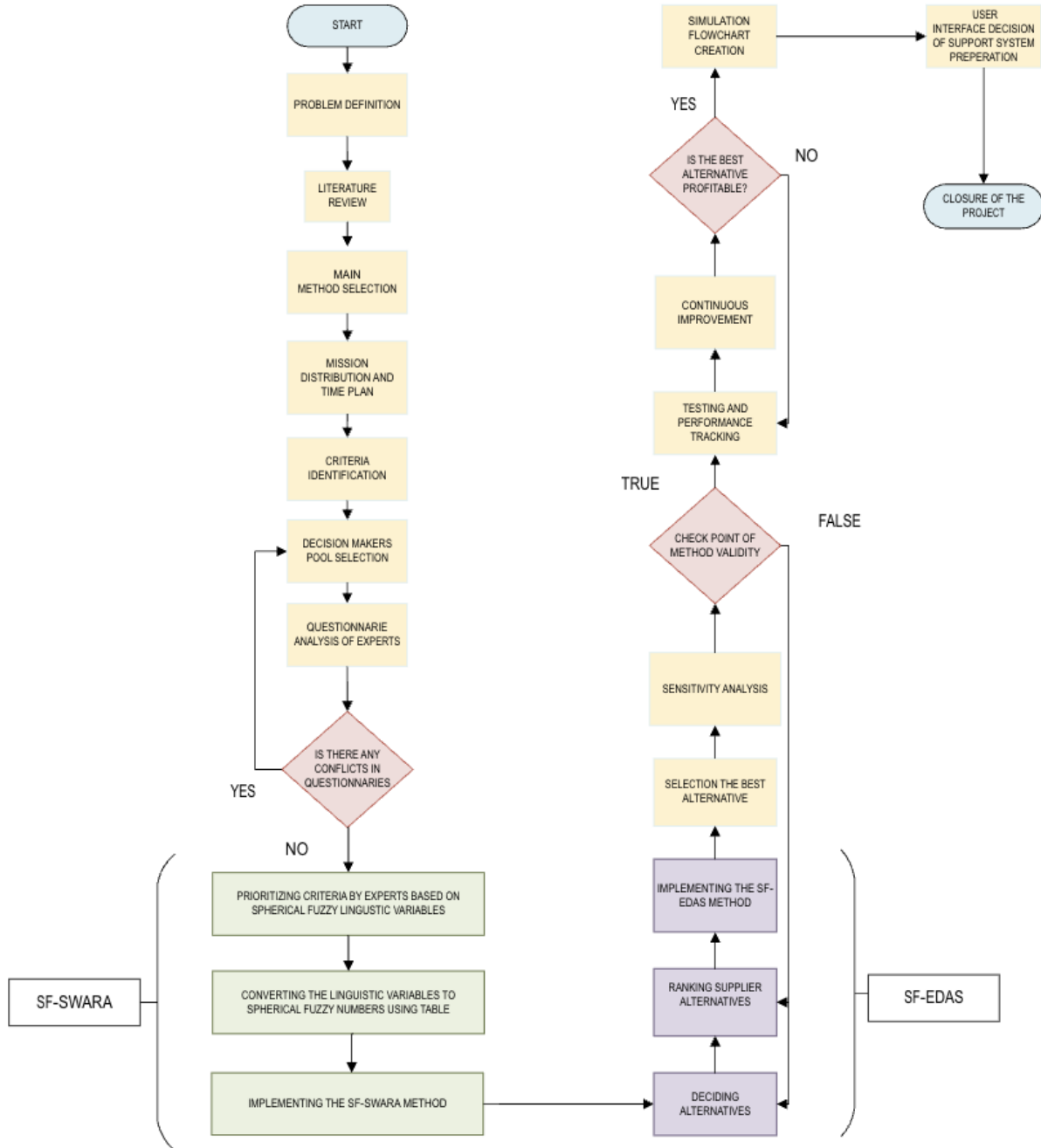


Figure 2. Flow Chart of the Implementation

Definition 3: For aggregation purposes, the spherical weighted arithmetic mean (SWAM) can be defined. Weights is given as $W_j (j = 1, \dots, n)$, where: $W_j \in [0,1]$ ve $\sum_{i=1}^n W_i = 1$

$$SWAM_w(\tilde{A}_{s_1}, \tilde{A}_{s_2}, \dots, \tilde{A}_{s_n}) = w_1 \tilde{A}_{s_1} + w_2 \tilde{A}_{s_2} + \dots + w_n \tilde{A}_{s_n} = \quad (6)$$

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$$\left\{ \left[1 - \prod_{i=1}^n \left(1 - \mu_{\tilde{A}_{Si}}^2 \right)^{w_i} \right]^{\frac{1}{2}}, \prod_{i=1}^n v_{\tilde{A}_{Si}}^{w_i}, \left[\prod_{i=1}^n \left(1 - \mu_{\tilde{A}_{Si}}^2 \right)^{w_i} - \prod_{i=1}^n \left(1 - \mu_{\tilde{A}_{Si}}^2 - \pi_{\tilde{A}_{Si}}^2 \right)^{w_i} \right]^{\frac{1}{2}} \right\}$$

Definition 4: Score function (which can be used for the rationalization process) and for ranking the SFSs is defined by the Accuracy function, which can be used [8].

$$sc(\tilde{A}_s) = (\mu_{\tilde{A}_s} - \pi_{\tilde{A}_s})^2 - (v_{\tilde{A}_s} - \pi_{\tilde{A}_s})^2 \quad (7)$$

$$ac(\tilde{A}_s) = \mu_{\tilde{A}_s}^2 + v_{\tilde{A}_s}^2 + \pi_{\tilde{A}_s}^2 \quad (8)$$

is preferable to but and only or and if [8].

Definition 5: The normalized global distance between $\tilde{A}_s = (\mu_{\tilde{A}_s}, v_{\tilde{A}_s}, \pi_{\tilde{A}_s})$ and $\tilde{B}_s = (\mu_{\tilde{B}_s}, v_{\tilde{B}_s}, \pi_{\tilde{B}_s})$ can be found in the following way [8].

$$dis_n(\tilde{A}_s, \tilde{B}_s) = \frac{2}{n\pi} \sum_{i=1}^n arccos(\mu_{\tilde{A}_s} \mu_{\tilde{B}_s} + v_{\tilde{A}_s} v_{\tilde{B}_s} + \pi_{\tilde{A}_s} \pi_{\tilde{B}_s}) \quad (9)$$

Definition 6: Let, \tilde{A}_s be a SFS on X [8].

$$E(\tilde{A}_s) = \frac{1}{n} \sum_{j=1}^n \left(1 - \frac{4}{5} [|\mu_{\tilde{A}_s}^2(x_i) - v_{\tilde{A}_s}^2(x_i)| + |\pi_{\tilde{A}_s}^2(x_i) - 0.25|] \right) \quad (10)$$

It is a measure of entropy for each SFS [8].

Step 1: Defining the problem and selecting appropriate experts and/or decision makers:

The number of necessary decision makers will be decided in agreement with the textile company where the study is carried out. It will be taken into consideration that the expert set will be competent people with different specializations.

WP 2: Determining the criteria and ranking the decision criteria according to the level of importance.

Step 2: Determining the appropriate set of criteria: The criteria suitable for the segments determined as green, agile and sustainable will be determined in accordance with Industry 4.0 and the company studied and applicability studies will be carried out. The expert pool formed after the determination of the criteria will be ranked according to the importance of the criteria.

WP 3: Implementation of SF-SWARA and SF-EDAS methods.

Step 3: Weighting the determined evaluation criteria with the SWARA method based on Spherical Fuzzy Numbers: The criteria are ranked individually according to their relative importance levels, in accordance with the systematics of the decision makers (DM) assigned in the previous step. The ranking is made from highest to lowest importance.

Step 3.1. Determining the value of \tilde{s}_j : The values of linguistic variables as "comparative importance of the average value" are determined according to linguistic criteria, adhering to Table 2 below.

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Table 2: Linguistic terms for spherical fuzzy numbers (Kutlu Gündoğdu and Kahraman, 2020a,b)

Linguistic Terms	(μ, ϑ, π)	Score Index (SI)
Absolutely More Importance (AMI)	0.9, 0.1, 0.1)	9
Very High Importance (VHI)	0.8, 0.2, 0.2)	7
High Importance (HI)	(0.7, 0.3, 0.3)	5
Slightly More Importance (SMI)	0.6, 0.4, 0.4)	3
Equally Importance (EI)	0.5, 0.5, 0.5)	1
Slightly Low Importance (SLI)	0.4, 0.6, 0.4)	1/3
Low Importance (LI)	(0.3, 0.7, 0.3)	1/5
Very Low Importance (VLI)	0.2, 0.8, 0.2)	1/7
Absolutely Low Importance (ALI)	(0.1, 0.9, 0.1)	1/9

Step 3.2 Determine the coefficient \tilde{k}_j : \tilde{k}_j coefficient j. criterion (j+1). It expresses superiority over the criterion and is achieved through pairwise comparison. The coefficient is calculated using the following equations.

$$\{ \quad 1 \quad j = 1 \quad , \quad \tilde{s}_j + 1 \quad j > 1 \quad \quad \quad (11)$$

Step 3.3 Determining the score of the \tilde{k}_j coefficient: The score calculation of the \tilde{k}_j coefficient is calculated using the following equation (12).

$$SI(\tilde{k}_j) = \sqrt{100 * \left[(\mu_{k_j} - v_{k_j})^2 - (\eta_{k_j} - v_{k_j})^2 \right]} \quad \text{for all } \mu_{k_j} \geq v_{k_j} \quad (12)$$

Step 3.4 Determining the value of qj: qj refers to the value corrected to lie between 0-1. Calculation of qj value is done using the following equation (13).

