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Determining the Importance Level of Sustainable Innovation Applications via Hesitant AHP: An Application on Food Firms

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Abstract

Sustainable innovation, which is the innovation element focused on environmental, social and common awareness and creating value today, has directed businesses to new application and awareness-raising areas not only in today but in future generations. It builds itself a new stance apart from the traditional business forms with the dynamics it contains in the concept and aims to increase the basic capabilities of the enterprises. So, in the new world order brought about by globalization, there are serious socio-economic crises, and it is important that organizations mobilize and implement sustainable innovations. With this regard, elements for sustainable innovation organizations can be classified as economical, social, regulations, market demand, information management, cross-functional cooperation, organization culture, new career opportunities, management commitment, technical innovations and non-technical innovations. The important elements for sustainable innovation organizations listed above are also seen as one of the important building blocks for the needs of future generations. In the comprehensive literature review, the existence of a limited number of studies regarding the degree of importance for sustainable innovation elements is another factor that increases the importance of the subject. In this study, the degree of importance for sustainable innovation elements in food manufacturing enterprises with 10 or more employees in Erzurum has been determined. Hesitant fuzzy sets based Analytic Hierarchy Process (AHP) was applied in the analysis section.

Keywords: Innovation, Sustainability, Sustainable innovation, Hesitant fuzzy sets, Analytic hierarchy process.

1 | Introduction

The intense competition conditions brought by the globalization phenomenon have brought the concept of sustainability to the forefront in today's businesses. Enterprises whose main purpose is to make a profit would like to gain continuity and competitiveness in the sector. These businesses focus on sustainable practices by developing different talents and elements from their competitors. Sustainable practices are activities aimed at

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creating social and environmental added value that covers not only today but also the expectations and needs of future generations. One of these practices is undoubtedly sustainable innovation. Since the concept is valid in every field today, it has created an imperative for businesses. The concept has been integrated with environmental and social practices. The concept of sustainability needs an imperative for the population to be at or below any carrying capacity. And this concept defines natural, human, human-created, social, cultural, scientific, etc. of the society in a participatory process that creates and maintains a respectful vision that allows all its resources to be used prudently [1].

Oxford Dictionary defines the concept of "sustainability" as maintaining a certain ratio or level in the same way, which defines natural balance by avoiding the consumption of natural resources. At this point, two elements stand out in the concept of sustainability. The first of these is to be described for a very long time compared to the "future generations" and human life. Second, "steady growth arithmetic" emphasizes that numbers can reach enormous levels for reasonable periods thanks to the continuous increase in population or resource consumption rates [2].

The main reason for the emergence of sustainability concerns is the limited resources. Businesses can provide resources sustainably by increasing technical capacity, profitability, and quality. Resource efficiency means minimizing environmental impacts in all business activities, using resources sustainably, producing more with less, and strategic sustainability. In businesses that see the environment as an opportunity and want to turn it into an advantage, environmental impact assessment is based on the planning of development practices with ecological objectives. Enterprises acting with this approach can minimize the impact of the damage that may occur during development and production on the natural system and society. Minimum resource utilization, resource reuse, and recycling are of critical importance to ensure sustainability. All these efforts have also reduced waste and pollution generation. Using environmentally-based, resource-efficient technologies creates a cost-effective result and carries sustainability potential [3]. Businesses should put sustainability at the center of all decisions and produce innovative solutions to deal with problems such as resource scarcity, global warming, and climate change [4].

Regarding the concept of sustainable innovation, which is a fundamental concept for all areas, Kneipp et al. [5] stated that production and consumption patterns have changed significantly in the last 10 years. This change caused essential transformations in the environment and society. This situation has led to new demands and restrictions for businesses, which has led to an increased relationship of competitiveness with sustainable innovation. In other words, enterprises have adopted sustainable innovation practices in order to minimize their adverse effects on the environment and achieve business performance. Another definition of this concept states that they are related to products, processes, or practices as well as changing philosophies and organizational values in order to achieve the purpose of creating and realizing social and environmental value beyond economic returns [6]. On the other hand, sustainable innovation is a type of innovation that encourages competition among institutions, drives institutions to innovate, and ensures the continuation of the innovation process in the sector.

