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Antivirus Mask Selection Under Spherical Fuzzy Information

Serhat AYDIN*[1], Emrah KÖKSALMIŞ[1]

Abstract

Many individuals are facing antivirus mask scarcity with the exponential spread of COVID-19. A functional antivirus mask needs to be selected and made usable for everyone. Selection mask problem contains qualitative criteria, therefore utilizing fuzzy logic for this problem is a useful approach. To optimize the efficiency of choosing antivirus masks, we propose using one of the new types of ordinary fuzzy sets, named Spherical fuzzy sets. For this purpose, we determine 4 different alternatives and 6 criteria. Then, we gather the data under spherical information and applied the Spherical fuzzy AHP method to the problem. Then, we propose an entropy based Spherical fuzzy AHP method. We compare the results of Spherical fuzzy AHP method, and an entropy based Spherical fuzzy AHP method. Moreover, we present a sensitivity analysis to explain how our model is influenced by changes in different weights of criteria. Finally, the best antivirus mask is determined for public use and we present the advantages of the proposed method in results section.

Keywords: Mask selection, spherical fuzzy sets, spherical AHP, COVID-19

1. INTRODUCTION

The Coronavirus Disease 2019 (COVID-19) epidemic occurred in the city of Wuhan, Hubei province in December 2019. The World Health Organisation announced the coronavirus (COVID-19) a pandemic on March 11, 2020 [1]. The infection spread to 330,000 persons within 2 weeks, resulting in 13,700 deaths [2]. The common signs of COVID-19 infection can be summarized as follows: cough, symptoms of respiration, shortness of breath, and fever. In more serious cases, influenza, severe acute respiratory syndrome, renal failure and even death may result from infection [3].

Being well educated on the COVID-19 virus, the illness it causes, and how it progresses, is the safest way to deter and slow down transmission. By washing your hands or using an alcohol-free rub regularly and not rubbing your skin, shield yourself and others from infection. The COVID-19 infection spreads basically through beads of spit or release from the nose when a contaminated individual hacks or wheezes, so it is important to take preventive measures [4].

Under the COVID-19 outbreak, masks have become important items for work and travel for hospital stays and ordinary citizens. Also, the use of masks to avoid droplet dissemination is advised by the authorities [5-7], so wearing a mask is one of the most significant prevention steps.

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MacIntyre et al. [8] found that mask conformity greatly decreases the risk of infection with influenza. Brienen et al. found that the use of face masks across the population may play an important role in delaying an influenza pandemic [9]. The worldwide market for masks and other personal safety devices are now 150 times that of the average amount, and the price is too much that of regular times in this pandemic. Perhaps, this mask scarcity problem will be further compounded by people's inadequate and wasteful usage of personal protection equipment to make it persist for a long period. Therefore, the powerful basic step to cope with the mask scarcity and the COVID-19 dissemination is to customize the usage of antivirus masks according to diverse individuals.

It is everybody's basic duty and responsibility to resist the COVID-19 without unnecessary security, particularly in the situation of the COVID-19 spreading and a mask shortage. Therefore, the rational collection and use of masks have a vital functional meaning for various classes of individuals. Masks of the same quality as those used by front-line medical personnel are not required for most persons. When selecting a mask to maximize the distribution of medical services, several factors must be considered. However, the limited knowledge and ambiguity of the COVID-19 extension increase the difficulties and challenges of choosing a suitable antivirus mask for decision-making. Therefore, considering qualitative factors in choosing mask is essential.

There are many different methods to make a consistent decision. On the other hand, when it comes to evaluating quantitative factors, fuzzy logic, suggested by Zadeh [10], is a very useful mathematical means to consider the qualitative factors. Also, fuzzy logic is an effective theory for modeling uncertainty. This is a mathematical means of expressing complexity and confusion in matters of decision-making. The theory of fuzzy sets has been the basis for the development of the linguistic approach and its corresponding fuzzy logic. In this approach any variable is treated as a linguistic variable, i.e., it can assume linguistic values. A linguistic value is composed of its syntactic value or label, a sentence belonging to a term set, and its semantic value, the membership distribution of a fuzzy set defined on a universe of discourse. Fuzzy logic is a logic whose truth-values are linguistic [11]. More information about linguistic fuzzy sets can be seen with the related references such as [12- 17].

Fuzzy logic theory has also been used as a logical tool in many MCDM methods. Fuzzy sets are a grouping of objects with a membership rating continuum. Each fuzzy set is aligned with a membership function, which assigns each object a membership score. The membership grades are normally set at [0,1]. FSs define the membership value $\mu_{(x)}$ and $0 \leq \mu_{(x)} \leq 1$. In the last 50 years, new types of fuzzy sets have been introduced to define the uncertainty more accurately. Therefore, a few extensions of fuzzy sets have been developed such as Intuitionistic fuzzy sets (IFSs) [18] Pythagorean fuzzy sets (PFSs) [19] q-rung orthopair fuzzy sets (q-ROFs) [20].

