Hesitant Fuzzy Linguistic Term Sets based AHP-ARAS Methodology for Assessment of Sustainability Action Areas

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Abstract

The advancing technology and innovations change the world rapidly. Both countries and companies need to make fast and effective decisions to keep up with the changing conditions and make our world sustainable. Accordingly, this study aims to present a Hesitant Fuzzy Linguistic Term Sets (HFLTS) based Analytic Hierarchy Process (AHP)-Additive Ratio ASsessment (ARAS) methodology for assessment of sustainability action areas. HFLTS is applied to propose experts' assessments by addressing the difficulty of expressing opinions by uncertainty. This technique provides flexibility by eliciting comparative linguistics expressions, resulting in an assessment environment closer to human thinking. The combined AHP-ARAS methodology offers many benefits such as ease of use for applying, the ability to overcome complex situations, the simplicity with which it may be extended to diverse fuzzy environments, flexibility, checking the consistency of decision-making. Plus, it considers the criteria's hierarchical structure and provides a direct and proportional relationship with the criteria weights. The criteria, consisting of sustainability action areas, are weighted with the Hesitant Fuzzy Linguistic (HFL) AHP method. Then, industries such as chemical, information technology, food production, apparel, etc. are evaluated with the HFL ARAS method. To illustrate the efficacy of the proposed methodology, an illustrative study is also provided. The results of this paper showed that the most appropriate criterion is "Increasing resource efficiency" and the first ranked industry is "Chemical Industry ".

Keywords
Action areas, AHP, ARAS, Hesitant fuzzy linguistic and Sustainability.

1. Introduction

Dueto the changing market needs, the rapid development of technology, volatile customer demands, increasing energy needs, and sustainability issues, many industries have to revisit their organizational structure (Jamwal et al. 2021; Escursell et al. 2021). The United Nations defined sustainability in 1987 as "filling the requirements of the present without compromising future generations' ability to fulfill their own needs." (United Nations 1987). European Union's political and legal framework about sustainability creates pressure for an organization in terms of global challenges and objectives. Therefore, organizations are expected to realize sustainable actions such as decreasing their carbon emissions to decarbonize the global economy in the medium term. However, in the long term, proactive sustainability management requires both following laws and foreseeing and preparing for future regulations (Federal Ministry for the Environment 2017).

To keep up with the changing circumstances and create a sustainable world, the organizations have to make fast and effective decisions considering the future. After releasing the United Nation's 2030 Agenda, which consists of seventeen Sustainable Development Goals (SDGs), the number of methodological assessments, frameworks, guidelines, and academic studies on sustainability has increased. However, the achievements of all the SDGs necessities complex decision-making processes, considering many criteria and trade-offs between goals (Sousa et al. 2021).Therefore, in this study, the Multi-Criteria Decision Making (MCDM) approach is utilized to support the decision-making of sustainability.

The objective of this study is proposing a Hesitant Fuzzy Linguistic Term Sets (HFLTS) based Analytic Hierarchy Process (AHP)-Additive Ratio ASsessment (ARAS) methodology for assessing sustainability action areas. Rodriguez et al. (Rodriguez et al. 2012) established a technique for presenting linguistic expressions using HFLTS to improve the linguistic flexibility in the MCDM process.

HFLTS is accepted as a robust and valuable approach since it offers flexibility and produces realistic results (Rodriguez et al. 2012).In HFLTS, decision-makers (DMs) can express their opinions and thoughts by using comparative linguistic expressions (e.g., at least, between, at most) to assess the criteria and alternatives. Therefore, with the utilization of the HFLTS approach, DMs' uncertainty of problem and hesitancy are overwhelmed.

In this study, the criteria (i.e., sustainability action areas) are determined based on the report of the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (ENCBNS) (Federal Ministry for the Environment 2017). There are four main criteria: fair operating practices, labor practices, human rights, environment, and sixteen sub-criteria. These sustainability action areas signify adverse effects that an organization should deal with. Using the Hesitant Fuzzy Linguistic (HFL) AHP method, the importance degrees of the sustainability action areas are calculated. Different industries are affected by these action areas in various ways. For instance, the use of chemicals in clothing production negatively affects workers' health, pollutes the water, and destroys the local population's livelihood (Federal Ministry for the Environment 2017). Therefore, the alternatives (i.e., industries) should be ranked according to the sustainability action areas. The alternatives are assessed by implementing the HFL ARAS method in this study.