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$$\left\{ \begin{array}{l} 1 \\ j = 1, \frac{k_{j-1}}{k_j} \\ j > 1 \end{array} \right. \quad (13)$$

Step 3.5 Determine the w_j value: w_j is used to indicate the relative weight of the evaluation criteria. The following inequalities are used to calculate the relative weights of the criteria:

$$w_j = \frac{q_j}{\sum_{k=1}^n q_k} \quad (14)$$

Step 4: The other Ranking supplier alternatives and selecting the most suitable supplier using the Spherical Fuzzy Numbers Based EDAS method: The main feature that distinguishes EDAS from other methods is that it considers average scoring rather than positive or negative ideals. At this stage, the Spherical fuzzy average scores of each criterion will be revealed. In the EDAS method, the average of all combined performance scores shown in the columns of the X_{agg} matrix is taken with equation (15). [28]

$$X^{agg} = [\langle \mu_{11}, v_{11}, \pi_{11} \rangle \cdots \langle \mu_{n1}, v_{n1}, \pi_{n1} \rangle \cdots \langle \mu_{m1}, v_{m1}, \pi_{m1} \rangle \cdots \langle \mu_{mn}, v_{mn}, \pi_{mn} \rangle] \quad (15)$$

Equation (3) is used for the addition process. However, the scalar ($\lambda=1/m$) multiplication process explained by equation (5) is applied. [28]

$$\widetilde{AV}_j = \frac{1}{m} * \sum_{i=1}^m \langle \mu_{ij}, v_{ij}, \pi_{ij} \rangle = \langle \mu_{ij}^{AV}, v_{ij}^{AV}, \pi_{ij}^{AV} \rangle \quad (16)$$

Step 4.1 Calculating positive and negative distances using the average solution: Equation (15) and Equation (16) are used to calculate the distances to the mean solutions, respectively.[28] In the literature, there is no recommendation for the division of SFS. Therefore, the score function value ($sc(AV_j)$) rather than the average solution itself (AV_j) should be considered. Since the score of the average solution will be a scalar value, Equation (5) can be interpreted as multiplication by a scalar. [28]

$$\widetilde{PDA}_{ij} = \begin{cases} \frac{\text{maks}(0, (\mu_{ij} - \mu_{ij}^{AV}))}{sc(\widetilde{AV}_j)} & \text{if the degree of membership is considered} \\ \frac{\text{maks}(0, (v_{ij}^{AV} - v_{ij}))}{sc(\widetilde{AV}_j)} & \text{if the degree of non - membership is considered} \\ \frac{\text{maks}(0, (\pi_{ij}^{AV} - \pi_{ij}))}{sc(\widetilde{AV}_j)} & \text{if the degree of Neutrality is considered} \end{cases} \quad (17)$$

$$\widetilde{NDA}_{ij} = \begin{cases} \frac{\text{maks}(0, (\mu_{ij}^{AV} - \mu_{ij}))}{sc(\widetilde{AV}_j)} & \text{if the degree of membership is considered} \\ \frac{\text{maks}(0, (v_{ij} - v_{ij}^{AV}))}{sc(\widetilde{AV}_j)} & \text{if the degree of non - membership is considered} \\ \frac{\text{maks}(0, (\pi_{ij} - \pi_{ij}^{AV}))}{sc(\widetilde{AV}_j)} & \text{if the degree of Neutrality is considered} \end{cases} \quad (18)$$

Step 4.2 In the weighting of the PDA and NDA values, the objective criteria weights are combined with the PDA and NDA values. A scalar operator is applied by Equation (5) and then the summation is shown by Equation (3). The weights of the PDA and NDA values are defined by Equation

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(17) and Equation (18).[28]

$$\widetilde{SP}_i = \sum_{j=1}^m w_j * \widetilde{PDA}_{ij} \quad (19)$$

$$\widetilde{SN}_t = \sum_{j=1}^m w_j * \widetilde{NDA}_{ij} \quad (20)$$

Step 4.3 Normalization Process and Selection of the Best Alternative Based on the Evaluation Score: To sum the positive and negative weight values, they all need to be normalized. First, the score function counting SP and SN SF should be simplified by Equation (7) and then Equation (19) and Equation (20) should be used to find the normalized values [28]

$$NSP_i = \frac{sc(\widetilde{SP}_i)}{maks_i sc(\widetilde{SP}_i)} \quad (21)$$

$$NSN_i = 1 - \frac{sc(\widetilde{SN}_i)}{maks_i sc(\widetilde{SN}_i)} \quad (22)$$

Step 4.4 The evaluation score (AS_j) of each alternative as the sum of the normalized weights, positive and negative distances is calculated by Equation (21). All alternatives can be ranked according to this AS_j value. [28]

$$AS_i = \frac{NSP_i + NSN_i}{2} \quad (23)$$

WP 4: Testing phase of optimal supplier decisions and controls.

A control process will be conducted to test the accuracy of the most suitable suppliers identified using SF-SWARA and SF-EDAS methods. A situation analysis will be made by comparing the company's previous data of the ongoing process with the selected supplier. New high-scoring alternatives will be entered into the system from the company's currently monitored variable pool and performance controls will be ensured.

WP 5: Completion of the modeling with the formation of the control mechanism and preparation of the interface prototype as an alternative to the software side.

The prototype presentation of the autonomous system that will contribute to the company in modeling and simulation will be made. The data required for the forecasting side will be created by utilizing previous manual calculations and the data set where company data is collected. At the same time, a Python-based interface prototype will be developed to present the project's decision support system in a user-friendly format. Through this interface, the user will be able to enter the appropriate values and get results with the specified SF-SWARA and SF-EDAS equations.

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5. PROJECT TARGETS AND SUCCESS CRITERIA

NO	Name of Work Packages and Objectives	Success Criteria and Contribution to the Success of the Project
1	<p>Work Package Name: Comprehensive literature review on MCDM. Selection of the MCDM method and forming a systematic method flow</p> <p>Work Package Objective: To identify a MCDM framework that will create unique value and decide on the group of experts whose opinions will be applied for weighting.</p>	<p>Contribution to Project Success: 15%</p> <p>Success Criteria: A literature review will be conducted to provide at least 20 references.</p> <p>Develop a pioneering MCDM method for textiles with high intrinsic value.</p> <p>Contracting with 3-10 CVs specialized in various fields.</p>
2	<p>Work Package Name: Determination of the group of Competent Decision Makers. Identification of decision criteria and ranking of decision criteria according to importance level</p> <p>Work Package Objective: To establish sustainable, green and agile criteria that align with company interests and to obtain a consistent rubric for weighting by taking various expert opinions.</p>	<p>Contribution to Project Success: 20%</p> <p>Success Criteria: Identify at least 4 criteria for each of the green, sustainable and agile criteria and ensure that the weight assignments are not the same for all CVs.</p>
3	<p>Work Package Name: Implementation of KB-SWARA and KB-EDAS methods</p> <p>Work Package Objective: To evaluate the outputs of the method and select the most suitable supplier.</p>	<p>Contribution to Project Success: 25%</p> <p>Success Criteria: The criteria will be weighted by KB-SWARA method, and the alternatives will be evaluated by KB-EDAS method. The decision problem will be solved by using other MCDM methods and the results will be compared and validated with the results of the method we have used.</p>
4	<p>Work Package Name: Testing phase of optimal supplier decisions and controls</p> <p>Work Package Objective: Monitoring the performance of selected suppliers and making improvements according to the progress</p>	<p>Contribution to Project Success: 20%</p> <p>Success Criteria: If the most suitable supplier is not the company's current supplier, ensure that the new supplier is at least 5% more efficient than the previous one.</p>
5	<p>Work Package Name: Completion of the modeling with the formation of the control mechanism and preparation of the interface prototype as an alternative to the software side</p> <p>Work Package Objective: Creating a simulation interface that models and predicts the method</p>	<p>Contribution to Project Success: 20%</p> <p>Success Criteria: Creation of a simulation interface with modeling that will replicate the manual calculations performed and predict the course of the most suitable supplier in the short term, 1-2 months.</p>

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6. RISKS AND B PLANS

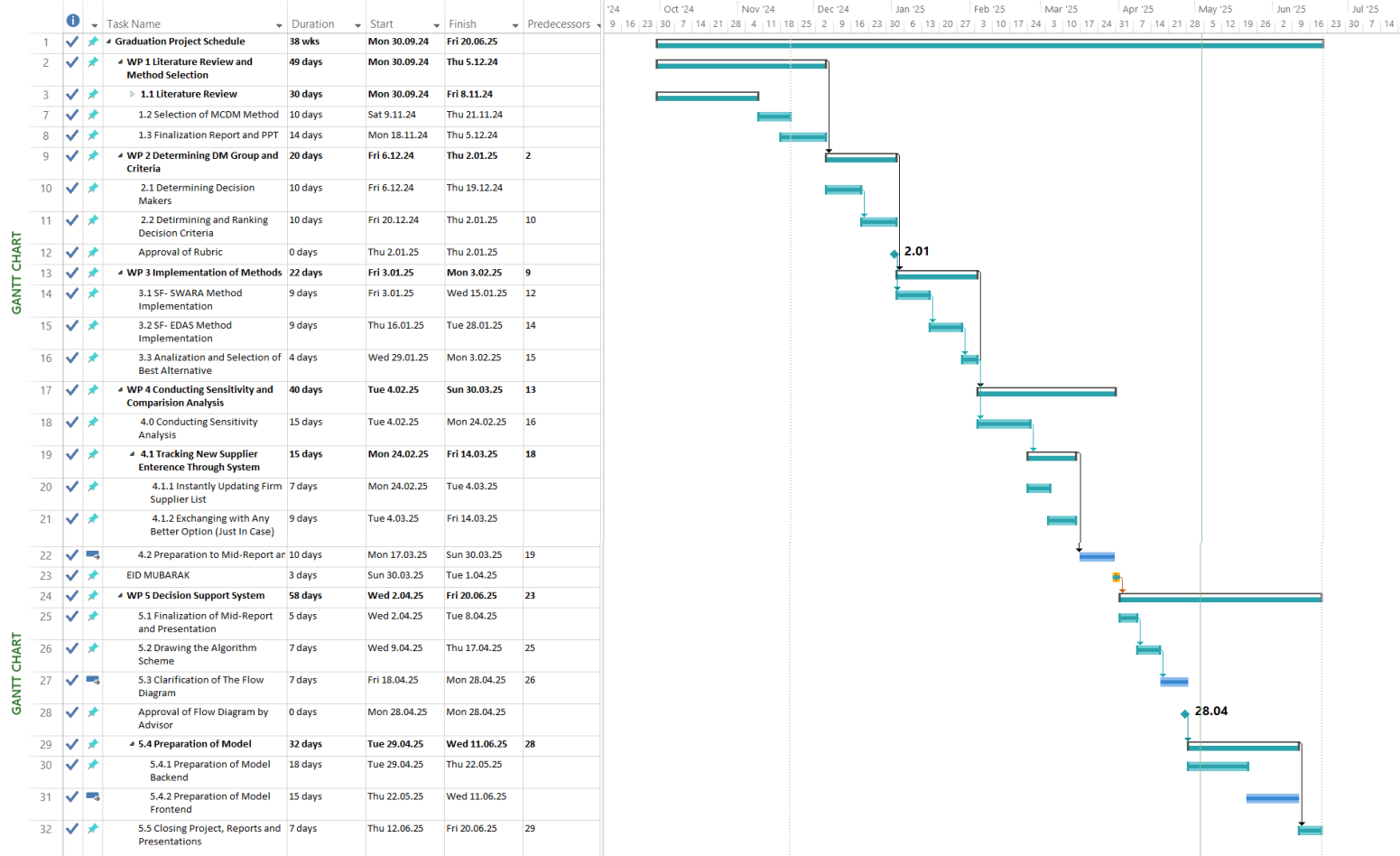
Work Package #	Risk	B-Plan
WP 2	There is a possibility that the participation rate in the survey to be administered to experts will be low.	In cases where the data set is insufficient, new decision makers in the field will be identified and the pool of experts will be expanded, thus providing a more comprehensive data collection process.
WP 2	Disagreements among decision makers when weighing the criteria. Disagreements that may occur when blending the opinions of more than one decision maker reduce the accuracy of the decisions to be taken.	A consensus will be achieved by using the arithmetic average in the process of blending the opinions of decision makers. Although the number of decision makers is generally expected to be three, weighting processes can be followed with Excel.
WP 5	Technical difficulties that may occur during interface design.	While designing the application, by testing it on other suitable platforms, platform-specific problems can be identified, and adjustments can be made.

