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ABSTRACT

Innovation is an important instrument for actors in financial sectors, as in many other sectors, to compete in challenging conditions and provide innovative solutions to their clients. They realize many innovation projects, especially for reasons such as improving the products of banking and increasing their financial strength. Since the open innovation method introduces a framework for gathering many different project ideas, there is a need to select the most suitable ones in the context of innovation management. The department supervising the innovation management has limited resources that can be dedicated to this effort so that decision analysts must evaluate various project ideas and determine a proper ranking. In case many attributes should be considered in assessing the alternative innovative ideas, they can be efficiently and effectively ranked via multiple attribute decision-making (MADM) methods. When the decision process needs several experts, the decision process can be very complicated and renamed as Group MADM (G-MADM). In the project idea selection problem, the alternative ideas are required to be evaluated by the decision-makers. To model the uncertainty and vagueness in their judgments, fuzzy-based G-MADM methods are developed as beneficial tools because of their representation power in quantification. A recent fuzzy set concept introduced in the literature is spherical fuzzy sets (SFS) which can simultaneously model the positive and negative opinions as well as the possible hesitancy of the decision-makers. For considering the extensive human judgment representation power of SFSs, Analytic Hierarchy Process (AHP) and Weighted Aggregated Sum Product Assessment (WASPAS) tools are utilized under spherical fuzzy environment. SF-AHP obtains the importance of the attributes which are currently used in real-life innovation management applications maintained in the relevant committees of the bank. Ten alternative innovation ideas are evaluated by SF-WASPAS to select the most appropriate one for the bank and its customers.

1 INTRODUCTION

Many different innovation definitions can be found in the literature but their common feature is that innovation is a creative thinking process. Although creative thinking is a mainly mental activity, innovation has been accepted as the corporeal or external result of it. Therefore, innovation, by definition, includes change, renewal, and development.

The Oslo Manual defines innovation as the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization, or external relations [1]. Innovation management, on the other hand, basically provides the definition of innovation, the operation of the process, and enables the idea management systems to collect, evaluate and implement ideas to others.

In today's globalizing world, the ability of companies and other organizations in maintaining their competitive advantage, continuing their activities, and surviving in the market depends on how quickly and effectively they can adapt to innovation [2]. Therefore, in order to be more innovative, companies try to go beyond their borders [3] and adapt their innovation processes to the open innovation process as much as possible. In this manner, they aim to reach more innovative project ideas from their employees, customers, and all stakeholders with or without interaction. In fact, in the last decade, Idea Management Systems (IMS) have developed the scope of collecting innovative ideas from large communities via the internet, to develop and improve these ideas based on cooperation and managing them comprehensively in company processes [4].

An important stage of IMSs is the evaluation of the collected ideas. At this stage, it is tried to find the best of all alternatives by applying quantitative methods via considering the expert judgments about the ideas. In case many attributes should be considered in assessing the alternative innovative ideas with respect to decision attributes affecting the outcome decision, the alternatives can be efficiently and effectively ranked via Multiple Attribute Decision-Making (MADM) methods. When the decision process requires many experts who are called decision-makers, it can be very complicated and renamed as group MADM (G-MADM).

Different issues such as the difficulty in conveying the ideas by the owners, the different approaches of the evaluators to the subject, the uncertainty in the data, resulted in these evaluations to be approached with fuzzy logic theory. As a matter of fact, in such cases, it is recommended to use fuzzy logic theory to strengthen the solution of the problem [5].

One of the latest fuzzy set definitions introduced in the literature is Spherical Fuzzy Sets (SFS) which can simultaneously model the positive and negative opinions as well as the possible hesitancy of the decision-maker. This independently 3D representation style of the different aspects of expert opinions is the strength and contribution of SFSs. In the study, considering this extensive human judgment representation power of SFSs, Analytic Hierarchy Process (AHP) and Weighted Aggregated Sum Product Assessment (WASPAS) G-MADM tools are utilized under spherical fuzzy environment, based on IMSs applied in the banking sector. While SF-AHP obtains the importance of the attributes, SF-WASPAS is used to select the most appropriate idea for the bank and its customers.

The study consists of five main sections. After the introduction, a literature review has been provided in the next section. Section 3 details the proposed method. In section 4, the application of the method and its findings are presented. General discussion and conclusion have been detailed in the final section.

2 LITERATURE REVIEW: INNOVATION IDEA EVALUATION

The basic activity in innovation management is the transformation of projects from the idea to a commercial output. For this purpose, strategic decisions are made in IMSs involving many problem-solving activities. In order to eliminate the uncertainties that may be encountered in the selection of innovative ideas, the activities to be carried out pass through the stages of determining the projects, selection of the most suitable one, and its implementation.

Hrastinski et al. [6] investigated a range of selected products and pointed out that existing commercial systems use fairly simple opinion assessment methods. Gangi and Wasko [7] mentioned that none of the existing methods in practice have a significant impact on which ideas are implemented by organizations. Bothos et al. [8] tried to find a time-efficient and effective automatic idea evaluation system in forecasting markets. Gorski and Heinekamp [9] provided an illustrative example of how the indeterminate front end of the innovation process can work as part of an IMS.