Spherical fuzzy sets (SFSs) are suggested by Kutlu Gündoğdu and Kahraman [21]. SFSs are based on the spherical fuzzy distances and satisfy the condition as follows $0 \leq {\mu_{(x)}}^2 + {v_{(x)}}^2 + {\pi_{(x)}}^2 \leq 1$. The hesitancy degree is represented by $\pi_{(x)}$ and hesitancy degree can be determined in the spherical representation based on the given membership and non-membership values. So, a decision maker's hesitancy may be specified independently of membership degrees and non-membership degrees.

Multi criteria decision making (MCDM) is a collection of strategies that form a decision science sub-branch and combine numerous approaches. The approach of modeling and assessing the decision process according to the criteria in such a way that the expert's benefit is maximized after the process is based on MCDM. Many researchers developed different MCDM methods as follows: AHP [22], ANP [23], TOPSIS [24], ELECTRE [25], etc.

Analytic Hierarchy Process (AHP) is a systematic method that can easily solve the problems that contain several alternatives and several criteria. It is based on the creation and identification of the priority vector of the synthesized pairwise comparison matrix. AHP uses integer numbers to calculate the importance of alternatives, but real-world challenges require considerable vagueness and ambiguity, also require the use of fuzzy numbers. AHP and fuzzy logic have since been merged and transformed into an interactive paradigm called fuzzy AHP.

In the literature there some studies about the COVID-19 mask using and selection problem as follows: Yang et al. [26] proposed a decision support algorithm for selecting an antivirus mask over the COVID-19 with fuzzy sets. They evaluated 6 different alternatives according to the 4 different criteria. They proposed some aggregation spherical fuzzy operators to handle the problem. Shahzadi and Akram [27] developed an MCDM method to assess an antivirus mask with Fermatean fuzzy sets. Moreover, they developed some aggregation operators and gave some properties of proposed operators. Wang et al. [28] realized a laboratory study to Selection of homemade mask materials for preventing transmission of the COVID -19. They demonstrated that the risk of contamination can be reduced to the fullest degree by homemade masks using available materials. Lam et al. [29] suggested some precautions and replied frequently asked questions on mask selection problem. Fen et al. [30] discussed about the rational use of face masks in the COVID-19 pandemic. They compared the recommendations for using a mask by different health authorities. Zheng et al. [31] suggested some recommendations to overcome the pandemic. They discussed many issues in their paper such as Medical masks selection, hand-hygiene items, gloves, etc. They collected and summarized the expertise obtained from delivering pharmacy services during the COVID-19 epidemic in Chinese community pharmacies. Bartoszko et al. [32] compared the different types of masks for healthcare workers. They conducted an observational study and concluded that medical masks and N95 respirators provide similar protection against the pandemic. There are few studies on the COVID-19 mask selection problem, most of the research use empirical data to solve the mask selection problem. Therefore, there is a gap in the literature to use an MCDM method to evaluate the mask used during the COVID-19 pandemic.

In this study, we used a hybrid model including SFSs and AHP method. The method, named Spherical Fuzzy AHP, is utilized to solve the mask selection decision making problem. The criteria are determined to evaluate the mask selection problem, and steps of the algorithm are applied to the problem. Moreover, we present an entropy based Spherical fuzzy AHP method, and we implement the proposed method to the mask selection problem. Also, a sensitivity analysis is applied. In application section, the proposed method is applied to an important subject: COVID 19 mask selection problem. The World Health Organization (WHO) advises the use of masks as part of a comprehensive package of prevention and control measures to limit the spread of SARS-CoV-2, the virus that causes COVID-19. Therefore, using a suitable mask is important to prevent the spread of virus. The proposed method is utilized to select the best mask during pandemic for this aim. The originality of the paper is that it proposes a hybrid method including the entropy theory and spherical fuzzy AHP method to solve the mask selection problem for the first time in the literature.

The remainder of the paper's composition is as follows: The preliminaries of SFSs and the steps of the Spherical fuzzy AHP method are introduced in Section 2. An example is given with Spherical fuzzy AHP method in Section 3. Section 4 clarifies the proposed method and clarifies the calculation steps of the proposed method to the mask selection problem. A sensitivity analysis is performed in Section 5. Finally, the conclusion is given in Section 6.

2. MATERIAL AND METHOD

First, we represent the preliminaries of spherical fuzzy sets in this section. Then, we discuss the spherical AHP method.