This study contributes to integrating AHP-ARAS methods based on HFLTS with the fuzzy envelope approach introduced by (Liu and Rosa M Rodríguez 2014). The second contribution of this study is applying the HFL AHP-ARAS methodology for the first time in the sustainability area. The combined HFL AHP-ARAS methodology has many benefits such as ease of use for applying, ability to overcome complex situations, ease of extension to different fuzzy environments, flexibility, checking the consistency of decision-making, considering the hierarchical structure of criteria, and providing a direct and proportionate link with the weights of the criterion (Medineckiene et al. 2015; Büyüközkan and Güler 2021; Onar et al. 2016). Moreover, Group Decision Making (GDM) approach is preferred to remove the partiality in the decision-making process. Our GDM based HFL MCDM methodology is then applied with the participation of industrial experts to exemplify the possible utilization of the presented methodology. This way, the effects of sustainability action areas on the chemical industry, information technology industry, food production industry, apparel industry, and service industry are assessed.

The organization of this study is as the following. In the next section, the background of the subject is provided concisely. In the third section, the background of the study is offered to present HFLTS, AHP, and ARAS methods. The proposed HFL AHP-ARAS methodology is provided in the fourth section. The application for the proposed methodology is provided in section 5. Finally, the conclusion is presented in the sixth section.

2. Literature Review

In 2015, 193 United Nations member nations accepted the Sustainable Development Goals (SDGs) to be reached by the end of 2030, the starting point of countries, companies, and people who plan to start working on sustainability. The SDGs are a global call to end poverty, safeguard the environment, and guarantee that all people live in peace and prosperity (United Nations).

The SDG also includes sustainability in companies and business processes. In the traditional management approach, company management is only accountable to company shareholders; in the corporate sustainability approach, the scope of accountability has expanded. Through sustainability reports, stakeholders can evaluate company performance and compare it with another company operating in the same sector (Sachs et al. 2021; Strateji and Başkanlığı 2019; Dantas et al. 2021).

The sustainability approach provides many benefits to companies. These are raising awareness, motivating and directing employees, generating long-term capital and advantageous financing terms, developing their skills, developing management systems, effective risk management, creating new business opportunities and innovation opportunities, continuous improvement, brand value, ensuring trust and reputation, oriented towards stakeholders transparency (Sinclair 2009; Sachs et al. 2021).

Sustainability management is only effective when all sustainability subjects and action areas are examined in the context of the business, like strategies to promote sustainability in the workplace. Various action areas are relevant for firms depending on the industry, and they give first advice for chosen sectors. The action areas should assist businesses in determining significant sustainability consequences that may be utilized to define action areas for sustainability management (Federal Ministry for the Environment 2017).

In sustainability literature, a variety of MCDM techniques are employed. AHP, TOPSIS, ANP, DEMATEL, BWM, TODIM, and PROMETHEE are the most commonly used MCDM methods in the sustainability area. (Büyüközkan and Karabulut 2018) presented a literature review of sustainability performance evaluation. (Tsai et al. 2009) used the DEMATEL method to select socially responsible investment in the sustainability balanced scorecard concept. The green supplier selection for the sustainability of thermal power equipment is presented by (Zhao and Guo 2014).

In the related literature, the HFL AHP method is employed in a variety of applications such as water conservation, estimation of software cost, bridge construction, computer design, company performance review, selecting strategic places for islands and reefs, prioritization of marketplace and renewable energy choices, city assessment, retail location selection, alternative-fuel vehicle selection and warehouse location selection (Büyüközkan and Güler 2020).ARAS method is used with crisp numbers (Zavadskas and Turskis 2010; Medineckiene et al. 2015) in fuzzy environment and its extensions (e.g. type-2, interval-valued etc.) (Büyüközkan and Göçer 2018; Büyüközkan and Güler, 2020) have extended this method in a hesitant fuzzy environment.