The number of studies attempting to analyze content created by communities collaboratively is also quite high [10, 11, 12]. Adamides and Karacapilidis [13] provided an overview of using IT tools for collaboration in the innovation process. Christensen et al. [14] and Sethi et al. [15] aimed to facilitate the exchange of ideas and productivity while Bose [16] dealt with group decision support systems, negotiation, and discussion processes. Börjesson et al. [17] stated that there is an evaluation/choice of ideas for organizing them for innovation. According to Bröring et al. [18], each project is of course unique and requires a different approach to evaluation.

3 METHODS

Spherical fuzzy set (SFS) concept was developed as a generalization of Pythagorean fuzzy sets (PFS) and neutrosophic sets [19] to support the decision-making process via presenting a broader preference domain. It allows the decision-makers who are consulted for their expertise to specify their preferences with three elements: membership degree (μ – positive opinions), non-membership degree (υ – negative opinions), and hesitancy degree (π – hesitancy or indeterminacy level of their opinions). In SFSs, each degree is independently defined in [0,1] while their squared sum is between 0 and 1, too [20]: $0 \leq \mu^2\,(x) + \upsilon^2\,(x) + \pi^2\,(x) \leq 1$. Therefore, it is seen that the advantage of implementing SFSs into the decision process is based on their ability to combine the positive aspects of other fuzzy extensions into a unique theory.

In the study, two well-known MADM methods are extended into SFS environment for utilizing their comprehensive reality representation power. In obtaining the attribute weights, SF-AHP (spherical fuzzy analytic hierarchy process) is applied. Then, SF-WASPAS (spherical fuzzy weighted aggregated sum product assessment) method is implemented for the ranking of the innovative project ideas.

3.1 Spherical Fuzzy AHP (SF-AHP)

Analytic hierarchy process (AHP) as probably the most cited MADM approach, was introduced by Saaty [21]. AHP is a strong decision-making tool for both individualistic and group decision environments. Making evaluations that are based on attribute-based pairwise comparisons supports decision-makers in reaching a decision. Thanks to the nature of AHP improving the consistency of the decision judgments, AHP is a beneficial MADM tool today [22]. In the study, SF-AHP version is utilized to cope with the inherent uncertainty and ambiguity in the judgments of experts. The version used was developed by Gündoğdu and Kahraman [23].

Step 1. Construction of the decision hierarchy: A hierarchy representing the level-base relations among attributes and alternatives should be constructed. The goal is shown in Level 0, the main criteria are listed in Level 1, the sub-criteria of the related main criterion are organized in successive levels, and the alternatives are located at the bottom level. In the study, there are only main criteria affecting the innovative project idea selection process. Let $A = \{A_1,\ldots,A_n\}$ show the main criteria set in Level 1.

Step 2. Collecting the pairwise comparisons from the expert group: The decision-makers build their pairwise comparison matrices using spherical fuzzy linguistic terms (SFLT) specified in Table 1. The aggregation of these individualistic evaluations ($\tilde{A}_j$, j=1,…,n) in SF-AHP is handled via spherical weighted arithmetic mean (SWAM) operator (Eq. 1). In aggregation, the decision-makers' expertise and knowledge weights are represented by $w = (w_1, w_2, \dots, w_k)$. The aggregated pairwise comparison matrix is shown by $\tilde{A}$.

$$SWAM_w(\tilde{A}_1, \tilde{A}_2, \dots, \tilde{A}_n) = w_1\tilde{A}_1 + w_2\tilde{A}_2 + \cdots + w_n\tilde{A}_n$$
$$= \left\{\left[1 - \prod_{j=1}^{n}\left(1 - \mu_{\tilde{A}_j}^2\right)^{w_j}\right]^{\frac{1}{2}}, \prod_{j=1}^{n} \upsilon_{\tilde{A}_j}^{w_j}, \left[\prod_{j=1}^{n}\left(1 - \mu_{\tilde{A}_j}^2\right)^{w_j} - \prod_{j=1}^{n}\left(1 - \mu_{\tilde{A}_j}^2 - \pi_{\tilde{A}_j}^2\right)^{w_j}\right]^{\frac{1}{2}}\right\} \quad (1)$$

Table 1 SFLT for SF-AHP [23, 24]

SI	***Meaning***	***(μ,υ,π)***	***SI***	***(μ,υ,π)***
9	Absolutely more importance	(0.9,0.1,0)	8	(0.85,0.15,0.05)
7	Very high importance	(0.8,0.2,0.1)	6	(0.75,0.25,0.15)
5	High importance	(0.7,0.3,0.2)	4	(0.65,0.35,0.25)
3	Slightly more importance	(0.6,0.4,0.3)	2	(0.55,0.45,0.35)
1	Equally importance	(0.5,0.4,0.4)	1/2	(0.45,0.55,0.35)
1/3	Slightly low importance	(0.4,0.6,0.3)	1/4	(0.35,0.65,0.25)
1/5	Low importance	(0.3,0.7,0.2)	1/6	(0.25,0.75,0.15)
1/7	Very low importance	(0.2,0.8,0.1)	1/8	(0.15,0.85,0.05)
1/9	Absolutely low importance	(0.1,0.9,0)		