In addition, it has been determined that the phenomenon of sustainable innovation defines four elements: innovation is about products, services, and organizational forms, and the information carried in people's minds. Innovation requires collaboration. Most importantly, innovation should be seen as an ongoing and permanent process [7]. Szekely and Strebel [8] defined sustainable innovation as creating something new, social, environmental, and economic that increases performance in three dimensions of sustainable development. These developments are not limited to technological changes. There are also changes in processes, operational applications, business models, thinking, and business systems. Foxon et al. [9], in their sustainable innovation processes work, suggested that by bringing innovations together, it is necessary to encourage the development of a sustainable innovation policy regime. At the same time, environmental policy regimes and public policy should be in this direction. Systems thinking should deal with complexity and system interactions as well as include innovation systems and policy-making processes. Sustainable innovation should implement strategies developed for stakeholder engagement both institutionally and as a procedure for

meeting policy objectives. More consistent and integrated policy tools should be designed to promote sustainability, and it was emphasized that policies for adaptive improvement should be reviewed, corrected, and learning mechanisms should be developed.

On the other hand, businesses generally view activities for sustainable practices as a cost factor. Therefore, they have a short-term perspective. In fact, this situation prevents the transformations and processes expected from businesses. Whereas, the solutions can be found only by sustainable innovation from the pressures of both global and local elements, and collaborations among various groups. At the same time, environmental and economic growth can be achieved through sustainable innovation. In this regard, sustainable innovation elements include: economic, social, and common aspects, regulations, market demand, information management, cooperation between functions, corporate culture, new business opportunities, management commitment, technical innovation, and non-technical innovation [10], [14]. The importance of creating sustainable innovation in all of the components mentioned above plays an active role in ensuring that all the activities of the enterprises are carried out smoothly, protecting future generations, and providing a competitive advantage with a cost advantage. Sustainable innovation process is also a multi-criteria decision-making problem in which quantitative and qualitative factors of enterprises' efficiency, environmental efficiency, and performance are handled together.

The purpose of the study in this context is the evaluation of sustainable innovation factors in food manufacturing enterprises with 10 or more employees in Erzurum. One of the multi-criteria decision-making methods, namely the Analytic Hierarchy Process (AHP), was used in this study. The following section of the study includes a comprehensive literature review on sustainable innovation and its importance. In the third section, information about the hesitant fuzzy sets and hesitant fuzzy AHP is presented, and the application section of the study is given in the following stage. In the last part, suggestions have been made regarding the results and future studies.

2|Literature Review

There is limited research on sustainable innovation practices that have been found in the literature. These studies can be summarized as follows:

Kemp and Arundel [15] developed a model that explains how environmental pressures respond in businesses based on Steger's work. In this study, the importance of a strategic approach has been emphasized in the model created based on environmental strategy, R&D, and technology synthesis. Rennings [16], in his study, has reached the finding that businesses are directed towards pollution control technology applications due to the environmental regulations. Foxon et al. [9] suggested that sustainable innovation policy implementations may be beneficial for the development of more sustainable innovation systems and the integration of environmental policy with other policy areas.

Charter and Clark [14] in the studies on the effect of the relationship between innovation and marketing on firm performance, the value of the marketing function and innovation for firm performance has been revealed many times. Research on sustainability and sustainable innovation in the past years has rapidly expanded along the axis of making new technologies and social applications enable societies to be more sustainable.

Carrillo-Hermosilla et al. [17] discussed innovation practices in businesses at three different levels. Firstly, it proceeds from the addition of components to innovation practices in the process that requires system change. It then proceeds from incremental innovation to radical innovation. The level of change needed by innovation practices causes some effects on the sustainable economy, environment, and society. Paraschiv et al. [18] have concluded that eco-innovation is an essential determinant of sustainability. According to his study, Dong et al. [19] have stated that both eco-innovation creates a competitive advantage, and it increases environmental performance. Ganapathy et al. [20] have noted that eco-innovation has not had a sufficient effect on sustainability performance. As a result of the study, which covers 2001-2010 by Lee and Min [21] in the Japanese manufacturing industry, it has been found that eco-innovation improves environmental and financial performance. In the study named Harvard Business Review [22], in the field of sustainable supply chain,

companies cooperate with their suppliers to use environmentally sensitive materials, show sensitivity to carbon emissions, minimize waste and pollution, and provide recycling opportunities.