In addition to the above for Project II, the risks that arose during the execution of the project and how they were overcome are included in the table below.

Work Package #	Risk	B-Plan
WP 2	The participation rate in the survey to be applied to experts was low.	New expert decision makers from different departments and companies were identified and a more comprehensive data collection process was provided.
WP 2	Disagreements among decision makers when weighing the criteria. Disagreements that may occur when blending the opinions of more than one decision maker reduce the accuracy of the decisions to be taken.	In the process of collating the opinions of decision makers, a consensus was reached using the arithmetic mean. The number of decision makers was determined as three, and the weighting processes were followed with Excel.
WP 5	Technical difficulties that might occur during interface design.	There were no significant technical problems during the interface design process. Tests conducted on different platforms were effective in preventing potential problems. Additionally, artificial intelligence support was received during the development of Python codes.

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7. WORK TIME PLAN OF THE PROJECT



8. DEMO PLAN

a. 8.1 CASE STUDY I - A Spherical Fuzzy Swara And Spherical Fuzzy Edas Approach For Supplier Selection Problem: A Case Study From The Accessory Department

Today, the acceleration of industrialization, which is influenced by rapidly changing and developing technology, is destroying nature and making the continuity of the world impossible. The main purpose of this case study is to find solutions to the problems related to green living and in this context, to focus on suppliers in the textile sector, which is one of the most damaging sectors in terms of water consumption. In the evaluation process, agility and green production titles were analyzed as criteria along with environmental factors; at the same time, it was aimed to reach more rational and applicable results by considering the profitability of the suppliers.

The study was conducted in a textile company operating in Istanbul with a significant market share. The product range of this company is quite wide, from clothing to accessories, from household products to glassware. The company cooperates with many suppliers to supply products worldwide and has included the ECO (ecological) category in its product segment in line with the increasing demands for environmentally friendly products, especially in the European market. The company strives to ensure

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that products in this category are produced with sustainable processes and sustainable materials, thus protecting both the environment and the company's presence in the competitive market.

In addition, a team of three decision makers was formed in the accessories department: a unit manager (DM1), a production specialist (DM2) and a purchasing specialist (DM3). The decision makers identified the five alternative suppliers with whom the company collaborated most frequently in the accessories department and conducted the evaluation process based on these firms. DM3 was responsible for procuring the goods and services needed by the company; DM2 provided technical guidance on raw materials and production processes; and DM1 managed compliance with company standards and general relations with suppliers.

Decision makers were weighted according to their level of experience: DM1 has more than 16 years of professional experience, DM2 has 6-10 years, and DM3 has 0-5 years. Accordingly, their contribution rates are 0.4, 0.3 and 0.3 respectively.

All of the criteria are considered as benefit criteria. The supplier that meets all criteria at the highest level is assigned as the best. After the criteria were determined, potential suppliers were investigated and five alternatives (S1, S2, S3, S4, S5) were selected. After all the parameters were verified, a questionnaire was prepared through MS Forms so that the decision makers' data could be used in the methods. In the first part of the questionnaire, decision makers were asked to rank the criteria and in the second part, they were asked to compare suppliers for each criterion. The data obtained were integrated into the MS Excel file where the formulas of SF-SWARA and SF-EDAS methods were applied. With the data obtained from the first part of the questionnaire, the criteria weights were calculated with the SF-SWARA method; based on the comparisons in the second part, the SF-EDAS method was applied and the suppliers were ranked.

As a result of the data analysis, the highest weight was given to the Innovation Capability (A1) criterion and the highest total performance score was obtained by Supplier 5. Results and visualizations are presented in section 10 and discussions are presented in section 11. In line with these findings, Supplier 5 was identified as the strongest candidate in terms of sustainability, agility and operational suitability in the accessories department and it was recommended to strengthen the cooperation.



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b. 8.2 CASE STUDY II - A Spherical Fuzzy Swara And Spherical Fuzzy Edas Approach For Supplier Selection Problem: A Case Study From The Label Department

Today, the acceleration of industrialization, which is influenced by rapidly changing and developing technology, is destroying nature and making the continuity of the world impossible. The main purpose of this case study is to find solutions to the problems related to green living and in this context, to focus on suppliers in the textile sector, which is one of the most damaging sectors in terms of water consumption. In the evaluation process, agility and green production titles were analyzed as criteria along with environmental factors; at the same time, it was aimed to reach more rational and applicable results by considering the profitability of the suppliers.

This study, based on the label department, was conducted in the same Istanbul-based textile company. Within the scope of the ECO product strategy, the company aims to transition to sustainable materials and production processes in areas such as the label department, which are units in direct contact with the consumer. Therefore, a supplier that both complies with environmental standards and has technical competence should be selected.

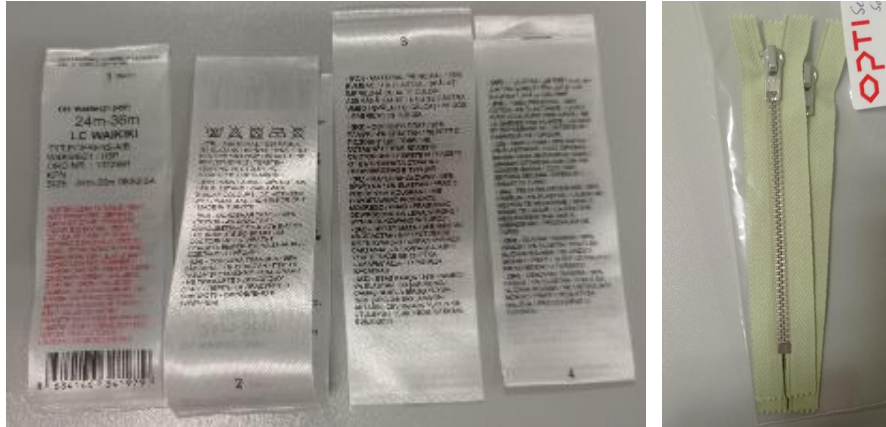
Three expert decision makers were assigned in this process: label department manager (DM1), production expert (DM2) and procurement expert (DM3). The decision makers identified the five potential suppliers that the label department worked with most frequently and conducted their analysis on these suppliers. DM1 was responsible for general availability and relationships, DM2 for technical production knowledge and DM3 for procurement processes.

Decision makers are weighted according to their experience: DM1 has over 16 years of experience, DM2 has 6-10 years of experience and DM3 has 0-5 years of experience. Correspondingly, weight coefficients of 0.4, 0.3 and 0.3 were assigned respectively.

All criteria were treated as utility criteria and five potential suppliers (S1-S5) were analyzed after the criteria names were determined. An MS Forms questionnaire was prepared to collect decision maker data, which consisted of two parts. In the first part, decision makers ranked the criteria; in the second part, they compared the five suppliers for each criterion. The collected data was transferred to an Excel file containing the formulas of SF-SWARA and SF-EDAS methods and the analysis was carried out in this environment. The data obtained from the first part provided the criteria weights with SF-SWARA and the second part provided the supplier scores with SF-EDAS.

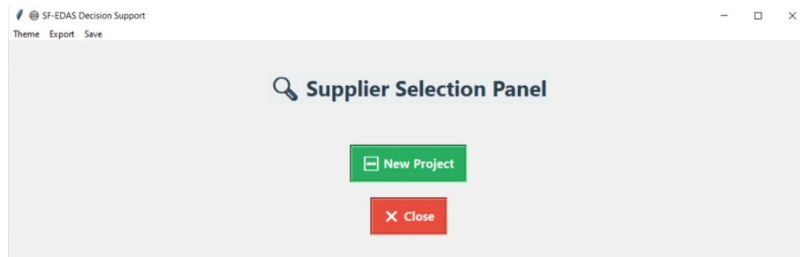
As a result of these analyses, Green Distribution stood out as the criterion with the highest weight, and Supplier 1 received the highest ranking among the suppliers. In the label department, this supplier stood out with its high performance, especially in green competencies and waste management, and despite some limits in flexibility, the overall level of success was found to be high. The discussions are detailed in chapter 11. As a result, it is planned to continue to cooperate with Supplier 1 for the label department in line with the sustainable supply chain approach.

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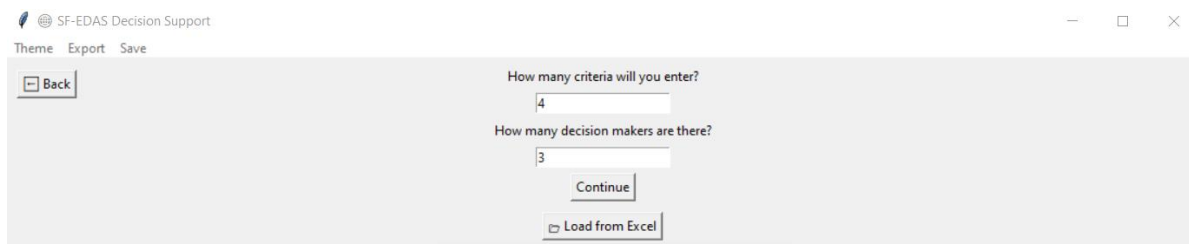
c. 8.3 User Interface Design

The following part explains how to use the created decision support system and introduces its user interfaces. The user interfaces are made to allow decision makers to take part in the assessment process in an easy-to-use and methodical way.



Supplier Selection Panel: This initial screen is where the system begins. Here, the user can select the "Close" option to end the program or utilize the "New Project" button to begin a new evaluation procedure. The interface is intended to be straightforward, intelligible, and instructive.