Step 3. Controlling the consistency of each comparison: The consistency of a pairwise comparison matrix is checked in AHP to reach a more reliable decision. Saaty [21] developed an eigenvector-based consistency measure which is called *CR* (consistency ratio). The classical definition is $CR = \frac{(\lambda_{max} - n)/(n-1)}{RI}$ where n is the size of the matrix (which is equal to the number of the attribute in a single matrix) and *RI* is obtained from Random Index table. By modifying the consistency measure developed by Abdullah and Najib [25] for intuitionistic fuzzy extension of AHP, Camci et al. [24] proposed a *CR* formula for SF-AHP. If *CR* is found less than 0.10, it is concluded that there is a tolerable inconsistency.

$$CR = \frac{(\sqrt{\sum_i \pi_{\tilde{A}}^2 / n})/(n-1)}{RI} \quad (2)$$

Step 4. Calculation of the SF weights of attributes: This step determines the importance values (weights) of the attributes ($\tilde{\omega}_j$). SWAM operator which is given in Eq. (1) is performed to compute the SF weights. In the formula, $w_1 = w_2 = \cdots = w_n = 1/n$ is assumed [23].

Step 5. Defuzzification of the SF weights of attributes: For ranking purposes, SF numbers representing the attribute weights are defuzzified via the score function given in Eq. (3).

$$\omega_j = S(\widetilde{\omega}_j) = \sqrt{\left|100 * \left[\left(3\mu_{\widetilde{\omega}_j} - \frac{\pi_{\widetilde{\omega}_j}}{2}\right)^2 - \left(\frac{\upsilon_{\widetilde{\omega}_j}}{2} - \pi_{\widetilde{\omega}_j}\right)^2\right]\right|} \tag{3}$$

As a result of SF-AHP, the weights of the attributes (ω_j) and their ranking is obtained.

3.2 Spherical Fuzzy WASPAS (SF-WASPAS)

WASPAS was introduced by Zavadskas et al. [26] as an integration of the two well-known methods: SAW (simple additive weighting) and WPM (weighted product model). It is shown that a joint generalization of the weighted aggregation increases the ranking accuracy.

SAW is a well-known and commonly used method in the MADM field. In the original methodology [27], first, the alternatives' normalized performance scores are weighted and then they are ranked in descending order of the sum of these scores. WPM is very similar to SAW but it uses multiplication operation rather than addition. Each alternative is compared by multiplying the number of ratios where each ratio is raised to the power of the weight of attribute. There is no need for normalization in WPM so that it is called dimensionless analysis [28]. WASPAS was extended into SFS environment by Kutlu Gundogdu and Kahraman [29].

Step 1. Let $X = \{x_1, \ldots, x_m\}$ be a set of m alternatives, $A = \{A_1, \ldots, A_n\}$ be a set of attributes, $\omega = \{\omega_1, \ldots, \omega_n\}$ be the weight vector of attributes obtained by SF-AHP, and $w = (w_1, w_2, \ldots, w_k)$ be the weights of decision-makers. First, decision-makers construct the alternative evaluation matrices $(D^1, D^2, \ldots, D^k)$ where $D^e = \langle \mu_{ij}^e, \upsilon_{ij}^e, \pi_{ij}^e \rangle$ by utilizing the SFLT given in Table 2.

Table 2 SFLT for SF-WASPAS [29]

Linguistic Term	*Abb.*	μ	υ	π
Absolutely More Importance	AMI	0.9	0.1	0.1
Very High Importance	VHI	0.8	0.2	0.2
High Importance	HI	0.7	0.3	0.3
Slightly More Importance	SMI	0.6	0.4	0.4
Equally Importance	EI	0.5	0.5	0.5
Slightly Low Importance	SLI	0.4	0.6	0.4
Low Importance	LI	0.3	0.7	0.3
Very Low Importance	VLI	0.2	0.8	0.2
Absolutely Low Importance	ALI	0.1	0.9	0.1

Step 2. Evaluations are aggregated by using SWAM operator given in Eq. (4) and D^{agg} represents the aggregated decision matrix.

$$D^{agg} = SWAM_w\left(D^1, D^2, \ldots, D^k\right) = w_1 D^1 + w_2 D^2 + \cdots + w_k D^k = \langle \mu_{ij}, \upsilon_{ij}, \pi_{ij} \rangle$$

$$= \left\{\left[1 - \prod_{e=1}^{k}\left(1 - \left(\mu_{ij}^e\right)^2\right)^{w_e}\right]^{\frac{1}{2}}, \prod_{e=1}^{k}\left(\upsilon_{ij}^e\right)^{w_e}, \left[\prod_{e=1}^{k}\left(1 - (\mu_{ij}^e)^2\right)^{w_e} - \prod_{e=1}^{k}\left(1 - (\mu_{ij}^e)^2 - (\pi_{ij}^e)^2\right)^{w_e}\right]^{\frac{1}{2}}\right\} \tag{4}$$

Step 3. SAW is performed on D^{agg} by considering the attribute weights (ω_j) to determine the $\widetilde{SAW}_i$ SF scores of each alternative as given in Eq. (5).