The proposed HFL AHP-ARAS methodology has merits that separate itself from other studies. Firstly, expert judgments are based on HFLTS, and they are aggregated by using the fuzzy envelope technique proposed by (Liu and Rosa M Rodríguez 2014). Secondly, to the best of the authors' knowledge, it is the first publication that combines HFL AHP-ARAS methods for the sustainability field. Thirdly, with the utilization of the GDM approach, the partiality in the decision-making process has been overcome.

3. Methodology

3.1Hesitant Fuzzy Linguistic Term Sets

Decisionprocesses in the real world are not always straightforward. The uncertain environment frequently complicates the available choices and how to select them. Linguistic knowledge can help with uncertainty management. In 2010, hesitant fuzzy sets were offered as a linguistic technique for the first time (Torra 2010). Rodriguez et al. (Rodriguez et al. 2012) established a model for presenting linguistic expressions using HFLTS to improve the richness of linguistic flexibility in the MCDM process.

DMs use comparative language terms to evaluate the given criteria and alternatives in HFLTS. It is a solid and helpful technique to overcome uncertainty and hesitancy. It provides flexibility with linguistic expressions, as well as realistic results (Rodriguez et al. 2012; Büyüközkan and Güler 2020).
An HFLTS, H_s, denotes a subset of the set's linguistic elements $S = \{s_0, \ldots, s_g\}$(Rodriguez et al. 2012).
The HFLTS's upper bound $H_{s+}$and lower bound H_{s-} are characterized as

$$H_{s+} = max(s_i) = s_j\ ,\ s_i \in H_S \ and\ s_i \leq s_j \ \forall_i \quad (1)$$

$$H_{s-} = min(s_i) = s_j\ ,\ s_i \in H_S \ and\ s_i \leq s_j \ \forall_i \quad (2)$$

The E_{GH}function is used to convert comparative linguistic term sets into HFLTS(Rodriguez et al. 2012), (Torra 2010).

The superior bound $H_{s+}$and inferior bound H_{s-} are described as (Liu and Rosa M Rodríguez 2014):

$$env(H_S) = [H_s^-, H_s^+],\ H_s^- \leq H_s^+ \quad (3)$$

3.2 Hesitant Fuzzy Linguistic AHP Method

(Saaty 1990)'s AHP model is the most extensively used in the MCDM area. It is a powerful and straightforward MCDM tool that prioritizes many factors. HFL AHP is often employed when there is vagueness in the decision-making process. A hesitant judgment is expressed by multiple alternative values (Büyüközkan et al. 2021). Because of its straightforward structure and capability for solving complicated choice issues, the AHP method is highly preferred in MCDM literature (Büyüközkan et al. 2021).This paper implemented the HFL AHP method for calculating the criteria weights. The steps of HFL AHP are explained next:

Step 1. The criteria are evaluated by creating pairwise comparison matrices. Then, the linguistic expressions are converted into HFLTS. The linguistic scale used in HFL AHP is illustrated in Table 1.

Table 1. Linguistic scale for HFL AHP (Onar et al. 2016)

Linguistic expression	**Fuzzy numbers**
Absolutely Low Importance (ALI)	(0.11,0.11,0.14)
Very Low Importance (VLI)	(0.11,0.14,0.2)
Essentially Low Importance (ESLI)	(0.14,0.2,0.33)
Weakly Low Importance (WLI)	(0.2,0.33,1)
Equally Low Importance (ELI)	(0.33,1,1)
Exactly Equal (EE)	(1,1,1)
Equally High Importance (EHI)	(1,1,3)
Weakly High Importance (WHI)	(1,3,5)
Essentially High Importance (ESHI)	(3,5,7)
Very High Importance (VHI)	(5,7,9)
Absolutely High Importance (AHI)	(7,9,9)

Step 2. OWA operator is used for creating the HFLTS fuzzy envelope, which yields a trapezoidal fuzzy number (Liu and Rosa M. Rodríguez 2014).
$A = \{a_1, a_2,..., a_n\}$ represents a set of components that will be aggregated. It is worth noting that it differs from the set of alternatives. In this case, the OWA operator *F* is described as follows (Liu and Rosa M. Rodríguez, 2014):

$$F\ (a_1, a_2,..., a_n) = wb^T = \sum_{i=1}^{n} w_i b_i, \quad (4)$$

where w= (w1, w2,..., wn)T denotes the weights vector, with wi ∈ [0, 1] and $\sum_{i=1}^{n} w_i = 1$ and b denotes the associated ordered values vector, and bi ∈ b is the ith largest value in A.