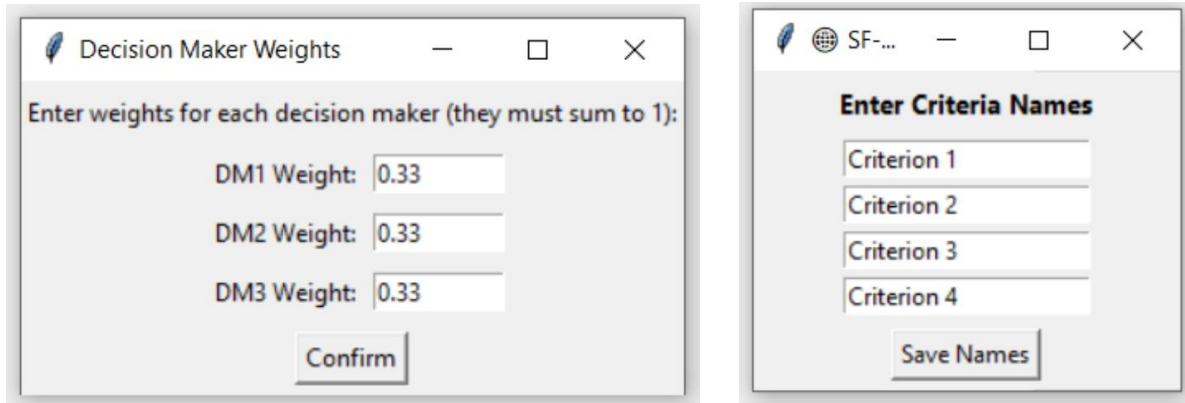
8.3.1. Swara Data Entry Panel (For Manual Entry)



Manually entering criteria with data about decision makers: The user interface on this screen allows users to manually enter the number of decision makers and criteria to be used in the study. The user clicks the "Continue" button to move on to the data entry procedure after

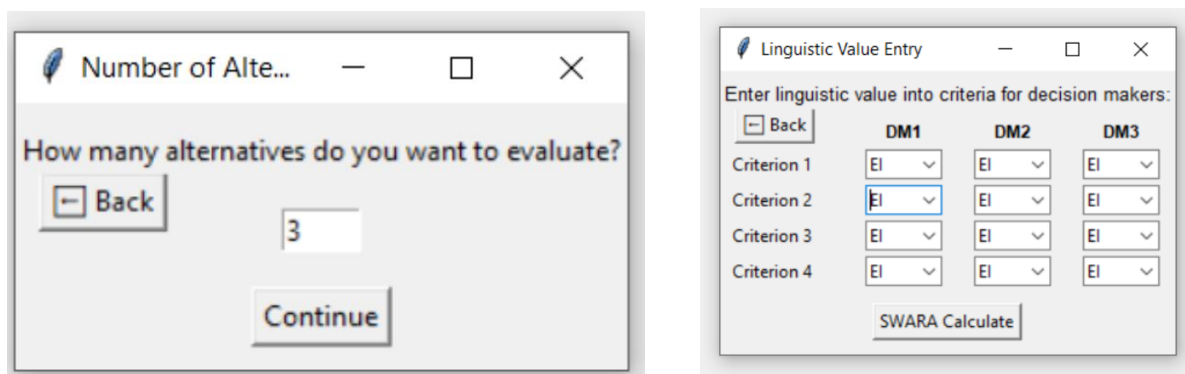
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entering numerical values in the appropriate fields. Users who prefer to enter data straight from the program or who do not want to utilize Excel can use this way.



Decision Maker Weights: Decision-makers utilize this screen to enter weight values that represent how much they contribute to the process. It is necessary to set the weights' sum to 1. The decision makers' influence on the ultimate choice is determined by the values they enter.

Enter Criteria Names: This page is used by users to specify the evaluation criteria. The "Save Names" button gives each criterion a name and saves it to the database. Criterion-based computations require this step.



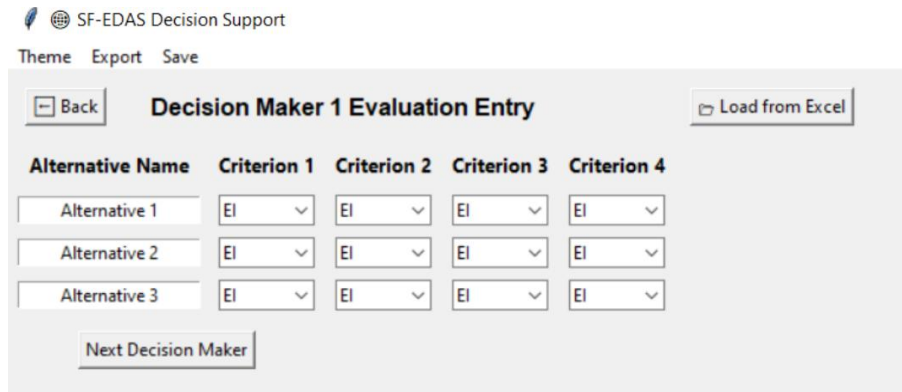
Number of Alternatives: The user chooses how many options to include in the evaluation process using this user interface. The evaluation matrices and screens are automatically shaped by the system to match the entered numbers.

Linguistic Value Entry: Decision-makers use language phrases (such as EI, or Equal Importance) to convey their assessments in relation to each criterion. This screen is set up to supply information for the SWARA technique. The "SWARA Calculate" button is used to determine the criterion weights once all entries have been finished.

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SWARA Weights Result (Text View): The user is shown the weights of the determined criterion as text. The user can examine and confirm the computation results on this screen. To move on to the following step, click the "OK" button.

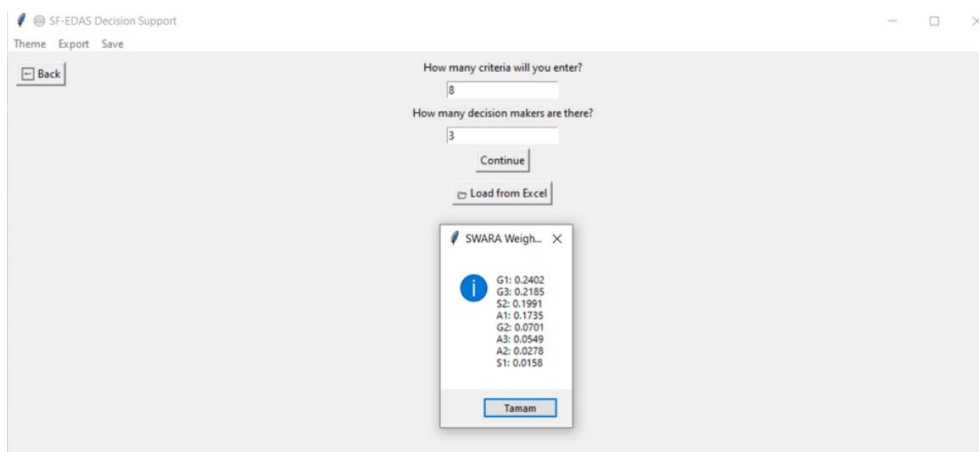
EDAS Evaluation Entry Interface (FOR MANUAL ENTRY)



Extended Format: The extended entry screen is utilized when there are more criteria and options. Users can enter all data using the same interface and conduct a thorough examination thanks to this page.

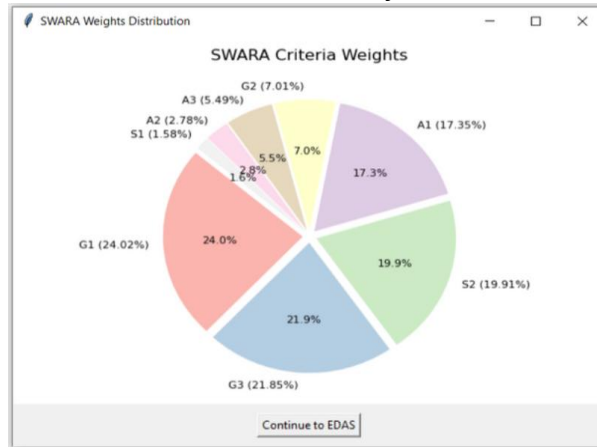
8.3.2. Swara Data Entry Panel (For Load Excel)

This interface eliminates the need for manual entry by loading decision makers' evaluation data into the system via an Excel file. The "Load from Excel" option allows the user to automatically transfer data pertaining to all alternatives and criteria.



Criteria and Decision Maker Import: Although it is possible to manually enter the number of criteria and decision makers, the system can additionally import data from an Excel file. Users may enter data more quickly and accurately with this functionality.

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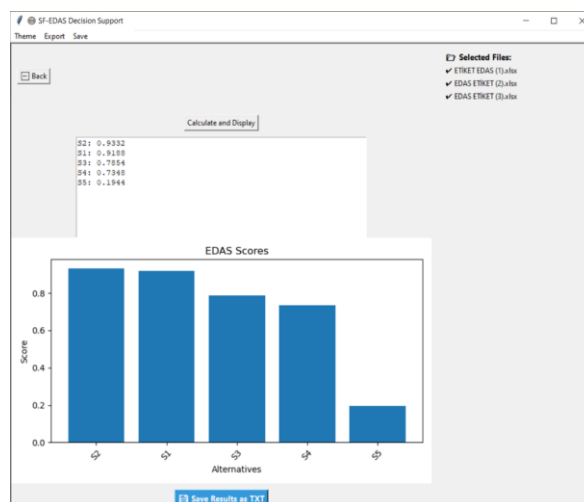


Graphical Output Interfaces (Pie & Bar Charts): (Here, the prior SWARA pie chart can also be assessed.) A bar chart displaying the alternative scores of the EDAS stage gives the viewer a chance to compare them visually. The graphic makes it simple to examine each alternative's overall score.

EDAS Evaluation Entry Interface (FOR LOAD EXCEL):

Alternative Name	G1	G3	S2	A1	G2	A3	A2	S1
Alternative 1	EI	EI	EI	EI	EI	EI	EI	EI
Alternative 2	EI	EI	EI	EI	EI	EI	EI	EI
Alternative 3	EI	EI	EI	EI	EI	EI	EI	EI

Excel Upload Screens: This screen enables bulk uploads of each decision maker's EDAS evaluation files to the system. The system displays the files that were uploaded and prepares them for examination.



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Final Score Display Panel: The scores of the options are determined by EDAS computations utilizing the information in the submitted Excel files. Both text and a bar chart are used to present the results. These outcomes can be exported by the user.

9. FINANCIAL EVALUATION

Kind of Budget	Requested Budget Amount (TL)	Request Justification
Consumables	500	Stationery supply.
Service Procurement	4500	Printout, app purchase (for survey), interface design workshop.
Transportation	4000	Transportation costs for the necessary visits (experts, companies, etc.) during the project.
TOTAL	9000	

The financial organization of the project was prepared by estimating the cost points required for the completion of the Graduation Project I and Graduation Project II phases. In the planned budget is a budget of 500 TL for stationery and other materials, 4500 TL for implementation services, for instance survey applications, software purchases and interface design, and 4000 TL for expert interviews and field visits were foreseen. The total budget of 9000 TL is shown in Table.