$$\widetilde{SAW}_i = \sum_{j=1}^{n}\left(\omega_j * \langle \mu_{ij}, \upsilon_{ij}, \pi_{ij} \rangle\right) = \langle \mu_i^{SAW}, \upsilon_i^{SAW}, \pi_i^{SAW} \rangle \tag{5}$$

where

$$\omega_j * \langle \mu_{ij}, \upsilon_{ij}, \pi_{ij} \rangle = \{\left(1-\left(1-\mu_{ij}^2\right)^{\omega_j}\right)^{\frac{1}{2}}, \upsilon_{ij}^{\omega_j}, (\left(1-\mu_{ij}^2\right)^{\omega_j} - \left(1-\mu_{ij}^2-\pi_{ij}^2\right)^{\omega_j})^{\frac{1}{2}}\} \tag{6}$$

and

$$\langle \mu_{i1}, \upsilon_{i1}, \pi_{i1} \rangle \oplus \langle \mu_{i2}, \upsilon_{i2}, \pi_{i2} \rangle = \{\left(\mu_{i1}^2+\mu_{i2}^2-\mu_{i1}^2\mu_{i2}^2\right)^{\frac{1}{2}}, \upsilon_{i1}\upsilon_{i2}, (\left(1-\mu_{i2}^2\right)\pi_{i1}^2 + \left(1-\mu_{i1}^2\right)\pi_{i2}^2 - \pi_{i1}^2\pi_{i2}^2)^{\frac{1}{2}}\} \tag{7}$$

Step 4. WPM is applied on D^{agg} for obtaining the $\widetilde{WPM}_i$ SF scores of each alternative as given in Eq. (8).

$$\widetilde{WPM}_i = \prod_{j=1}^{n} \langle \mu_{ij}, \upsilon_{ij}, \pi_{ij} \rangle^{\omega_j} = \langle \mu_i^{WPM}, \upsilon_i^{WPM}, \pi_i^{WPM} \rangle \tag{8}$$

where

$$\langle \mu_{ij}, \upsilon_{ij}, \pi_{ij} \rangle^{\omega_j} = \{\mu_{ij}^{\omega_j}, \left(1-\left(1-\upsilon_{ij}^2\right)^{\omega_j}\right)^{\frac{1}{2}}, (\left(1-\upsilon_{ij}^2\right)^{\omega_j} - \left(1-\upsilon_{ij}^2-\pi_{ij}^2\right)^{\omega_j})^{\frac{1}{2}}\} \tag{9}$$

and

$$\langle \mu_{i1}, \upsilon_{i1}, \pi_{i1} \rangle \otimes \langle \mu_{i2}, \upsilon_{i2}, \pi_{i2} \rangle = \{\mu_{i1}\mu_{i2}, \left(\upsilon_{i1}^2+\upsilon_{i2}^2-\upsilon_{i1}^2\upsilon_{i2}^2\right)^{\frac{1}{2}}, (\left(1-\upsilon_{i2}^2\right)\pi_{i1}^2 + \left(1-\upsilon_{i1}^2\right)\pi_{i2}^2 - \pi_{i1}^2\pi_{i2}^2)^{\frac{1}{2}}\} \tag{10}$$

Step 5. $\widetilde{SAW}_i$ and $\widetilde{WPM}_i$ SF values are combined by employing a threshold value (λ). Eq. (11) is used for finding the aggregated performance values of alternatives determined by SAW and WPM, independently.

$$\tilde{Q}_i = \lambda \widetilde{SAW}_i + (1-\lambda)\widetilde{WPM}_i = \langle \mu_i \;, \upsilon_i \;, \pi_i \; \rangle \tag{11}$$

where

$$\lambda \widetilde{SAW}_i = \{\left(1-\left(1-\left(\mu_i^{SAW}\right)^2\right)^{\lambda}\right)^{\frac{1}{2}}, \left(\upsilon_i^{SAW}\right)^{\lambda}, (\left(1-\left(\mu_i^{SAW}\right)^2\right)^{\lambda} - \left(1-\left(\mu_i^{SAW}\right)^2-\left(\pi_i^{SAW}\right)^2\right)^{\lambda_j})^{\frac{1}{2}}\} \tag{12}$$

$$(1-\lambda)\widetilde{WPM}_i = \{\left(1-\left(1-\left(\mu_i^{WPM}\right)^2\right)^{(1-\lambda)}\right)^{\frac{1}{2}}, \left(\upsilon_i^{WPM}\right)^{(1-\lambda)}, (\left(1-\left(\mu_i^{WPM}\right)^2\right)^{(1-\lambda)} - \left(1-\left(\mu_i^{WPM}\right)^2-\left(\pi_i^{WPM}\right)^2\right)^{(1-\lambda)})^{\frac{1}{2}} \tag{13}$$

Step 6. $\tilde{Q}_i$ SF values are defuzzified to rank the alternatives in preference order.

$$Q_i = (\mu_i \; - \pi_i \;)^2 - (\upsilon_i \; - \pi_i \;)^2 \tag{14}$$

Accuracy function values might be considered to resolve the equality issue. Accuracy function is $Acc_i = \mu_i^2 + \upsilon_i^2 + \pi_i^2$.

4 APPLICATION

For application, 10 project ideas generated for a Turkish bank were evaluated with respect to 7 attributes. In the study, we propose the usage of SF-AHP for calculating the weights of the attributes and SF-WASPAS to obtain the preference ranking of the ideas. The attributes are listed as follows:

A_1: *Return on Investment (ROI) Time:* It is a rough estimate of how long the project idea can meet its ROI value. Periods can vary in a range of shorter than 1 year to longer than 5 years or not predictable. This attribute is a cost-type one where shorter times are preferable.

A_2: *Resource Requirement:* How much resource is required for the project? Resource requirement is a cost type criterion where smaller requirements are preferable. The term resource may cover the people, the hardware, the software, the training, or the technology.