Step 3. Reciprocal values in the pairwise comparison matrix ($\widetilde{C}$) are computed as:

$$\widetilde{c_{ij}} = (\frac{1}{c_{iju}}, \frac{1}{c_{ijm2}}, \frac{1}{c_{ijm1}}, \frac{1}{c_{ijl}}) \quad (5)$$

Step 4. Fuzzy geometric mean ($\tilde{r}_i$) of $\tilde{C}$ is calculated as:

$$\tilde{r}_i = (\tilde{c}_{i1} \otimes \tilde{c}_{i2} \ldots \otimes \tilde{c}_{in})^{1/n} \quad (6)$$

Step 5. Fuzzy weight ($\widetilde{w}_i^{CR}$) of every main criteria is computed as:

$$\widetilde{w}_i^{CR} = \tilde{r}_i \otimes (\tilde{r}_1 \otimes \tilde{r}_2 \ldots \otimes \tilde{r}_n)^{-1} \quad (7)$$

Step 6. Fuzzy global weights of the sub-criteria's are computed as:

$$\widetilde{w}_{ij}^{G} = \widetilde{w}_i^{CR} \times \widetilde{w}_j^{CR} \quad (8)$$

where $\widetilde{w}_{ij}^{G}$ symbolizes sub-criteria global weight.
Step 7. Trapezoidal fuzzy numbers $\widetilde{w}_{ij}^{G}$ using are defuzzified and these values are normalized as:

$$w_{ij}^{G} = \frac{\alpha+2\beta+2\gamma+\delta}{6} \quad (9)$$

$$w_{ij}^{N} = \frac{w_{ij}^{G}}{\sum_i \sum_j w_{ij}^{G}} \quad (10)$$

3.3 Hesitant Fuzzy Linguistic ARAS Method

ARAS approach was introduced by (Zavadskas and Turskis 2010) and demonstrated its application in a case study. (Turskis and Zavadskas 2010) employed the same strategy in the fuzzy environment. This method is used in various fields, including technology, supply chain, facility location, ergonomics, construction, human resources, and management.

ARAS technique has several advantages, including constructing a proportional link between criteria weights, the capacity to handle very complicated problems, ease of use, efficacy, and ease of adaptation to various fuzzy environments (Büyüközkan and Güler 2020).We implemented the HFL ARAS method to evaluate the alternatives in this study. The steps of HFL ARAS are explained next:

Step 1: The decision matrix is built with linguistic expressions, which are then transformed into HFLTS. The linguistic scale used in HFL ARAS is provided in Table 2. Please refer to (Büyüközkan and Güler 2020) for details of the ARAS method.

Table 2. Linguistic scale for HFL ARAS (Beg and Rashid 2013)

Linguistic expression	**Fuzzy Numbers**
None (N)	(0,0,0.17)
Very Low (VL)	(0,0.17,0.33)
Low (L)	(0.17,0.33,0.5)
Medium (M)	(0.33,0.5,0.67)
High (H)	(0.5,0.67,0.83)
Very High (VH)	(0.67,0.83,1)
Perfect (P)	(0.83,1,1)

Step 2: Normalization of decision matrix is realized as:
For maxima desirable costs of criteria:

$$\tilde{\tilde{x}}=\frac{\widetilde{x_{ij}}}{\sum_{i=0}^{m}\widetilde{x_{ij}}} \tag{11}$$

For minima desirable costs of criteria:

$$\widetilde{x_{ij}}=\frac{1}{\widetilde{x_{ij}}^{*}}, \qquad \widetilde{\widetilde{x_{ij}}}=\frac{\widetilde{x_{ij}}}{\sum_{i=0}^{m}\widetilde{x_{ij}}} \tag{12}$$

Step 3: Elements of the weighted normalized decision matrix are calculated as:

$$\widehat{\widetilde{x_{ij}}}=\widetilde{\widetilde{x_{ij}}}\widetilde{w_j}\ ,\ i=0,1,\ldots,m \tag{13}$$

where w_j symbolizes the j^{th} criterion's weight and:

$$\sum_{j=1}^{n} w_j = 1 \tag{14}$$

Step 4: Optimality function value of i^{th} alternative is calculated as:

$$\widetilde{S_i}= \sum_{j=1}^{n}\widehat{\widetilde{x_{ij}}}\ ,\ i=0,1,\ldots,m \tag{15}$$

Step 5: Center of area approach is used to determine the outcome as follows:

$$S_i=1/3(S_{i\alpha}+S_{i\beta}+S_{i\gamma}) \tag{16}$$

Step 6: Utility degree of alternatives is calculated as:

$$K_i=\frac{S_i}{S_0}\ ,\ i=0,1,\ldots,m \tag{17}$$

where S_0 denotes value of the most ideal criterion.