The main reasons for such deviations include unanticipated needs, changes in market conditions (as mentioned above for exchange rate changes) and additional data collection requirements that may arise during the project. However, it is anticipated that the budget will be managed effectively overall, and deviations will be kept to a minimum, and these deviations have been considered as far as possible when assigning the budget.

10. RESULTS

Step1: A literature review was carried out and as a result, possible criteria sets were collected in the problem pool.

Step2: As a result of the articles analyzed, the most demanded criteria were selected. For this study, 8 criteria were determined in 3 subcategories as shown in Table 4 and their definitions are stated in the appendix section.

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Table 3. Name of Criteria

Criteria	
G1	Green Distribution
G2	Green Competencies
G3	Green Manufacturing System
A1	Innovation capability
A2	Flexibility
A3	Reverse Logistic
S1	Long-Term Relationship
S2	Waste Management

Step3: Before deciding on these linguistic terms, a questionnaire was created for the companies and the data was taken from there. Linguistic term assignments were made according to the frequency of use of the selected criteria. At this stage, linguistic terms contain ABB nomenclatures according to the criterion degree (found in Table 3). After the assignment of the linguistic terms, the value sets μ , ν , π , respectively, of these values are created.

Step4: Multiple matrix criteria sets are reduced to single sets, customized and assigned values

Step5: Applying the SWAM formula Eq.6, the criteria weights were calculated for all criteria and terms in turn.

Step6: After applying the Score formula, the scores were sorted from largest to smallest and finally s_j, k_j, q_j values were found respectively by using formulas (methodology part formulas of 11-12-13-14). These values were reduced to a single term and weight values were found and ranked.

a. Application of SF-SWARA for CASE STUDY I

Table 5. Final criteria weights for SF-SWARA Case Study I

Criteria	Calculating final criterion weights using SWARA.						
	Score	Criteria ranking	s_j	k_j	q_j	w_j	
G1	1,131	A1	1,592		1	1,000	0,262
G2	0,116	G1	1,131	0,461	1,461	0,685	0,180
G3	0,327	S2	0,911	0,220	1,220	0,561	0,147
A1	1,592	G3	0,327	0,584	1,584	0,354	0,093
A2	0,055	S1	0,288	0,039	1,039	0,341	0,089
A3	0,178	A3	0,178	0,110	1,110	0,307	0,081
S1	0,288	G2	0,116	0,062	1,062	0,289	0,076
S2	0,911	A2	0,055	0,061	1,061	0,273	0,072
Sum of q_j						3,810	1,00

The weights of the evaluation criteria calculated by SF-SWARA (from Table 5) are shown in the Pie Chart in Figure 10 for easy visualization. The SF-SWARA results provide critical priorities for supplier selection. According to the results of the study conducted in the Excel application, the eight criteria in decreasing order are: Innovation Capability (A1), Green Distribution (G1), Waste Management (S2),

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Green Production System (G3), Long-Term Relationship (S1), Reverse Logistics (A3), Green Competencies (G2), Flexibility (A2). It is seen that the two most important criteria are related to the attributes of "agile" and "green".

The ranking of the criteria according to their weights obtained from SWARA is given in Figure 10.

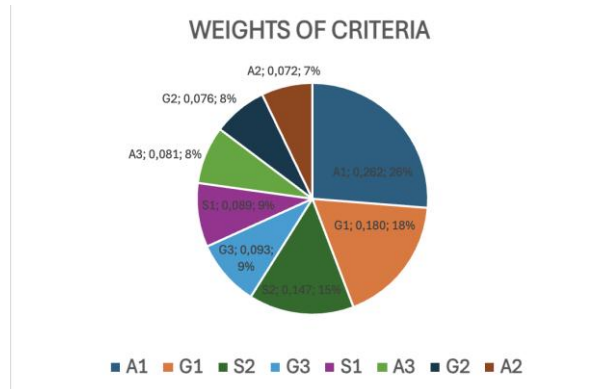


Figure 10: Weights of Criteria FOR Case Study I

b. Application of SF-SWARA for CASE STUDY II

Table 7. Final criteria weights for SF-SWARA Case Study II

Criteria	Calculating final criterion weights using SWARA.						
	Score	Criteria Ranking	Sj	Kj	Qj	Wj	
G1	4,908	G1	4,908		1	1,000	0,347
G2	1,482	G3	4,465	0,443	1,443	0,693	0,241
G3	4,465	S2	4,069	0,396	1,396	0,496	0,172
A1	3,559	A1	3,559	0,510	1,510	0,329	0,114
A2	1,838	S1	2,535	1,024	2,024	0,162	0,056
A3	0,326	A2	1,838	0,697	1,697	0,096	0,033
S1	2,535	G2	1,482	0,356	1,356	0,071	0,025
S2	4,069	A3	0,326	1,156	2,156	0,033	0,011
Sum of Qj					2,880	1,00	

The weights of the evaluation criteria calculated by SF-SWARA (from Table 5) are shown in the Pie Chart in Figure 10 for easy visualization. The SF-SWARA results provide critical priorities for supplier selection. According to the results of the study conducted in the Excel application, the eight criteria in decreasing order are: Green Distribution (G1), Green Manufacturing System (G3), Waste Management (S2), Innovation Capability (A1), Long-Term Relationship (S1), Flexibility (A2), Green Competencies (G2), Reverse Logistics (A3) Both of the two most important criteria appear to be related to the “Green” qualification.

The ranking of the criteria according to their weights obtained from SWARA is given in Figure 10.

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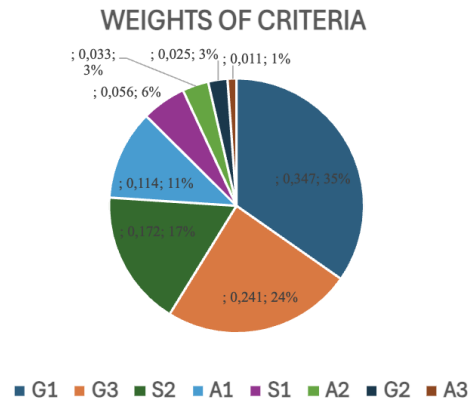


Figure 10: Weights of Criteria FOR Case Study II

Step7: Since it was important to evaluate alternatives from different perspectives, linguistic importance was assigned for each decision maker. After the assignment of linguistic terms, value sets μ , ν , π , respectively, were created for each decision maker and each alternative supplier. (Table2) Multiple matrices, which were separate for each decision maker, are reduced to a single matrix by applying the SWAM method. Then the mean must be found for each value of μ , ν , π . After the average were found, the score for each criterion should be calculated by applying the Score formula. (Equation7).

Step8: PDA and NDA values should be found by applying the PDA and NDA formula for each criterion and alternatives as mentioned in the methodology section.

Step9: SP_i and SN_i values should be found by applying the SP_i and SN_i formula for each criterion and alternatives as mentioned in the methodology section.

Step10: With the NSN_i and NSP_i formulas mentioned in the Methodology part, the performance scores of the alternatives were calculated with the normalized scores obtained by using the PDA and NDA values, and then the AS_i formula was applied, and the results were ranked according to the AS_i values. These scores, which were converted into precise values by defuzzification, enabled an objective comparison of the performance of the suppliers. The supplier with the highest AS_i value was determined as the most suitable alternative.

c. Application of SF-EDAS for CASE STUDY I

The priorities varying according to departments reflect the operational perspectives of decision makers. For the company cooperating in the label department, the Green Distribution criterion is prioritized, and it is important that the environmental impact of logistics processes is at the lowest level in the product group reaching the consumer. Suppliers' attention to processes such as green packaging and low emission transportation played a decisive role in the evaluation process.

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The performance scores of each supplier according to the accepted criteria weights were calculated by SF-EDAS method. Positive and negative distances were normalized to obtain the average solution index (ASi) for each alternative.

Table 6. Final criteria weights for SF-EDAS Case Study I

ASI values for Defuzzification, Normalization, and Supplier Sorting												
Alters	#μ	#ν	#π	sc(SPi)	NSPi	#μ	#ν	#π	sc(SNi)	NSNi	ASi	Ranking
S1	0,003	0,000	0,003	0,029	0,309	0,003	0,000	0,001	0,029	0,690	0,4995	5,000
S2	0,007	0,000	0,002	0,066	0,717	0,007	0,000	0,004	0,066	0,285	0,5010	3,000
S3	0,009	0,000	0,006	0,092	1,000	0,009	0,000	0,000	0,092	0,000	0,5000	4,000
S4	0,002	0,000	0,001	0,022	0,242	0,002	0,000	0,003	0,022	0,760	0,5013	2,000
S5	0,002	0,000	0,000	0,021	0,227	0,002	0,000	0,004	0,021	0,777	0,5023	1,000

SF EDAS
RESULT

The ranking of alternative suppliers according to their rates obtained from SF-EDAS is given in Figure 11.



Figure 11. Ranking Value of Suppliers Case Study I

Accordingly, the ranking should be: **S5 > S4 > S2 > S3 > S1**.

Supplier 5 ranked first with the highest ASi value (0.5023), while Supplier 1 received the lowest score (0.4995) (as shown in Table 6 and Figure 11).

d. Application of SF-EDAS for CASE STUDY II

In the accessories department, the reason why the Innovation Capability criterion received the highest weight for the company is that the goals of product differentiation and competitive advantage are moving in the same direction as sustainability. It represents the rapid adaptation of green and agile integrations while revealing the prioritization of suppliers with high technology and design flexibility.

In case study 2, the SF-EDAS approach was used to evaluate supplier performance scores in the same way. Based on the normalized positive and negative distances, the average solution index (ASi) was calculated for each alternative. It is seen that Supplier 1 ranked first with an ASi score of 0.5000, while Supplier 2 ranked last with a score of 0.4132 (as shown in Table 8 and Figure 11).

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Table 8. Final criteria weights for SF-EDAS Case Study II

ASi values for Defuzzification, Normalization, and Supplier Sorting												
Alters	#μ	#ν	#π	sc(SPI)	NSPI	#μ	#ν	#π	sc(SNi)	NSNi	ASI	Ranking
S1	0,016	0,000	0,006	0,162	1,000	0,016	0,000	0,000	0,162	0,000	0,50000000	1,000
S2	0,007	0,003	0,002	0,039	0,243	0,007	0,000	0,002	0,067	0,583	0,4132	5,000
S3	0,016	0,000	0,006	0,161	0,998	0,016	0,000	0,000	0,162	0,002	0,4999989	2,000
S4	0,000	0,000	0,000	0,003	0,019	0,000	0,000	0,005	0,003	0,979	0,4989	3,000
S5	0,000	0,000	0,002	0,002	0,015	0,000	0,000	0,010	0,010	0,936	0,4756	4,000

SF EDAS
RESULT

The ranking of alternative suppliers according to their rates obtained from SF-EDAS is given in Figure 11.