A_3: *Execution Risk:* It is used to estimate the risk of the project during development or execution. Some projects may have higher risks because of having dependencies to outsource firms or they might be risky because of affecting so many groups/departments within the company. The wider effect is evaluated as higher risk in general and this attribute is again a cost type one.

A_4: *Expected Benefit for the Bank*: It addresses any benefit for the bank which may be an increase in the revenue or decrease in the costs. This is a benefit-type attribute where higher values are preferred.

A_5: *Expected Benefit for Customers:* It addresses any benefit for the customers which may be an increase in customer satisfaction or loyalty. This is a benefit-type attribute.

A_6: *Risk Impact:* This is the impact of the project to decrease any existing risks such as compliance risk, operational risk, or financial risk. So this is a benefit type attribute.

A_7: *R&D Impact:* The bank has an R&D center, so looking for R&D projects as well. The project idea may have a higher R&D impact that includes some new technologies such as blockchain, AR/VR, or AI technologies.

In the beginning step focusing on attribute weighting, first, the attributes were compared in a pairwise manner by the experts using the SFLT given in Table 1 and then these comparisons were converted to the attribute weights representing their importance levels. While Table 3 shows the pairwise comparisons, Table 4 presents the results of SF-AHP. In the application, there was no need for aggregating individual comparisons because the attributes were compared in a group environment based on consensus. Thus, there was only one comparison matrix to process. The group's CR value was found as 0.021 via Eq. (2) so that it is accepted as a tolerable inconsistency. As seen in Table 4, the ranking of the attributes is found as $A_5 \succ A_7 \succ A_2 \succ A_4 \succ A_6 \succ A_3 \succ A_1$. The expected benefit for the customer attribute took the first place as a reasonable finding because the bank as a service provider company focuses on customer satisfaction in the first place.

In the second step designed for ranking the alternative project ideas, 4 experts were consulted and their evaluations representing the performances of 10 alternatives with respect to 7 attributes were gathered via SFLT given in Table 2. Due to the space limitation, their individualistic SF decision matrices are not depicted. The aggregated decision matrix is given in Table 5. The details of the alternative project ideas are not also shared because of the data protection and security rule of the bank in which we applied the proposed MADM method. The results are summarized in Table 6 and Table 7. Table 6 shows the SF application results of SAW and WPM while Table 7 presents the defuzzified results which were found via Eq. (14) considering λ ranging between 0 and 1.

Fig. 1 shows the changes in the ranking of the alternatives. Considering any threshold value of λ, a decision analyst can easily find the most appropriate alternative. As a common selection in the literature, we set λ=0.5 and obtained the corresponding preference ranking of alternatives: $x_6 \succ x_3 \succ x_4 \succ x_8 \succ x_1 \succ x_{10} \succ x_5 \succ x_9 \succ x_7 \succ x_2$. For the continuum given in Fig. 1, A_6 is ranked in the first place for $\lambda \in [0,0.9]$. Accordingly, it is interpreted that A_6 has the priority and it will be a stable and robust alternative in case changing parameter values are considered.

5 DISCUSSION AND CONCLUSION

In the banking sector, as in many other sectors, global competition is increasing day by day. Banks attach more importance to innovation every day in order to maintain their strength in the markets and to participate in the competition. Using Innovation Management Systems, it collects innovative project ideas from its employees and stakeholders and tries to offer impressive solutions by implementing these projects quickly and effectively.

Table 3 Comparison of Attributes in SF-AHP

	A_1			A_2			A_3			A_4			A_5			A_6			A_7		
A_1	0.50	0.40	0.40	0.40	0.60	0.30	0.40	0.60	0.30	0.20	0.80	0.10	0.10	0.90	0.00	0.40	0.60	0.30	0.30	0.70	0.20
A_2	0.60	0.40	0.30	0.50	0.40	0.40	0.70	0.30	0.20	0.20	0.80	0.10	0.20	0.80	0.10	0.70	0.30	0.20	0.20	0.80	0.10
A_3	0.60	0.40	0.30	0.30	0.70	0.20	0.50	0.40	0.40	0.10	0.90	0.00	0.10	0.90	0.00	0.40	0.60	0.30	0.30	0.70	0.20
A_4	0.80	0.20	0.10	0.80	0.20	0.10	0.90	0.10	0.00	0.50	0.40	0.40	0.40	0.60	0.30	0.70	0.30	2.00	0.60	0.40	0.30
A_5	0.90	0.10	0.00	0.80	0.20	0.10	0.90	0.10	0.00	0.60	0.40	0.30	0.50	0.40	0.40	0.70	0.30	0.20	0.55	0.45	0.35
A_6	0.60	0.40	0.30	0.30	0.70	0.20	0.60	0.40	0.30	0.30	0.70	0.20	0.30	0.70	0.20	0.50	0.40	0.40	0.40	0.60	0.30
A_7	0.70	0.30	0.20	0.80	0.20	0.10	0.70	0.30	0.20	0.40	0.60	0.30	0.45	0.55	0.35	0.60	0.40	0.30	0.50	0.40	0.40