Erdal and Korucuk [23], in the case of logistics enterprises in the transportation and warehousing sector, revealed the importance of innovation objectives for increasing turnover, increasing market share, decreasing costs, and increasing profit margin. In a study, Kuo and Smith [24] have determined that national and international environmental regulations have a significant impact on improving the strategies of businesses. The pressure to comply with environmental regulations turns the reactive attitudes of the companies into a proactive way to improve their strategies. Enterprises under this pressure announce their sustainability strategies to their stakeholders mostly through corporate social responsibility reports.

Açıkalın and Kayabaşı [13] have shown that the factors that affect sustainable innovation in businesses act together and strengthen each other. Some of the findings are that corporate culture functions with regulations as an essential factor, but that information management has not yet developed fully for sustainable innovation. It has also been seen that large enterprises volunteer to be the first implementers of sustainable innovation to transform traditional business practices. In addition, sustainable innovations have not been regarded as a normal business case, but have been seen as an initiative that requires patience and investment from a long-term perspective.

Yurdakul and Kazan [4] have determined that eco-innovation can be a solution to sustainability concerns. As the importance of eco-innovation increases among strategic decisions, the sustainability level of businesses is positively affected. Demirdağ et. al. [25] determined the success criteria for innovative management in hotel businesses with corporate identity in Giresun province in Turkey and revealed the best hotel. Memiş and Korucuk [26] investigated fast food businesses. They investigated the determination of the importance levels of marketing innovation criteria and the selection of the most ideal company according to the level of implementation of innovation criteria within the framework of the determined importance levels. Harsanto et. al. [27] made a systematic review to synthesize empirical knowledge on sustainable innovation in the textile industry. After a systematic search process, 41 identified articles met the inclusion criteria and were then qualitatively analyzed using thematic analysis. Lin et. al. [28] studied in detail the links between sustainability innovation, knowledge sharing, and green volunteering for entrepreneurial triumph in manufacturing.

As a result, when the literature on sustainable innovation elements has been scanned, no studies on the importance of sustainable innovation elements in the food sector have been found. In addition, hesitant fuzzy AHP distinguishes the study from other studies while determining the importance of decision criteria. When the study has been evaluated for the stated reasons, it is thought that it will make an important contribution to the literature. The aim of the study in this direction is to determine the degree of importance of sustainable innovation elements in food enterprises with 10 or more employees in Erzurum province by using hesitant fuzzy sets based AHP method.

3 | Methodology

3.1 | Hesitant Fuzzy Sets

Hesitant fuzzy sets are developed by Torra [29] for overcoming the problems of contradictions in the judgments of decision makers.

Let A be a fixed set, a hesitant fuzzy set on A can be written as follows:

$$C = \{< a, h_C(a) > | a \in A\}, \quad (1)$$

where $h_C(a)$ ranges between [0,1] showing the membership degrees of the element $a \in A$ to the set C. Some definitions related to h are given below [30], [31]:

Upper $h^+(a)$ and lower bound $h^-(a)$ of h can be computed as follows:

$$h^{-}(a) = \min h(a). \quad (2)$$

$$h^{+}(a) = \max h(a). \quad (3)$$

The complement of h is calculated as follows:

$$h^{c} = \cup_{\gamma \in h} \{1 - \gamma\}. \quad (4)$$

The envelope of hesitant fuzzy linguistic term sets consisting of upper and lower bounds can be obtained as *Eq. (5)*:

$$nv(H_S) = [H_{S^-}, H_{S^+}], \ H_{S^-} \leq H_{S^+}. \quad (5)$$

Upper (H_{S^+}) and lower bounds (H_{S^-}) of hesitant fuzzy linguistic term sets are stated as below:

$$H_{S^+} = \max\{S_i\} = S_j, S_i \leq S_j \text{ and } S_i \in H_S, \ \text{for all I.} \quad (6)$$

$$H_{S^-} = \min\{S_i\} = S_j, S_i \leq S_j \text{ and } S_i \in H_{S,+}, \ \text{for all i.} \quad (7)$$

An Ordered Weighted Average (OWA) for dimension n can be written as *Eq. (8)* by considering OWA: $R^n \rightarrow R$:

$$\text{OWA}\ (c_1, c_2, \dots, c_n) = \sum_{j=1}^{n} w_j d_j, \quad (8)$$

where d_j shows the jth largest aggregated elements of $c_1, c_2, \dots, c_n$ and $W = (w_1, w_2, \dots, w_n)^T$ can be defined as a weighted vector under the conditions of $w_i \in [0,1], i = 1,2, \dots, n$ and $\sum_{i=1}^{n} w_i = 1$.