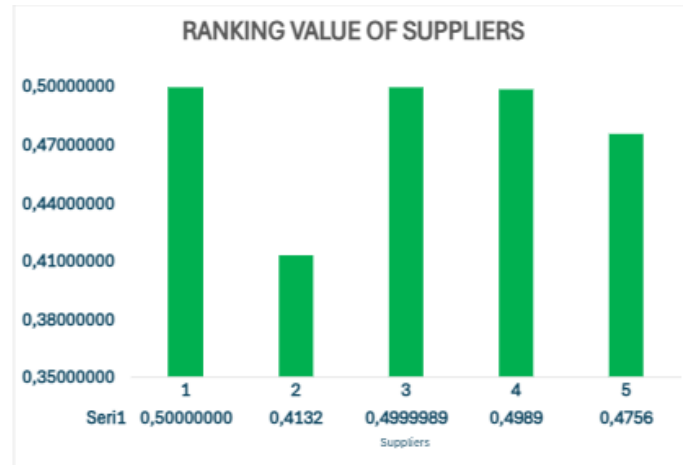


Figure 11. Ranking Value of Suppliers Case Study II

Accordingly, the ranking should be: **S1 > S3 > S4 > S5 > S2**.

These results demonstrate the adaptability of SF-SWARA and SF-EDAS methods to multidimensional and real-world scenarios. Differences in the ranking of suppliers indicate the ability of the model to respond to industry needs.

This result phase proved that the project was feasible and that the chosen methods—SF-SWARA and SF-EDAS—were effective in addressing the problem. Differences in the ranking of suppliers demonstrate the ability of the model to respond to industry needs. Overall, this study finds that integrating green and agile dimensions is critical to creating a sound decision-making framework in sustainable supplier selection.

The findings show that the project is on schedule to achieve its goals. The project’s ability to provide a strong foundation for selecting green, agile suppliers in the textile sector is proven by the progress made.

Table 10. Work packages progress chart

Work Package #	Completed (%)	Notes
WP 1	%100	This work package has been completed as planned. Risk countermeasures have been determined.

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WP 2	%100	Preliminary assessment expert selection has been completed. Green, sustainable and agile criteria have been determined.
WP 3	%100	SF-SWARA and SF-EDAS implementation process has been completed.
WP 4	%100	Initial testing and monitoring framework has been created.
WP 5	%100	Early-stage interface prototype development and validation studies have been completed

11. DISCUSSION

Sustainability has become an important issue as pandemic and climate change problems have become evident. Green as a sophisticated sub-branch of the sustainability concept presents an eco-friendly solution to the processes of the supply chain. Agility, resilience to change, or the ability to manage change has become an inevitable approach in this volatile environment. Considering that the textile industry is one of the biggest polluters after the cement industry, appropriate supplier selection based on aforementioned elements is crucial, and optimizing the selection process should have been the first priorities of the government, giant industry firms as a main responsibility by giving adequate incentives to the researchers.

This study endeavors to fill the gap of comprehensive sustainable, agile supplier selection under spherical fuzzy environment study in the textile industry by implementing SF-SWARA and SF-EDAS hybrid integration. 8 criteria were selected and divided into 3 subcategories as 3 criteria for green, 3 criteria for agile, and 2 criteria for sustainable. The criteria pool has been compiled from previous literature. 5 decision makers were invited to the research to fulfill the surveys about assigning weights of criteria and the ranking of the suppliers. The weight calculations of the criteria were made through SF-SWARA. For the application, linguistic terms and expert opinions were used to rank the changing priorities. For the ranking of 5 alternatives, suppliers, SF-EDAS was used. Distance-based approach was used to obtain an ideal solution. Both negative and positive deviations were evaluated based on distance from the average solutions and a solution was attained. The hybridization of the described methods makes them particularly suitable for dynamic supplier selection scenarios.

Hence, this study offered both remarkable theoretical and practical contributions. The theoretical contributions were concretely realized as the method was successfully implemented. Moreover, the application filled an important gap in the literature as the first known study integrating SF-SWARA and SF-EDAS methods. In addition, agile and sustainable issues were addressed in the same study within the framework of spherical fuzzy. Thus, by developing a different approach to supplier selection, it reduces operational intensity and cost. Moreover, a more comprehensive study of the weights of the criteria and their effects on the outcome was carried out. An auxiliary decision-making system applicable to real-life scenarios, supported by consistency analysis, has been created and added value has been produced for the industry on the practical side.

When the Garg et al. (2022) score, Eq.(7) was used, the score values of various alternatives and the associated NSP_i values were negative. This prevents the formula from being applicable and violates the range of $0 \leq AS_i \leq 1$. Therefore, it is inconvenient to use this score formula. Therefore, the failure was overcome by substituting the new score formula Eq.(12) Tas et al (2021).

The results of the study for the label and accessories departments show how operational priorities in different departments influence the level of importance given to selected criteria and supplier rankings. First of all in the label department, the highest weight is given to Green Distribution (G1), followed by

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green manufacturing system (G3) and waste management (S2). The focus of the label department is more on how logistics processes evaluate the environmental impact and resource utilization. Criteria such as Flexibility and Reverse Logistics have lower weights, indicating that the same criteria may have different priorities in different contexts.

In the accessories department, the highest priority was given to Innovation Capability (A1) (0.262), followed by Green Distribution (G1) (0.180) and waste management (S2) (0.147). In addition to environmental factors, product innovation and a technology-oriented approach were also emphasized here. Flexibility (A2) ranked last. This distribution shows that the accessories department is more focused on innovation and competitiveness than on green living; it is more concerned with strategic differentiation than with logistical or operational flexibility.

Supplier rankings reflected the differences in this priority. In the label department, the ranking is $S1 > S3 > S4 > S4 > S5 > S2$. S1 ranked first with the highest ASi score (0.5000) due to its high achievement in criterion G1. S2 was ranked last due to its incompatibility with the determining criteria.

It was then applied for the accessories department and the ranking is $S5 > S4 > S2 > S3 > S1$. S5 ranked first with an ASi score of 0.5023 due to its strong membership and low negativity values in highly weighted criteria such as A1 and G1. S1 is at the bottom of the list due to its low performance and poor alignment with critical criteria. It is particularly noteworthy that the ASi scores are close, indicating that the ranking is sensitive.

Sensitivity analyses for both departments show that the rankings are generally stable. S1 in the label department and S5 in the accessories department maintained their leadership in all scenarios. This shows that SF-SWARA and SF-EDAS methods provide reliable and consistent results in different scenarios.

12. ASSESSMENT OF ENGINEERING STANDARDS

1. ISO 9001 (Quality Management)

Project Connection: To continuously improve the overall quality of the project, ISO 9001 provides for continuous auditing of suppliers' quality management processes. Thus, the selected suppliers meet the criteria by offering more efficient and quality solutions based on continuous improvement rules.

In our project.

Monitoring and reporting supplier processes and improving evaluation criteria based on more accurate data.

2. ISO 14001 (Environmental Management)

Project Connection: It will help select environmentally friendly suppliers; this standard will increase the project's sensitivity to environmental sustainability. This standard encourages suppliers to minimize their negative impact on the environment.

In our project:

It will show how environmental management practices are implemented by suppliers. resource efficiency and it will show how environmental factors such as waste management are considered in supplier selection and how their impact changes in the results.

3. ISO 20400 (Sustainable Supply)

Project Connection: This standard provides a framework for how to apply sustainability in supplier selection. The project aims to create a network with suppliers who fulfill their environmental and social responsibilities. ISO 20400 is one of the most important standards in achieving this goal.

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In our project:

It will guide the assessment of suppliers' environmental and social impacts. Determining sustainability strategies and using them by supplier companies will allow us to examine their positive effects on selection.

4. ISO 53001 (Sustainability Development Management)

It is a standard that allows suppliers to evaluate their asset management processes. Efficiency and sustainability will contribute to our long-term goals. This standard will help us examine how suppliers optimize their energy, material and monetary resources in our project.

5. PEP 8 (Coding Style Guide)

Project Connection: PEP 8 improves the readability and accuracy of Python codes. Our project will be carried out within the framework of determined coding standards, will facilitate the continuous development of the software and strengthen cooperation among project employees.

In our project:

All code will be aimed to be written in accordance with PEP 8 standards. For example, details such as variable naming and line length will be followed. Compliance with PEP 8 will be checked during the code review phase. Thus, the error rate will be reduced.

6. PEP 257 (Documentation Style Guide)

Project Connection: PEP 257 ensures that software documentation is clear and understandable. Accurate documentation of the software to be created within the scope of the project is provided for long-term maintenance and adaptation of new developers.

In our project:

Each function, class and module have a meaningful document prepared for it. The functions and operation of the software are explained in detail in these descriptions. During code review, documents are reviewed for completeness and clarity. It looks at the quality of documentation of software coming from suppliers. One of the important requirements of supporting the project is the correct documentation of the vendor's software, features and modules.

13. UNIVERSAL AND SOCIAL EVALUATION OF THE PROJECT/ LIMITATIONS

Within the scope of this project, SF-SWARA and SF-EDAS methods were used for sustainable, environmentally friendly and agile supplier selection processes. However, as in every project, there are some limitations in this study:

1. Limitations Related to Production Application:

The project's system is founded on alternative ranking and theoretical criterion weighting. Depending on the companies' internal procedures, data infrastructures, and decision-making cultures, this system's application in actual production settings may vary. The system could require complete criteria-based data entry, and these not all companies can give.

2. Limitations Related to Social, Political and Security:

Supply chain processes are affected not only by technical and environmental factors but also by social and political factors. Within the scope of this project, social-political factors such as political stability, legal regulations or ethical trade principles in the countries where the suppliers are located have not been taken into account. In addition, collecting and analyzing supplier information in a digital environment may also pose some risks in terms of data security.

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3. Environmental Limitations:

Although the criteria used in the project focus on environmental sustainability, the measurement of these criteria is entirely based on the decision makers' assessments. External environmental audit reports may be needed to objectively measure the actual environmental impacts. This may affect the accuracy of the criteria.