5. Application for Assessment of Sustainability Action Areas

Many organizations have already engaged with social responsibility in their business practices in terms of sustainability. An application about sustainability assessment of different industries is realized to validate our proposed methodology's usefulness. Three DMs assessed the sustainability action areas and industries. All DMs have enough expertise and understanding in the field of sustainability. DMs are selected based on their expertise and knowledge in sustainability. In this study, DMs' weights are assumed to be equal.

The evaluation criteria, which contain four main criteria and sixteen sub-criteria, are based on the report of the Federal Ministry for ENCBNS (Federal Ministry for the Environment 2017). They are shown in Table 3 and, these criteria are the action areas inspired by the international norm on social responsibility ISO 26000. These action areas indicate adverse effects that an organization should deal with.

Table 3. Evaluation criteria (Federal Ministry for the Environment 2017)

Main Criteria	Sub-Criteria
C1. Environment	C11. Avoiding environmental impacts and hazardous materials
	C12. Climate change mitigation and adaptation
	C13. Increasing resource efficiency
	C14. Avoiding loss of biodiversity
C2. Human rights	C21. Banning child and forced labour
	C22. Equal opportunities and non-discrimination
	C23. Freedom of association
	C24. Avoiding complicity
C3. Labor practices	C31. Employment and employment relationships
	C32. Working conditions and social protection
	C33. Health and safety at work
	C34. Social dialogue
C4. Fair operating practices	C41. Fighting corruption
	C42. Responsible political involvement
	C43. Fair competition
	C44. Respecting property rights

Organizations should focus on the negative impact on the environment and those affected. The organization should pay attention to groups that are potentially even more vulnerable (e.g., the elderly, children, people with disabilities) in terms of human rights. Since there is increasing demand for ethical and sustainable work practices, labor practices must be reconsidered. Moreover, sustainable growth highlights the significance of competition and fair operating practices.

Depending on the industry, different action areas affect organizations in terms of sustainability. Therefore, in this study, different industries indicate alternatives. The five alternatives are determined based on the report of the Federal Ministry for ENCBNS (Federal Ministry for the Environment 2017) and the authors' own elaboration. They can be listed as Chemical Industry (A1), Information Technology Industry (A2), Food Production Industry (A3), Apparel Industry (A4) and, Service Industry (A5). In the following section, these alternatives (i.e., industries) are assessed considering the four main criteria and sixteen sub-criteria (i.e., action areas) provided in Table 3.

5.1 Calculation of Criteria Weights

DMs first assess the main criteria using the linguistic scale provided in Table 1. The evaluation of the main criteria is presented in Table 4.The linguistic expressions provided in Table 4 are converted into fuzzy numbers by using (3). Then, by using (4)-(7), the weights of each main criterion are computed. The relative weights of the main criteria are shown in Table 5.

Table 4.Pairwise comparisons of the main criteria

	C1	**C2**	**C3**	**C4**
C1	EE	Between EHI and WHI	Between WHI and ESHI	Between ESHI and AHI
C2		EE	Between EHI and WHI	Between EHI and WHI
C3			EE	Between ELI and EHI
C4				EE

Table 5.Relative weights of the main criteria

	C1	C2	C3	C4	Relative Weights
C1	(1,1,1,1)	(1,1,3,5)	(1,3,5,7)	(3,6.78,7.22,9)	(0.150,0.335,0.837,1.629)
C2	(0.2,0.33,1,1)	(1,1,1,1)	(1,1,3,5)	(1,1,3,5)	(0.076,0.120,0.450,0.864)
C3	(0.14,0.2,0.33,1)	(0.2,0.33,1,1)	(1,1,1,1)	(0.33,1,1,3)	(0.035,0.080,0.197,0.509)
C4	(0.11,0.14,0.15,0.33)	(0.2,0.33,1,1)	(0.33,1,1,3)	(1,1,1,1)	(0.033,0.073,0.162,0.386)

To obtain the weights of sub-criteria, each sub-criterion's evaluation matrices are constructed using the linguistic scale provided in Table 1. Table 6 illustrates the evaluation matrix of the first criterion (C11). The other sub-criteria evaluation matrices are structured as in Table 6.