Table 4 The Results of SF-AHP

	SF Weights			$S(\tilde{\omega}_j)$	ω_j	*Ranking*
A_1	0.357	0.639	0.275	9.332	0.094	7
A_2	0.520	0.496	0.242	14.378	0.144	3
A_3	0.384	0.627	0.264	10.192	0.102	6
A_4	0.728	0.274	1.020	14.219	0.143	4
A_5	0.763	0.238	0.199	21.885	0.219	1
A_6	0.457	0.539	0.291	12.245	0.123	5
A_7	0.627	0.370	0.265	17.480	0.175	2

Table 5 Aggregated SF Decision Matrix for SF-WASPAS

	A_1			A_2			A_3			A_4			A_5			A_6			A_7		
ω_j	*0.094*			*0.144*			*0.102*			*0.143*			*0.219*			*0.123*			*0.175*		
x_1	0.85	0.15	0.15	0.60	0.40	0.40	0.60	0.40	0.40	0.35	0.65	0.36	0.66	0.34	0.33	0.30	0.71	0.31	0.24	0.77	0.25
x_2	0.56	0.44	0.40	0.46	0.54	0.40	0.35	0.65	0.36	0.30	0.71	0.31	0.53	0.48	0.37	0.30	0.71	0.31	0.43	0.59	0.37
x_3	0.85	0.15	0.15	0.69	0.31	0.33	0.56	0.44	0.40	0.46	0.54	0.40	0.51	0.49	0.40	0.43	0.59	0.37	0.51	0.49	0.40
x_4	0.85	0.15	0.15	0.85	0.15	0.15	0.46	0.54	0.40	0.46	0.54	0.40	0.40	0.60	0.40	0.40	0.60	0.40	0.30	0.71	0.31
x_5	0.60	0.40	0.40	0.60	0.40	0.40	0.51	0.49	0.40	0.56	0.44	0.40	0.60	0.40	0.40	0.15	0.85	0.15	0.30	0.71	0.31
x_6	0.60	0.40	0.40	0.40	0.60	0.40	0.60	0.40	0.40	0.60	0.40	0.40	0.76	0.24	0.26	0.40	0.60	0.40	0.56	0.44	0.40
x_7	0.69	0.31	0.33	0.56	0.44	0.40	0.60	0.40	0.40	0.60	0.40	0.40	0.51	0.49	0.40	0.24	0.77	0.25	0.15	0.85	0.15
x_8	0.60	0.40	0.40	0.60	0.40	0.40	0.46	0.54	0.40	0.51	0.49	0.40	0.56	0.44	0.40	0.56	0.44	0.40	0.40	0.60	0.40
x_9	0.60	0.40	0.40	0.60	0.40	0.40	0.40	0.60	0.40	0.30	0.71	0.31	0.51	0.49	0.40	0.46	0.54	0.40	0.30	0.71	0.31
x_{10}	0.46	0.54	0.40	0.56	0.44	0.40	0.56	0.44	0.40	0.51	0.49	0.40	0.40	0.60	0.40	0.40	0.60	0.40	0.40	0.60	0.40

Table 6 SF Evaluation Results of SF-WASPAS

	$\widetilde{SAW}_i$			$\widetilde{WPM}_i$		
A1	0.575	0.458	0.295	0.463	0.604	0.299
A2	0.445	0.578	0.334	0.420	0.640	0.319
A3	0.594	0.422	0.317	0.548	0.484	0.340
A4	0.597	0.434	0.281	0.474	0.579	0.323
A5	0.516	0.503	0.340	0.439	0.612	0.311
A6	0.604	0.407	0.327	0.561	0.468	0.344
A7	0.512	0.514	0.327	0.409	0.648	0.291
A8	0.534	0.472	0.356	0.521	0.505	0.358
A9	0.473	0.544	0.345	0.436	0.617	0.330
A10	0.471	0.536	0.359	0.457	0.575	0.355

Table 7 Ranking of Alternatives for Changing λ Values

Q_i	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
A1	-0.066	-0.055	-0.043	-0.031	-0.019	-0.007	0.004	0.016	0.028	0.040	0.052
A2	-0.093	-0.088	-0.083	-0.079	-0.074	-0.070	-0.065	-0.061	-0.056	-0.051	-0.047

A3	0.023	0.027	0.031	0.035	0.040	0.044	0.048	0.053	0.057	0.061	0.066
A4	-0.043	-0.031	-0.019	-0.007	0.005	0.017	0.029	0.041	0.053	0.065	0.077
A5	-0.074	-0.066	-0.058	-0.051	-0.043	-0.035	-0.027	-0.019	-0.011	-0.003	0.004
A6	0.031	0.035	0.039	0.043	0.047	0.051	0.055	0.059	0.063	0.066	0.070
A7	-0.113	-0.102	-0.091	-0.079	-0.068	-0.057	-0.046	-0.034	-0.023	-0.012	0.000
A8	0.005	0.006	0.007	0.009	0.010	0.011	0.013	0.014	0.015	0.017	0.018
A9	-0.072	-0.067	-0.062	-0.057	-0.052	-0.047	-0.043	-0.038	-0.033	-0.028	-0.023
A10	-0.038	-0.036	-0.034	-0.032	-0.030	-0.028	-0.026	-0.025	-0.023	-0.021	-0.019