A triangular fuzzy membership function $\widetilde{B} = (a, b, c)$ can be considered for determining the comparative linguistic terms based on hesitant fuzzy sets. The definition domain of $\widetilde{B}$ is the same as $\{s_i, \dots, s_j\} \in H_S$. Min and max operators can be used to calculate the elements of a and c:

$$a = \min\left\{a_L^i, a_M^i, a_M^{i+1}, \dots, a_M^j, a_R^j\right\} = a_L^i. \quad (9)$$

$$c = \max\left\{a_L^i, a_M^i, a_M^{i+1}, \dots, a_M^j, a_R^j\right\} = a_R^j. \quad (10)$$

The parameter b can be calculated by using the elements of $a_M^i, a_M^{i+1}, \dots, a_M^j \in T$ via OWA in terms of aggregation as *Eq. (11)*:

$$b = \text{OWA}_{Ws}\left(a_M^i, a_M^{i+1}, \dots, a_M^j\right). \quad (11)$$

3.2 | Hesitant Fuzzy Analytic Hierarchy Process

Steps of the hesitant fuzzy AHP based on Buckley's [32] method for weighting the criteria are summarized as below [15]:

Step 1. Pairwise comparison matrices consisting of criteria are created.

Step 2. Linguistic terms are transformed into triangular fuzzy numbers by using the scale given in *Table 1*.

Table 1. Linguistic Scale for Hesitant Fuzzy AHP.

Linguistic Term	Triangular Fuzzy Number	Trapezoidal Fuzzy Number
Absolutely high importance	(7,9,9)	(7,9,9,9)
Very high importance	(5,7,9)	(5,7,7,9)
Essentially of high importance	(3,5,7)	(3,5,5,7)
Weakly high importance	(1,3,5)	(1,3,3,5)
Equally high importance	(1,1,3)	(1,1,1,3)
Exactly equal	(1,1,1)	(1,1,1,1)
Equally low importance	(0.33,1,1)	(0.33,1,1,1)

Table 1. Continued.

Linguistic Term	Triangular Fuzzy Number	Trapezoidal Fuzzy Number
Weakly low importance	(0.2,0.33,1)	(0.2,0.33,0.33,1)
Essentially low importance	(0.14,0.2,0.33)	(0.14,0.2,0.2,0.33)
Very low importance	(0.11,0.14,0.2)	(0.11,0.14,0.14,0.2)
Absolutely low importance	(0.11,0.11,0.14)	(0.11,0.11,0.11,0.14)

Each component $\left(\tilde{b}_{ij}^{r}\right)$ of a pairwise comparison matrix $\widetilde{B^{r}}$ shows a fuzzy number and is formed as below:

$$\widetilde{B^{r}} = \begin{bmatrix} 1 & \widetilde{b_{12}^{r}} & \cdots & \widetilde{b_{1n}^{r}} \\ \widetilde{b_{21}^{r}} & 1 & \cdots & \widetilde{b_{2n}^{r}} \\ \vdots & \vdots & \cdots & \vdots \\ \widetilde{b_{n1}^{r}} & \widetilde{b_{n2}^{r}} & \cdots & 1 \end{bmatrix}, \tag{12}$$

where $\left(\tilde{b}_{ij}^{r}\right)$ shows the rth decision maker's judgment related to the comparison of the ith component to the jth one.

Step 3. Consistency of each fuzzy pairwise matrix is evaluated via the defuzzification process in terms of the graded mean integration approach [33]. A triangular fuzzy number $\widetilde{B} = (a, b, c)$ is transformed into a crisp value as *Eq. (13)*:

$$B = \frac{a + 4b + c}{6}. \tag{13}$$

Decision makers reevaluate the pairwise comparisons until achieving a consistent value.

Step 4. The fuzzy envelope approach [34] is applied to aggregate decision makers' judgments. Linguistic scale for hesitant AHP is ordered from the lowest (lv_0) to the highest one (hv_r).