Table 6.Pairwise comparisons of the first criterion (C11)

	C11	C12	C13	C14
C11	EE	Between VLI and ESLI	Between ESLI and ELI	Between ELI and EHI
C12		EE	Between ELI and EHI	Between EHI and WHI
C13			EE	Between WHI and ESHI
C14				EE

The linguistic expressions provided in Table 4 are converted into fuzzy numbers by using (3). Then, by using (4)-(7), the weights of each sub-criterion are computed. Then, defuzzification is realized using (9), and then the values are normalized (10). These final results are provided in Table 7.

Table 7.Weights of criteria

Sub-Criteria	Global Weights				Defuzzified Weights	Normalized Weights
C11	0.004	0.029	0.102	0.696	0.160	0.0532
C12	0.016	0.093	0.427	2.380	0.573	0.1900
C13	0.012	0.108	0.393	2.431	0.574	0.1904
C14	0.005	0.032	0.151	0.919	0.215	0.0713
C21	0.008	0.045	0.253	1.359	0.327	0.1085
C22	0.006	0.028	0.203	1.174	0.274	0.0908
C23	0.002	0.008	0.060	0.367	0.084	0.0279
C24	0.003	0.011	0.064	0.452	0.101	0.0335
C31	0.001	0.005	0.015	0.107	0.024	0.0081
C32	0.002	0.015	0.044	0.367	0.081	0.0269
C33	0.008	0.046	0.133	0.786	0.192	0.0636
C34	0.001	0.008	0.022	0.211	0.046	0.0151
C41	0.003	0.018	0.089	0.589	0.134	0.0446
C42	0.001	0.007	0.026	0.242	0.052	0.0171
C43	0.003	0.014	0.078	0.448	0.106	0.0351
C44	0.001	0.011	0.045	0.319	0.072	0.0239

The consistency ratio is determined for the evaluation matrices to assess the consistency. The results showed that DMs' evaluations are consistent.

The most appropriate criterion is found as "C13.Increasing resource efficiency", the second important one is "C12. Climate change mitigation and adaptation," and the third-ranked criterion is "C21. Banning child and forced labor".

5.2 Assessment of Alternatives

Three DMs evaluate the alternatives by using expressions provided in Table 2. Table 8. illustrates the evaluation of DMs for the first criterion (i.e. C11. Avoiding environmental impacts and hazardous materials).

Table 8.Evaluation of alternatives of the first criterion (C11)

	DM1	DM2	DM3
A1	Between VH and P	Between H and VH	Between VH and P
A2	Between M and H	Between M and H	At least VH
A3	At least P	At least P	At least P
A4	Between M and H	Between VH and P	Between M and H
A5	At least VH	Between H and VH	At least VH

The fuzzy envelope and OWA operator are used to transform the linguistic expressions in Table 8 into fuzzy values. The fuzzy values for C11 are provided in Table 9.

Table 9.Fuzzy decision matrix of the first criterion (C11)

	DM1	DM2	DM3
A1	(0.67, 0.83, 1)	(0.67, 0.83, 1)	(0.67, 0.83, 1)
A2	(0.5, 0.67, 0.83)	(0.5, 0.67, 0.83)	(0.67, 0.83, 1)
A3	(0.83, 1, 1)	(0.83, 1, 1)	(0.83, 1, 1)
A4	(0.5, 0.67, 0.83)	(0.67, 0.83, 1)	(0.5, 0.67, 0.83)
A5	(0.67, 0.83, 1)	(0.67, 0.83, 1)	(0.67, 0.83, 1)

Then, the matrix is normalized by using (11)-(12), and the normalized matrix is weighted by using the criteria weights obtained in HFL AHP and (13). The optimality function value of alternatives is determined with (15), and the center of area method is applied using (16). Their utility degree is determined by using (17) to rank the alternatives. The outcomes of the HFL ARAS method are given in Table 10.