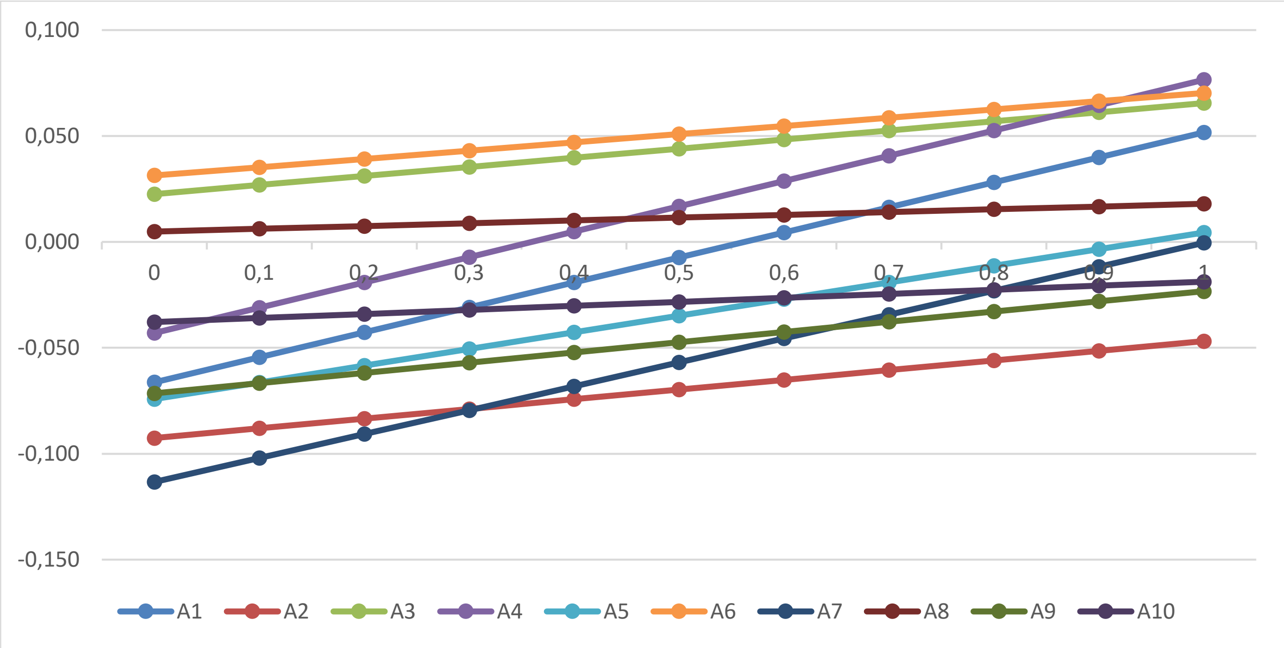

Figure 1: Ranking of alternatives via SF-WASPAS by considering changing λ values

The large number of project ideas collected at this stage should be selected appropriately, and limited resources and time should be managed effectively. In innovation management, many different MADM methods are used to enumerate project ideas and to choose the right one.

Although most of these methods are developed based on accurate measurement concepts, they may not give precise and clear results as performance measurement parameters. If all or some of the alternatives are uncertain, considering various factors such as uncertainties in innovative project ideas from different sources, incomplete or incommensurable information, different levels of knowledge and experience of decision-makers, differences in preference, and subjective judgments, then fuzzy MADM methods are required.

This study proposes a SFS-based MADM method for the selection of innovative project ideas within the scope of innovation management in the banking sector. In project selection, SF-AHP and SF-WASPAS methods are combined. SF-AHP method was used in determining the attribute weights, and SF-WASPAS was used in ranking the alternatives.

As a result of the applied MADM model, the expected benefit for the customers and R&D impact were determined as the most important ones. In addition, execution risk and ROI time were considered as the least important attributes. Then, SF-WASPAS found that that the most suitable project was the project specified in the 6th alternative.

Since innovation management is an area that is becoming increasingly important for every sector, similar studies can be carried out for different sectors as well as in the banking sector. The most important limitation is that we do not consider the potential relations among the attributes. Future studies can apply some network-based models such as DEMATEL and ANP. Last, without utilizing linguistic term sets, the experts can directly state their ideas with specifying membership degrees, and it will be a more realistic application of SFS-based MADM.

REFERENCES

[1] M. Oslo, "The measurement of scientific and technological activities. Proposed Guidelines for Collecting and Interpreting Technological Innovation Data. European Commission and Eurostat-Manual de Oslo-Diretrizes Para Coleta E İnterpretação De Dados Sobre İnovação. Traduzido pela FINEP.", 2006.

[2] B. Oralhan, M. A. Büyüktürk, "Avrupa Birliği Ülkeleri ve Türkiye'nin İnovasyon Performansının Çok Kriterli Karar Verme Yöntemleriyle Kıyaslanması", Avrupa Bilim ve Teknoloji Dergisi, vol.16, pp. 471-484, 2019.

[3] H. Chesbrough, "Open Innovation: The New Imperative for Creating and Profiting from Technology", Harvard Business School Press: Boston, MA, 2003.

[4] A. Westerski, C. A. Iglesias, T. Nagle, "The road from community ideas to organisational innovation: a life cycle survey of idea management systems." International Journal of Web-Based Communities. vol.7(4), pp. 493-506, 2011.

[5] F. M. Deng, "Guiding Principles on Internal Displacement," International Migration Review, vol.33(2): pp. 484-493, 1999.

[6] S. Hrastinski, C. Keller, S. A. Carlsson, "Design exemplars for synchronous e-learning: A design theory approach," Computers & Education, vol.55(2), pp. 652-662, 2010.