4. Sustainability:

Although the aim of the project is to support sustainable supply chain management, the system does not monitor whether the selected suppliers will truly exhibit sustainable behavior in the long term. In other words, the system makes decisions based only on the current assessment; it does not continuously monitor the dynamic nature of sustainability.

5. Economic Limitations:

Detailed information must be collected from decision makers to implement the model. The management of this process requires time, labor, and technical knowledge. This may mean additional costs for small businesses. In addition, the supplier selected as a result of the implementation of the system may not always be the lowest-cost option.

6. Other Limitations:

Fuzzy logic is an essential component of the SF-SWARA and SF-EDAS methods which translate declarative statements into numerical models. Subjective assessments like "high importance" and "low importance" are associated with particular numerical equivalents during this translation procedure. However, not every decision maker may use these linguistic expressions in the same sense; for example, the expression "medium importance" may correspond to a value of 0.5 for one participant, while this value may correspond to a value of 0.7 for another. This situation may cause uncertainties and inconsistencies based on interpretation in the evaluations.

Since the project was developed specifically for the textile sector, it was determined that the criteria set was suitable for this sector. However, it is planned that these criteria will be changeable by the user in the interface to be designed. Although this flexibility makes the system adaptable to different production types (e.g. ready-made clothing, yarn, fabric production, etc.) and different company scales, users need to be able to define and evaluate new criteria correctly. Otherwise, the reliability of the results provided by the system may decrease.

14. CONCLUSION

The fact that this project addresses the concepts of greenness, sustainability and agility together in the supplier selection process shows that it presents an innovative decision support model created specifically for the textile industry. The integration of SF-SWARA and SF-EDAS methods has provided a reliable and feasible solution for multi-criteria and uncertainty decision-making processes.

In the study, the criteria decided in cooperation with experts and literature reviews were determined through interviews and surveys with industry experts, which gave the model theoretical as well as high practical validity. The findings were in line with the decision makers' priorities and revealed that suppliers with high agility and environmental sensitivity were prioritized.

Although some technical limitations were identified (e.g. negative values in scoring or balance issues in weighting), this did not weaken the overall strength of the model; on the contrary, it provided important insights to identify areas for improvement.

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Furthermore, a digital interface has been designed for the model to enable users to carry out the decision process easily and quickly. Thanks to this interface, decision makers can access the ranking results quickly and visually by entering the criteria weights and alternative suppliers into the system.

In conclusion, this project presents a data-driven green, agile and sustainable supplier selection approach that contributes to both academic literature and sectoral applications. In future studies, it is recommended to strengthen and test this model in different sectors with larger pools of experts and to integrate it with smart systems

15. PLAN FOR FUTURE STUDIES

Our project is supported by TÜBİTAK 2209-A support, which allows us to develop our project in more detail. With this support, we aim to conduct advanced and new analyses on the data obtained, improve the software design, and expand the data set with the participation of more experts in the field. We also aim to ensure the sectoral validity of our project by establishing collaborations with the industry. Our project will participate in the YAEM (44th National Congress on Operations Research and Industrial Engineering (YAEM 2025) event to be held in 2025, and we aim to further improve our project with the feedback we receive. We aim to publish the results in academic journals and present them at conferences.

16. ASSESSMENT OF ENGINEERING COURSES

The courses we have completed throughout the project have made a substantial contribution to the selection and application of the methods, as well as to the study from inception to completion. Our ideology and supporting course are fundamentally founded on the Decision Analysis course, which provided us with a thorough foundation in MCDM (Multi-Criteria Decision Making) techniques. This knowledge significantly influenced the selection of the SF-SWARA and SF-EDAS methods employed in the project. We acquired an understanding of the generation of solutions to real-world problems through case studies, in addition to the methods such as TOPSIS, AHP, and VIKOR that we studied in this course. Throughout the project, this experience served as a guide for us to effectively manage the complexity of the supplier selection process and to conduct the criteria weighing in a professional manner. It also demonstrated that the method we selected was the correct and logical choice.

The knowledge gained from Supply Chain Management courses helped us to understand the structural dynamics of the supply chain and to ensure effective management of resources. In addition, it has helped us to identify deficiencies in the operation process and to analyze and find solutions. In other words, it was possible to identify needs, determine and optimize agility and sustainability criteria in the supplier selection process.

In the second phase of the project, the Python knowledge learned in the Introduction to Programming and advanced programming course, Python's extensive library of data analytics and modelling will be used in the implementation and simulation of the SF-SWARA and SF-EDAS methods, as well as the design of a user-friendly interface for the decision support system. This will enable the project to reach a wider impact area with software-based solutions.

Finally, the analysis and quality techniques we learned in Project Management and quality engineering courses have facilitated the transfer of project outputs to industrial and academic applications while filling out reports. Our project management skills helped us to plan processes in a systematic way and save time while preparing reports.

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18. SUPPORT LETTERS



T.C.
TÜRKİYE BİLİMSEL VE TEKNOLOJİK ARAŞTIRMA KURUMU BAŞKANLIĞI
Bilim İnsanı Destek Programları Başkanlığı

Sayı : B.14.2.TBT.0.06.01.00-221-745761
Konu : "2209-A Üniversite Öğrencileri Araştırma
Projeleri Destekleme Programı 2024 Yılı 1.
Dönem Başvurunuz"

07/05/2025

Sayın ŞEVVAL KAZ

2209-A Üniversite Öğrencileri Araştırma Projeleri Destekleme Programı 2024 Yılı 1. dönem çağrısına yaptığınız 1919B012423187 numaralı başvuru destek almaya hak kazanmıştır.

Projenizin ilgili mevzuat, çağrı duyurusu ve alınan taahhütnamelerde yer alan yükümlülükler doğrultusunda yürütülmesi gerektiğini hatırlatır, araştırmanızda başarılar dileriz.



Dr. Hatice DAĞLIOĞLU
Bilim İnsanı Destek Programları Başkanı
V.

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19. APPENDIX I - LITERATURE REVIEW					
Heading	Author and Year	Country	Methodology	Problem Addressed	Findings
Studies on Problems Based on EDAS Method	Ghorabae et al. (2015)	Not Specified	EDAS method for ABC inventory classification	ABC classification of inventory list using average unit price, annual dollar usage, and delivery time	EDAS provided the best solution compared to 6 previous methods
	Ghorabae et al. (2016)	Not Specified	Fuzzy EDAS method for chemical supplier selection	Selecting the most suitable chemical supplier for laundry detergent production based on 6 criteria	Evaluated chemical suppliers based on expert opinions and 6 criteria
	Yürüyen and Ulutaş (2020)	Turkey	Fuzzy AHP and Fuzzy EDAS for 3PL company selection	Selecting a 3PL company for military vehicle manufacturing in Ankara	Highlighted the importance of working with the right 3PL to gain competitive advantage
	Demirtaş et al. (2020)	Turkey	Fuzzy EDAS for supplier selection	Supplier selection based on quantitative and qualitative criteria	Product quality identified as the most important criterion; appropriate supplier selected

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	Polat and Bayhan (2020)	Russia	Fuzzy EDAS for HVAC-AHU supplier selection	Selecting suppliers for HVAC-AHU systems for a green shopping mall project in Moscow	Ranked HVAC-AHU alternatives effectively for green certification systems
Studies on Problems Based on SWARA Method	Sahin et al. (2022)	Turkey	Fuzzy SWARA and Fuzzy COPRAS for green supplier selection	Optimizing green lean supplier selection process using 10 criteria	Highlighted criteria optimization for sustainable and environmentally friendly suppliers
	Mishra et al. (2023)	India	Hesitant fuzzy SWARA and COPRAS for sustainable supplier selection	Optimizing decision-making for sustainable supplier selection with 5 alternatives	Proved the method's reliability with sensitivity analysis in the ABC trading company case
	Cakmak (2023)	Turkey	Hybrid Interval-Valued Neutrosophic SWARA and EDAS for MCDM problems	Creating a sustainable supplier park for a generator manufacturer with uncertainty in criteria	Identified 'lead time', 'operations control', and 'supplier location' as critical factors
	Ziquan et al. (2021)	Not Specified	Intuitionistic fuzzy SWARA and COPRAS for shipbuilding supplier selection	Supplier selection in the shipbuilding industry to reduce knowledge conflicts among experts	Addressed intertwined criteria and knowledge conflicts for better supply chain strategies

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Studies on Green Problem Using MCDM	Kopicki et al. (1993)	Not Specified	Proposed three approaches: reactive, proactive, and value-creating	Examining different approaches to green management	Emphasized integrating green practices into business strategies for sustainability
	Porter and Van Der Linde (1995)	Not Specified	Analyzed greening efforts and resource efficiency	Identifying benefits of greening efforts for resource efficiency and company profits	Revealed that greening benefits both companies and the environment
	Srivastava (2007)	Not Specified	Defined green supply chain management processes	Integrating environmental thinking into supply chain management	Outlined a comprehensive scope for green supply chain management
	Akandere and Zerenler (2017)	Turkey	Used correlation, regression, and descriptive statistics for analysis	Evaluating factors impacting green supply chain decisions in green star hotels	Highlighted the importance of appropriate green supplier selection for business performance
	Wang et al. (2009)	Not Specified	Fuzzy hierarchical TOPSIS for supplier selection	Providing more accurate weights for supplier selection problems	Validated the method with a numerical example and showed its objectivity and accuracy

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Studies on Supplier Selection Methods	Shemshadi et al. (2011)	Not Specified	VIKOR with trapezoidal fuzzy numbers and Shannon entropy	Multi-criteria group decision-making for supplier selection with linguistic terms	Integrated objective and subjective weights for effective supplier selection decisions
	Ayhan (2013)	Turkey	Fuzzy AHP for supplier selection in a gear motor company	Evaluating alternative suppliers based on criteria like quality, cost, and delivery	Demonstrated applicability in uncertainty scenarios and decision-making problems
	Badi et al. (2020)	Libya	Grey-MARCOS method	Optimal supplier selection for a steelmaking company in Libya (LISCO)	Proposed a hybrid model; results compared with CODAS, TOPSIS, and VIKOR methods to validate effectiveness.
	Rahman et al. (2022)	Bangladesh	SWARA-WASPAS model	Sustainable supplier selection in Bangladesh's textile dyeing industry	Identified 15 criteria; "chemical quality" most important; Supplier A in Singapore ranked highest.
Studies on Green Supplier	Adamides et al. (2024)	Greece	Modeled green supplier evaluation and selection with activity theory	Differences in green supplier evaluation and selection across industries	Highlighted industry-specific practices influenced by cultural and historical contexts