Table 10.Ranking of alternatives

	$S_{i\alpha}$	$S_{i\gamma}$	$S_{i\beta}$	S_i	K_i	Ranking
A0	0.016	0.325	4.713	1.685	1.000	-
A1	0.010	0.275	4.713	1.666	0.989	1
A2	0.007	0.230	4.440	1.559	0.926	4
A3	0.010	0.274	4.660	1.648	0.978	2
A4	0.010	0.286	4.713	1.591	0.944	3
A5	0.007	0.226	4.303	1.512	0.898	5

According to results in Table 10, the sustainability action areas have mainly affected the “Chemical Industry (A1)”. The ranking of the second, third, fourth, and fifth industries are Food Production Industry (A3), Apparel Industry (A4), Information Technology Industry (A2), and Service Industry (A5), respectively.

6. Conclusion

The SDGs aim to achieve sustainable development and welfare by monitoring progress on a global scale through fundamental indicators. These targets are overarching objectives that present goals for all countries, including the least developed, developing, and developed countries. The sustainability action areas need to be implemented in the right environment and suitable industries to support these goals.

This paper aims to present the HFL AHP-ARAS methodology for assessing sustainability action areas. The evaluation criteria were weighted with the HFL AHP method. Then, industries such as the chemical industry, information technology industry, food production industry, apparel industry, etc., were evaluated with the HFL ARAS method. The most appropriate criterion was found as “C13.Increasing resource efficiency” and the first ranked industry was determined as “Chemical Industry (A1)”. To illustrate the efficacy of the proposed methodology, an application was also provided.

For future studies, the decision-making problem can be handled by employing aggregation operations for the GDM to aggregate DM assessments. On the other hand, various fuzzy set extensions may be implemented into the framework. Moreover, different HFL MCDM methods can be used to make a comparison with their outcomes in the future.

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References
Beg, Ismat, and Tabasam Rashid. TOPSIS for Hesitant Fuzzy Linguistic Term Sets. *International Journal of Intelligent Systems*, vol. 28, no. 12, pp. 1162–71, 2013.

Büyüközkan, Gülçin, et al. Health Tourism Strategy Selection via SWOT Analysis and Integrated Hesitant Fuzzy Linguistic AHP-MABAC Approach. *Socio-Economic Planning Sciences*, vol. 74, pp. 100929, Apr. 2021.

Büyüközkan, Gülçin, and Fethullah Göçer. An Extension of ARAS Methodology under Interval Valued Intuitionistic Fuzzy Environment for Digital Supply Chain. *Applied Soft Computing*, vol. 69, pp. 634–54, 2018.

Büyüközkan, Gülçin, and Güler, Merve. A Combined Hesitant Fuzzy MCDM Approach for Supply Chain Analytics Tool Evaluation. *Applied Soft Computing*, vol. 112, pp. 107812 2021.

Büyüközkan, Gülçin, and Güler, Merve. Analysis of Companies' Digital Maturity by Hesitant Fuzzy Linguistic MCDM Methods. *Journal of Intelligent & Fuzzy Systems*, vol. 38, no. 1, pp. 1119–32 2020.

Büyüközkan, Gülçin, and Güler, Merve. Smart Watch Evaluation with Integrated Hesitant Fuzzy Linguistic SAW-ARAS Technique. *Measurement: Journal of the International Measurement Confederation*, vol. 153, p. 2020.

Büyüközkan, Gülçin, and Yağmur Karabulut. Sustainability Performance Evaluation: Literature Review and Future Directions. *Journal of Environmental Management*, vol. 217, pp. 253–67 2018.

Dantas, Thales E. T., et al. How the Combination of Circular Economy and Industry 4.0 Can Contribute towards Achieving the Sustainable Development Goals. *Sustainable Production and Consumption*, vol. 26, pp. 213–27 2021.

Escursell, Sílvia, et al. Sustainability in E-Commerce Packaging: A Review. *Journal of Cleaner Production*, vol. 280, p. 124314 Jan. 2021.

Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety. *Step-by-Step Guide to Sustainable Supply Chain Management*. p. 2017, https://www.bmu.de/fileadmin/Daten_BMU/Pools/Broschueren/nachhaltige_lieferkette_en_bf.pdf.

Jamwal, Anbesh, et al. Developing A Sustainability Framework for Industry 4.0. *Procedia CIRP*, vol. 98, pp. 430–35 Jan. 2021.

Liu, Hongbin, and Rosa M Rodríguez. A Fuzzy Envelope for Hesitant Fuzzy Linguistic Term Set and Its Application to Multicriteria Decision Making. *Information Sciences*, vol. 258, pp. 220–38 2014.

Liu, Hongbin, and Rosa M. Rodríguez. A Fuzzy Envelope for Hesitant Fuzzy Linguistic Term Set and Its Application to Multicriteria Decision Making. *Information Sciences*, vol. 258, pp. 220–38 Feb. 2014.

Medineckiene, Milena, et al. Multi-Criteria Decision-Making System for Sustainable Building Assessment/Certification. *Archives of Civil and Mechanical Engineering*, vol. 15, no. 1, pp. 11–18 2015.

Onar, Sezi Çevik, et al. A New Hesitant Fuzzy QFD Approach: An Application to Computer Workstation Selection. *Applied Soft Computing*, vol. 46, pp. 1–16 2016.

Rodriguez, Rosa M., et al. Hesitant Fuzzy Linguistic Term Sets for Decision Making. *IEEE Transactions on Fuzzy Systems*, vol. 20, no. 1, pp. 109–19 Feb. 2012.

Saaty, Thomas L. How to Make a Decision: The Analytic Hierarchy Process. *European Journal of Operational Research*, vol. 48, no. 1, pp. 9–26 1990.

Sachs, Jeffrey, et al. *Sustainable Development Report 2020: The Sustainable Development Goals and Covid-19 Includes the SDG Index and Dashboards*. Cambridge University Press, p. 2021.

Sinclair, Brian R. Culture, Context, and the Pursuit of Sustainability: Contemplating Problems, Parameters, and Possibilities in an Increasingly Complex World. *Planning for Higher Education*, vol. 38, no. 1, pp. 6–22 2009.

Sousa, Manuel, et al. Multiple Criteria Decision Making for the Achievement of the UN Sustainable Development Goals: A Systematic Literature Review and a Research Agenda. *Sustainability 2021, Vol. 13, Page 4129*, vol. 13, no. 8, p. 4129 Apr. 2021.

Strateji, T. C. Cumhurbaşkanlığı, and Bütçe Başkanlığı. Sürdürülebilir Kalkınma Amaçları Değerlendirme Raporu. *Ankara: TC Cumhurbaşkanlığı Strateji ve Bütçe Başkanlığı Yönetim Hizmetleri Genel Müdürlüğü Bilgi ve Belge Yönetimi Dairesi Başkanlığı*, p. 2019.

Torra, Vicenç. Hesitant Fuzzy Sets. *International Journal of Intelligent Systems*, vol. 25, pp. 529–539 2010.
Tsai, Wen-Hsien, et al. The Sustainability Balanced Scorecard as a Framework for Selecting Socially Responsible Investment: An Effective MCDM Model. *Journal of the Operational Research Society*, vol. 60, no. 10, pp. 1396–410 2009.
Turskis, Zenonas, and Edmundas Kazimieras Zavadskas. A New Fuzzy Additive Ratio Assessment Method (ARAS-F). Case Study: The Analysis of Fuzzy Multiple Criteria in Order to Select the Logistic Centers Location. *Transport*, vol. 25, no. 4, pp. 423–32 2010.
United Nations. *Sustainability*. p. 1987, https://www.un.org/en/academic-impact/sustainability.
---. *The 17 SDGs*. https://sdgs.un.org/goals.
Zavadskas, Edmundas Kazimieras, and Zenonas Turskis. A New Additive Ratio Assessment (ARAS) Method in Multicriteria Decision-making. *Technological and Economic Development of Economy*, vol. 16, no. 2, pp. 159–72 2010.
Zhao, H., and Sen . Selecting Green Supplier of Thermal Power Equipment by Using a Hybrid MCDM Method for Sustainability, *Sustainability*, vol. 6, no. 1, pp. 217–35 2014.

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