Parameters for the trapezoidal fuzzy membership function $\tilde{C} = (c, d, e, f)$ are calculated as follows:

$$c = \min\left\{c_L^i, c_M^i, c_M^{i+1}, \dots, c_M^j, c_R^j\right\} = c_L^i. \tag{14}$$

$$f = \max\left\{c_L^i, c_M^i, c_M^{i+1}, \dots, c_M^j, c_R^j\right\} = c_R^j. \tag{15}$$

$$d = \begin{cases} c_M^i, \quad \text{if } i + 1 = j, \\ OWA_{W^2}\left(c_M^i, \dots, c_M^{\frac{i+j}{2}}\right) \text{If } i + j \text{ is even}, \\ OWA_{W^2}\left(c_M^i, \dots, c_M^{\frac{i+j-1}{2}}\right) \text{If } i + j \text{ is odd}. \end{cases} \tag{16}$$

$$e = \begin{cases} c_M^{i+1}, \quad \text{if } i + 1 = j, \\ OWA_{W^1}\left(c_M^j, c_M^{j-1}, \dots, c_M^{\frac{i+j}{2}}\right) \text{If } i + j \text{ is even}, \\ OWA_{W^1}\left(c_M^j, c_M^{j-1}, \dots, c_M^{\frac{i+j-1}{2}}\right) \text{If } i + j \text{ is odd}. \end{cases} \tag{17}$$

The weight vector needs to be constructed for applying the OWA operation. For this purpose, Filev and Yager [35] determined the first and second types of weights via parameter α having a value between [0,1]. The first type of weights $W^1 = (w_1^1, w_2^1, \dots, w_n^1)$ can be determined as *Eq.(18)*:

$$w_1^1 = \alpha_2, w_2^1 = \alpha_2(1 - \alpha_2), \dots, w_n^1 = \alpha_2(1 - \alpha_2)^{n-2}. \tag{18}$$

The second type of weights $W^2 = (w_1^2, w_2^2, \dots, w_n^2)$ can be stated as below:

$$w_1^2 = {\alpha_1}^{n-1}, w_2^2 = (1-\alpha_1){\alpha_1}^{n-2}, \dots, w_n^2 = 1-\alpha_1, \quad (19)$$

where $\alpha_1 = \frac{h-(l-k)}{h-1}$ and $\alpha_2 = \frac{(l-k)-1}{h-1}$. In addition, h shows the number of terms for the linguistic scale, while l represents the rank of the highest evaluation, and k shows the lowest one for the interval.

Step 5. Collaborative pairwise comparison matri$(\tilde{E})$x is constructed.

$$\tilde{E} = \begin{bmatrix} 1 & \widetilde{e_{12}} & \cdots & \widetilde{e_{1n}} \\ \widetilde{e_{21}} & 1 & \cdots & \widetilde{e_{2n}} \\ \vdots & \vdots & \cdots & \vdots \\ \widetilde{e_{n1}} & \widetilde{e_{n2}} & \cdots & 1 \end{bmatrix}, \quad (20)$$

where $\tilde{e}_{ij} = (e_{ija}, e_{ijb1}, e_{ijb2}, e_{ijc})$, then reciprocal values of trapezoidal fuzzy values are obtained in terms of the fuzzy envelope approach as *Eq. (21)*:

$$\tilde{e}_{ji} = \left(\frac{1}{e_{ijc}}, \frac{1}{e_{ijb2}}, \frac{1}{e_{ijb1}}, \frac{1}{e_{ija}}\right). \quad (21)$$

Step 6. Fuzzy geometric mean for each row $(\tilde{fr}_i)$ of the collaborative pairwise matrix is calculated as follows:

$$\tilde{fr}_i = (\tilde{e}_{i1} \otimes \tilde{e}_{i2} \dots \otimes \tilde{e}_{in})^{1/n}. \quad (22)$$

Step 7. Fuzzy weight $(\tilde{w}_i)$ of each attribute is computed via $(\tilde{fr}_i)$ values as below:

$$\tilde{w}_i = \tilde{fr}_i \otimes \left(\tilde{fr}_1 \oplus \tilde{fr}_2 \cdots \oplus \tilde{fr}_n\right)^{-1}. \quad (23)$$

Step 8. The defuzzification process is applied in order to transform trapezoidal fuzzy numbers to crisp one using *Eq. (24)*:

$$DV = \frac{e_{ija} + 2e_{ijb1} + 2e_{ijb2} + e_{ijc}}{6}. \quad (24)$$

4 | Analysis

In this study, the elements for sustainable innovation organizations are determined according to the comprehensive literature review and stated in *Table 2*.

Table 2. Elements for sustainable innovation organizations.