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Selection Problem	Jianhua Wang and Nan An (2024)	Not Specified	Pythagorean fuzzy sets and TOPSIS with entropy weighting method	Green supplier evaluation with uncertain expert opinions in a fuzzy environment	Confirmed model applicability and effectiveness through case study comparison
	Qian Yu and Fujun Hou (2016)	China	Modified Multiplicative Analytic Hierarchy Process (MMAHP)	Green supplier selection considering both qualitative and quantitative factors	Demonstrated MMAHP's consistency and prevention of sequence reversals
Sustainable and Green Decision-Making Studies	Raghunathan Krishankumar (2021)	Not Specified	EDAS with dual hierarchy fuzzy language terms (DHHFL) for zero-carbon urban mobility	Prioritizing zero-carbon initiatives for sustainable urban mobility	Proposed a roadmap for sustainable city development aligned with zero-carbon targets
	Rahman et al. (2022)	Singapore	Hybrid SWARA and WASPAS for sustainable supplier selection	Sustainable supplier selection in the textile dyeing industry	Identified chemical quality as the most important criterion and validated WASPAS results

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	Jain et al. (2020)	India	Fuzzy Inference System (FIS) for supplier selection in steel and iron industry	Real-life supplier selection for a steel and iron company	Demonstrated the application of MCDM methodologies in industrial supplier selection
	Reema Agarwal and Anil Kumar Nishad (2023)	Not Specified	Fuzzy EDAS for identifying flexible and sustainable suppliers	Evaluating suppliers based on social, environmental, economic, and flexibility criteria	Concluded SRS3 as the best and SRS1 as the worst supplier for sustainability
	Hezam et al. (2024)	Not Specified	Hybrid SF-SWARA and SF-WEDBA for wave energy-based electricity generation	Selecting wave energy systems to optimize electricity generation	Highlighted the potential of wave energy as an alternative to conventional energy systems

20. APPENDIX II - DEFINITIONS OF CRITERIA

Major Criteria	Code	Sub-Criteria	Definition	Reference
Green Criteria	G1	Green Distribution	Green Distribution involves the transportation, storage and delivery of products using environmentally friendly logistics methods. It includes elements such as low-emission transport, energy-efficient storage, optimized logistics routes and sustainable packaging.	Harshad Sonar et al., (2022), BD Rouyendegh et al. (2020) Rouyendegh,B.D., Yildizbasi,A.&Üstünyer, P. (2020).

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	G2	Green Competencies	Green qualifications are a company's or supplier's commitment to environmental sustainability, including environmentally friendly production methods, waste management, renewable energy use, sustainable supply chain practices and eco-innovation.	Hsiu Mei Wang Chen et al., (2016) Konys, A. (2019). Green supplier selection criteria
	G3	Green Manufacturing System	A production system designed to minimize environmental impact by reducing waste, optimizing energy efficiency, and using sustainable materials. This includes cleaner production technologies, circular economy principles, and eco-friendly supply chains.	Esra Çiğdem Cezlan, (2022) Željko Stević et al., (2020), BD Rouyendegh et al. (2020)
Agile Criteria	A1	Innovation Capability	An organization's ability to create, implement, and obtain a competitive edge is known as its innovation capability. The ability of the company to manage its resources, procedures, technology, and culture in a way that encourages innovation is referred to as this skill.	Venkatesh et al., (2019) Alyasein et al.(2025)
	A2	Flexibility	Flexibility is the capacity to adjust to shifting demands, priorities, and market dynamics. It guarantees that teams are not limited by strict procedures and may promptly react to input, adjust plans, and continuously enhance the final result.	Venkatesh et al., (2019), Alamroshan et al., (2022), DK Behera et al., (2023)
	A3	Reverse Logistic	Transporting products from the final consumer back to the manufacturer or supplier for returns, recycling, refurbishing, or disposal is known as reverse logistics. It contributes to waste reduction, sustainability enhancement, and value recovery from old goods.	Akben i. (2021), X Zhang et al., (2020) M Tavana et al., (2021)
Sustainable Criteria	S1	Long-Term Relationship	A symbiotic relation type between stakeholders such as customers and suppliers, built on constant reliability, full transparency, and interacting with sustainability goals. Scope of the relationship is infinite collaboration, efficiency in the whole system, and resilience to change, guaranteeing environmental, social, and economic benefits as by products..	Tham et al., (2020), Liang et al. (2022), Huang et al. (2022)
	S2	Waste Management	Procedures for collecting, separating, transferring, recycling, and getting rid of waste produced by company operations without causing environmental damage. The fundamental components of this criterion are waste reduction plans and clean production methods.	Aksel Rasmussen et al., (2023) Yazdani et al. (2014), Izadikhah & Farzipoor Saen (2020)

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21. APPENDIX III- SURVEYS

Survey content promotion

EN
Dear Participant, As final-year **Industrial Engineering students at Istanbul Medipol University**, we are conducting our senior project on **Sustainable, Agile, and Green Supplier Selection using SF-SWARA & EDAS methods**. This study aims to support the supplier selection decision-making process. We kindly ask for your contribution by evaluating specific criteria.

Your responses will be used for **scientific analysis** and will remain **anonymous**. Thank you for your valuable participation!

TR
Değerli Katılımcı, İstanbul Medipol Üniversitesi **Endüstri Mühendisliği son sınıf öğrencileri** olarak bitirme projemizi **SF-SWARA & EDAS yöntemleriyle Sürdürülebilir, Çevik ve Yeşil Tedarikçi Seçimi** üzerine yapmaktayız. Bu çalışma, tedarikçi seçiminde karar verme sürecini desteklemek amacıyla gerçekleştirilmektedir. Sizden beklentimiz, belirli kriterleri değerlendirerek sürecimize katkı sağlamanızdır.

Cevaplarınız, **bilimsel bir analizde** kullanılacak olup **anonim** kalacaktır. Katılımınız için teşekkür ederiz!

Şevval KAZ - PROJECT LEADER (PROJE LİDERİ)
 Belinay AYDIN - MEMBER (ÜYE)
 Elif Nur SIRAĞAYA - MEMBER (ÜYE)
 Fatmanur TÜRKESİZ - MEMBER (ÜYE)
 Assoc. Prf. Melis Almula KARADAYI - ADVISER (DANIŞMAN)



Sector determination

2. Which sector do you work in?
 Çalıştığınız sektör

[Diğer ayrıntılar](#)

6
 Yanıtlar

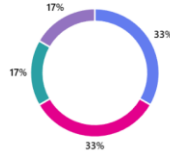
Son Yanıtlar
 "TEKSTİL"
 "TEKSTİL"
 "Tekstil"
 ...

Experience and title of decision-makers

3. How long is your professional experience?
 Mesleki deneyim süreniz

[Diğer ayrıntılar](#)

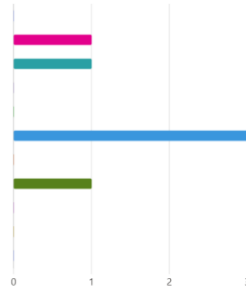
- 0-5 years (0-5 yıl) 2
- 6-10 years (6-10 yıl) 2
- 11-15 years (11-15 yıl) 1
- 16 years+ (16 yıl+) 1
- Diğer (Other) 0



4. What is your title at the company?
 Şirketteki unvanınız nedir?

[Diğer ayrıntılar](#)

- Chairman of the Board of Directors (Yönetim Kurulu Başkanı) 0
- Head of Top Management (Üst Yönetim Başkanı) 1
- General Manager (Genel Müdür) 1
- Assistant General Manager (Genel Müdür Yardımcısı) 0
- Academician (Akademisyen) 0
- Expert (Uzman) 3
- High Engineer (Yüksek Mühendis) 0
- Chief (Şef) 1
- Officer (Memur) 0
- Support and Operational Roles (Destek ve Operasyonel Roller) 0
- Other (Diğer) 0



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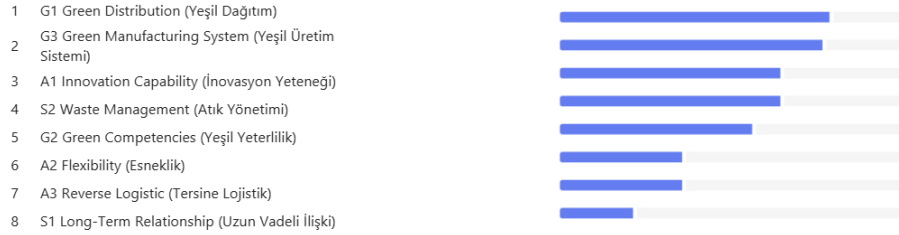
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Criteria ranking

5. Ranking of criteria by decision-makers. (Please arrange the boxes in order of importance!)

[Diğer ayrıntılar](#)

Kriterlerin karar vericiler tarafından sıralanması. (Lütfen kutucukları önem derecesine göre sıralayınız!)

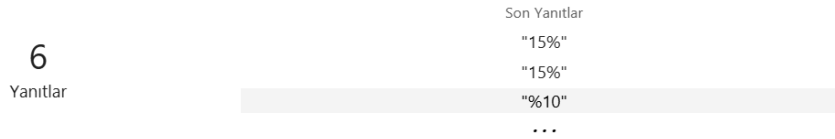


Results of pairwise comparison of criteria.

6. How much percentage (%) more important do you think the 1st most important criterion is than the 2nd most important criterion? (Compare with 5% and multiples.)

Sizce en önemli 1. kriter en önemli 2. kriterden yüzde (%) olarak ne kadar önemli? (%5 ve katları olacak şekilde kıyaslayınız)

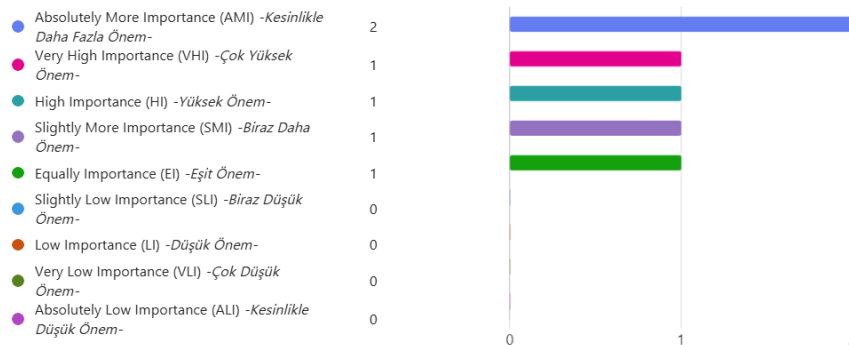
[Diğer ayrıntılar](#)



Importance ranking of alternatives according to criteria

13. What is the importance of "Green Distribution" (G1) compared to Supplier 1?
Tedarikçi 1'e kıyasla "Yeşil Dağıtım" (G1) kriterinin önemi nedir?

[Diğer ayrıntılar](#)



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