[7] P. M. Di Gangi, M. Wasko, "Open Innovation Through Online Communities," In Knowledge Management and Organizational Learning, Annals of Information Systems, Vol.4, W.R. King (ed) Springer Science+Business Media, Boston, 2009, pp. 199-213.

[8] E. Bothos, D. Apostolou, G. Mentzas, "IDEM: A prediction market for idea management," In Designing E-Business Systems. Markets, Services, and Networks. WEB 2008. Lecture Notes

in Business Information Processing, Vol 22., C. Weinhardt, S. Luckner, J. Stößer (eds) Springer, Berlin, Heidelberg, 2009, pp. 1-13.

[9] C. Gorski, E. Heinekamp, "Capturing employee ideas for new products," In The PDMA Toolbook 1 for New Product Development, P. Belliveau, A. Griffin, S. Somermeyer (eds) Wiley, 2002, pp. 219-242.

[10] J. Stromer-Galley, "Measuring Deliberation's Content: A Coding Scheme," Journal of Public Deliberation, vol.3(1), 2007.

[11] A. Spatariu, K. Hartley, L. D. Bendixen, "Defining and measuring quality in online discussions," Journal of Interactive Online Learning, vol.2(4), pp. 1-15, 2004.

[12] M. C. Nisbet, "The competition for worldviews: Values, information, and public support for stem cell research," International Journal of Public Opinion Research, vol.17(1), 90-112, 2005.

[13] E. D. Adamides, N. Karacapilidis, "Information technology support for the knowledge and social processes of innovation management," Technovation, vol.26(1), 50-59, 2006.

[14] C. M. Christensen, The Innovator's Dilemma: The Revolutionary Book that Will Change the Way You Do Business. New York, HarperBusiness Essentials, 2003.

[15] D. Sethi, S. E. Guisinger, S. E. Phelan, D. M. Berg, "Trends in foreign direct investment flows: A theoretical and empirical analysis," Journal of International Business Studies, vol.34(4), pp. 315-326, 2003.

[16] R. Bose, "Group support systems: technologies and products selection", Industrial Management & Data Systems, vol.103(9), pp. 649-56, 2003.

[17] S. Börjesson, F. Dahlsten, M. Williander, "Innovative scanning experiences from an idea generation project at Volvo Cars," Technovation, vol.26(7), 775-783, 2006.

[18] S. Bröring, L. M. Cloutier, J. Leker, "The front end of innovation in an era of industry convergence: evidence from nutraceuticals and functional foods," R&D Management, vol.36(5), pp. 487-498, 2006.

[19] F. Kutlu Gündoğdu, C. Kahraman, "Spherical fuzzy sets and spherical fuzzy TOPSIS method," Journal of Intelligent & Fuzzy Systems, vol.36(1), pp. 337-352, 2019.

[20] F. Kutlu Gündoğdu, "Principals of Spherical Fuzzy Sets," in Intelligent and Fuzzy Techniques in Big Data Analytics and Decision Making (INFUS'19), July 23-25, İstanbul, Turkey. Advances in Intelligent Systems and Computing, Vol.1029, C. Kahraman, S. Cebi, S. Cevik Onar, B. Oztaysi, A. Tolga, I. Sari (Eds), Springer, 2020, pp. 15-23.

[21] T. L. Saaty, The Analytic Hierarchy Process, Pittsburgh, USA: RWS Publications, (1980).

[22] T. L. Saaty, "How to make a decision: The analytic hierarchy process," European Journal of Operational Research, vol.48(1), pp. 9-26, 1990.

[23] F. Kutlu Gündoğdu, C. Kahraman, "A novel spherical fuzzy analytic hierarchy process and its renewable energy application," Soft Computing, vol.24, pp. 4607-4621, 2020.

[24] A. Camci, Ö. Çimen, S. Gül, "Selection of Contract Type in Construction Projects Using Spherical AHP Method," 4th International Conference on Intelligent Decision Science, 7th – 8th August, İstanbul, Turkey. Progress in Intelligent Decision Science – IDS2020, Advances in Intelligent Systems and Computing, Vol.1301, T. Allahviranloo, S. Salahshour, N. Arica (Eds) Springer, Cham, 2021, pp. 531-547.

[25] L. Abdullah, L. Najib, "Sustainable energy planning decision using the intuitionistic fuzzy analytic hierarchy process: choosing energy technology in Malaysia," International Journal of Sustainable Energy, vol.35, pp. 360-377, 2016.

[26] E. K. Zavadskas, Z. Turskis, J. Antucheviciene, A. Zakarevicius, "Optimization of Weighted Aggregated Sum Product Assessment," Elektronika Ir Elektrotechnika, vol.122(6), pp. 3-6, 2012.

[27] C. W. Churchman, R. L. Ackoff, "An Approximate Measure of Value," Journal of the Operations Research Society of America, vol.2(2), pp.107-226, 1954.

[28] E. Triantaphyllou, S. H. Mann, "An Examination of the Effectiveness of Multi-Dimensional Decision-Making Methods: A Decision-Making Paradox," Decision Support Systems, vol.5(3), pp. 303-312, 1989.

[29] F. Kutlu Gündoğdu, C. Kahraman, "Extension of WASPAS with Spherical Fuzzy Sets," Informatica, vol.30(2), pp.269-292, 2019.