Elements	Criteria Number
Economical	C1
Social	C2
Regulations	C3
Market demand	C4
Information management	C5
Cross-functional cooperation	C6
Organization culture	C7
New career opportunities	C8
Management commitment	C9
Technical innovations	C10
Non-technical innovations	C11

A survey was designed and responded to by 10 decision-makers who have expertise and have performed sustainable innovation applications for food firms with 10 or more employees in Erzurum, considering the OWA operations stated as *Eqs. (14)-(17)*, hesitant fuzzy linguistic term sets consisting of compromised judgments of 10 decision makers are aggregated into the trapezoidal fuzzy numbers as seen in *Table 3*.

Table 3. A compromised pairwise comparison matrix consists of trapezoidal fuzzy numbers.

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
C1	(1,1,1,1)	(0.2,0.825,1,1)	(0.325,0.527, 0.745,1)	(0.143,0.258, 0.657,1)	(1,1,3,5)	(0.225,1,1,3)	(0.127,0.263,1,1)	(1,2.451,3.528, 7)	(0.254,0.352,1,1)	(1,2.367,3.275, 7)	(0.126,0.235,1,1)
C2	(1,1,1.21,5)	(1,1,1,1)	(0.356,0.512, 1,1)	(0.256,1,1,3)	(0.124,0.325, 1,1)	(0.145,0.235, 0.452,1)	(0.149,0.324,1,1)	(1,1,3,5)	(0.124,0.325,1,1)	(0.225,1,1,3)	(1,2.367,3.275,7)
C3	(1,1.342,1.897 ,3.077)	(1,1,1.953, 2.809)	(1,1,1,1)	(0.254,0.352,1,1)	(0.124,0.325, 1,1)	(0.143,0.258, 0.657,1)	(0.256,1,1,3)	(0.356,0.512,1, 1)	(0.143,0.258, 0.657,1)	(0.225,1,1,3)	(0.149,0.324,1,1)
C4	(1,1.522,3.876 ,6.993)	(0.33,1,1, 3.906)	(1,1,2.841, 3.937)	(1,1,1,1)	(0.356,0.512, 1,1)	(0.124,0.325, 1,1)	(1,2.451,3.528,7)	(1,1,3,5)	(0.2,0.825,1,1)	(0.256,1,1,3)	(0.145,0.235, 0.452,1)
C5	(0.2,0.33,1,1)	(1,1,3.077, 8.064)	(1,1,3.077, 8.064)	(1,1,1.953, 2.809)	(1,1,1,1)	(0.127,0.263, 1,1)	(0.356,0.512,1,1)	(0.124,0.325,1, 1)	(0.256,1,1,3)	(1,2.451,3.528, 7)	(1,2.367,3.275,7)
C6	(0.33,1,1,4.44)	(1,2.212, 4.255,6.9)	(1,1.522,3.876, 6.993)	(1,1,3.077, 8.064)	(1,1,3.802, 7.874)	(1,1,1,1)	(0.149,0.324,1,1)	(1,1,3,5)	(0.225,1,1,3)	(0.256,1,1,3)	(0.124,0.325,1,1)
C7	(1,1,3.802, 7.874)	(1,1,3.086, 6.711)	(0.33,1,1,3.906)	(0.142,0.283, 0.408,1)	(1,1,1.953, 2.809)	(1,1,3.086, 6.711)	(1,1,1,1)	(0.127,0.263,1, 1)	(1,1,3,5)	(0.256,1,1,3)	(0,145,0.235, 0.452,1)
C8	(0.142,0.283, 0.408,1)	(0.2,0.33,1,1)	(1,1,1.953, 2.809)	(0.2,0.33,1,1)	(1,1,3.077, 8.064)	(0.2,0.33,1,1)	(1,1,3.802,7.874)	(1,1,1,1)	(0.356,0.512,1,1)	(0.127,0.263,1, 1)	(1,2.367,3.275,7)
C9	(1,1,2.841, 3.937)	(1,1,3.077, 8.064)	(1,1.522,3.876, 6.993)	(1,1,1.212,5)	(0.33,1,1, 3.906)	(0.33,1,1,4.44)	(0.2,0.33,1,1)	(1,1,1.953, 2.809)	(1,1,1,1)	(0.124,0.325,1, 1)	(0.143,0.258, 0.657,1)
C10	(0.142,0.305, 0.422,1)	(0.33,1,1, 4.44)	(0.33,1,1,4.44)	(0.33,1,1, 3.906)	(0.142,0.283, 0.408,1)	(0.33,1,1,3.906)	(0.33,1,1,3.906)	(1,1,3.802, 7.874)	(1,1,3.077,8.064)	(1,1,1,1)	(1,2.451,3.528,7)
C11	(1,1,4.255, 7.936)	(0.142,0. 305,0.422,1)	(1,1,3.086, 6.711)	(1,2.212, 4.255,6.9)	(0.142,0.305, 0.422,1)	(1,1,3.077, 8.064)	(1,2.212,4.255,6.9)	(0.142,0.305, 0.422,1)	(1,1.522,3.876, 6.993)	(0.142,0.283,0. 408,1)	(1,1,1,1)

After that, geometric means and normalized weights are calculated via *Eqs. (22)-(23)*. Then, the defuzzified weights of the criteria are computed by using *Eq. (24)* and are shown in *Table 4*.

Table 4. Geometric means, normalized and defuzzified weights for criteria.

Criteria	Geometric Means	Normalized Weights	Defuzzified Weights	Rank
C1	(0.345,0.679,1.293,1.822)	(0.013,0.045,0.16,0.391)	0.075281	9
C2	(0.339,0.656,1.165,1.952)	(0.013,0.043,0.144,0.419)	0.074637	10
C3	(0.303,0.56,0.983,1.485)	(0.011,0.036,0.121,0.319)	0.059892	11
C4	(0.436,0.825,1.434,2.336)	(0.016,0.054,0.177,0.501)	0.090822	7
C5	(0.476,0.798,1.628,2.527)	(0.017,0.052,0.201,0.542)	0.098865	4
C6	(0.485,0.91,1.783,3.358)	(0.018,0.059,0.219,0.72)	0.120334	1
C7	(0.465,0.692,1.396,2.712)	(0.017,0.045,0.172,0.581)	0.095905	6
C8	(0.407,0.594,1.365,1.912)	(0.015,0.039,0.168,0.41)	0.077891	8
C9	(0.489,0.75,1.434,2.693)	(0.018,0.049,0.177,0.577)	0.097187	5
C10	(0.424,0.868,1.195,3.31)	(0.015,0.057,0.147,0.71)	0.10521	2
C11	(0.492,0.774,1.501,2.942)	(0.018,0.051,0.185,0.631)	0.103975	3

According to *Table 4*, while C6 (Cross-functional cooperation) was obtained as the most important criterion for sustainable innovation organization, with having 0.120334 value, C3 (Regulations) was found as the least important one. Ranking of other criteria can be stated as C10>C11>C5>C9>C7>C4>C8>C1>C2 respectively.

5 | Conclusion

Increasing the sustainable innovation-oriented activities of firms will allow them to improve their competitiveness and increase their performance in the market. Firms can meet customer demands, needs, and expectations more clearly and appropriately by realizing sustainable innovation activities. Especially as a result of the analyses in the study, companies operating in the food sector can open up to new markets by giving more importance to the innovation dimension of the service.

By giving importance to research and development with Sustainable Innovation practices, they can develop new products with technology and expand their product and service network. From these perspectives, sustainable innovation practices gain importance in all businesses and are considered to be vital in terms of business efficiency and effectiveness.

In this study, the importance level of sustainable innovation applications is evaluated via the hesitant fuzzy sets-based AHP method. Elements for sustainable innovation organizations are acquired via a comprehensive literature review process. A survey related to the criteria ranking was responded to by 10 decision-makers having expertise and performing sustainable innovation applications for food firms with 10 or more employees in Erzurum.

Hesitant fuzzy sets are preferred because they provide more accurate and consistent outputs for real-world decision-making problems, including contradictions in decision makers' views. The most important (Cross-functional cooperation) and the least important criteria (Regulations) are determined as well. For future studies, other subjective weighting methods can be used to obtain the importance level of firms in different sectors. Additionally, elements for sustainable innovation organizations can be expanded.

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Author Contribution

Conceptualization, S.K.; Methodology, Ç.K.; Software, Ç.K.; formal analysis, Ç.K.; resources, S.K. and Ç.K.; writing-creating the initial design, S.K. and Ç.K.; writing-reviewing and editing, S.K. and Ç.K.; visualization, S.K. and Ç.K.; project management, S.K. and Ç.K. All authors have read and agreed to the published version of the manuscript.

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Data Availability

The dataset generated and/or analyzed during the current study is available without restriction within the manuscript.

Conflicts of Interest

The authors declare no conflict of interest. The authors have no relevant financial or non-financial interests to disclose.

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