2.1. Preliminaries of Spherical Fuzzy Sets

Definition 1: A spherical fuzzy set $\tilde{A}_S$ of the universe of discourse U is given by

$$\tilde{A}_S = \{\langle u, (\mu_{\tilde{A}_S}(u), \nu_{\tilde{A}_S}(u), \pi_{\tilde{A}_S}(u)) | u \in U\} \quad (1)$$

Where,

$\mu_{\tilde{A}_S}: U \to [0,1], \nu_{\tilde{A}_S}(u): U \to [0,1], \pi_{\tilde{A}_S}: U \to [0,1]$

and

$$0 \le \mu_{\tilde{A}_S}^2(u) + \nu_{\tilde{A}_S}^2(u) + \pi_{\tilde{A}_S}^2(u) \le 1 \forall u \in U \quad (2)$$

For each u, the numbers $\mu_{\tilde{A}_S}(u), \nu_{\tilde{A}_S}(u)$ and $\pi_{\tilde{A}_S}(u)$ are the degree of membership, non-membership and hesitancy of $u$to $\tilde{A}_S$, respectively.

Definition 2: Basic Operators

$$\tilde{A}_S \cup \tilde{B}_S = \Big\{max\{\mu_{\tilde{A}_S}, \mu_{\tilde{B}_S}\}, min\{\nu_{\tilde{A}_S}, \nu_{\tilde{B}_S}\}, min\Big\{\Big(1 - \Big(\big(max\{\mu_{\tilde{A}_S}, \mu_{\tilde{B}_S}\}\big)^2 + \big(min\{\nu_{\tilde{A}_S}, \nu_{\tilde{B}_S}\}\big)^2\Big)\Big)^{1/2}, max\{\pi_{\tilde{A}_S}, \pi_{\tilde{B}_S}\}\Big\}\Big\} \quad (3)$$

$$\tilde{A}_S \cap \tilde{B}_S = \Big\{min\{\mu_{\tilde{A}_S}, \mu_{\tilde{B}_S}\}, max\{\nu_{\tilde{A}_S}, \nu_{\tilde{B}_S}\}, max\Big\{\Big(1 - \Big(\big(min\{\mu_{\tilde{A}_S}, \mu_{\tilde{B}_S}\}\big)^2 + \big(max\{\nu_{\tilde{A}_S}, \nu_{\tilde{B}_S}\}\big)^2\Big)\Big)^{1/2}, min\{\pi_{\tilde{A}_S}, \pi_{\tilde{B}_S}\}\Big\}\Big\} \quad (4)$$

$$\tilde{A}_S \oplus \tilde{B}_S = \Big\{\big(\mu_{\tilde{A}_S}^2 + \mu_{\tilde{B}_S}^2 - \mu_{\tilde{A}_S}^2\mu_{\tilde{B}_S}^2\big)^{1/2}, \nu_{\tilde{A}_S}\nu_{\tilde{B}_S}, \Big(\big(1 - \mu_{\tilde{B}_S}^2\big)\pi_{\tilde{A}_S}^2 + \big(1 - \mu_{\tilde{A}_S}^2\big)\pi_{\tilde{B}_S}^2 - \pi_{\tilde{A}_S}^2\pi_{\tilde{B}_S}^2\Big)^{1/2}\Big\} \quad (5)$$

$$\tilde{A}_S \otimes \tilde{B}_S = \Big\{\mu_{\tilde{A}_S}\mu_{\tilde{B}_S}, \big(\nu_{\tilde{A}_S}^2 + \nu_{\tilde{B}_S}^2 - \nu_{\tilde{A}_S}^2\nu_{\tilde{B}_S}^2\big)^{1/2}, \Big(\big(1 - \nu_{\tilde{B}_S}^2\big)\pi_{\tilde{A}_S}^2 + \big(1 - \nu_{\tilde{A}_S}^2\big)\pi_{\tilde{B}_S}^2 - \pi_{\tilde{A}_S}^2\pi_{\tilde{B}_S}^2\Big)^{1/2}\Big\} \quad (6)$$

$$\lambda \cdot \tilde{A}_S = \Big\{\Big(1 - \big(1 - \mu_{\tilde{A}_S}^2\big)^{\lambda}\Big)^{1/2}, \nu_{\tilde{A}_S}^{\lambda}, \Big(\big(1 - \mu_{\tilde{A}_S}^2\big)^{\lambda} - \big(1 - \mu_{\tilde{A}_S}^2 - \pi_{\tilde{A}_S}^2\big)^{\lambda}\Big)^{1/2}\Big\} \quad (7)$$

$$\tilde{A}_S^{\lambda} = \Big\{\mu_{\tilde{A}_S}^{\lambda}, \Big(1 - \big(1 - \nu_{\tilde{A}_S}^2\big)^{\lambda}\Big)^{1/2}, \Big(\big(1 - \nu_{\tilde{A}_S}^2\big)^{\lambda} - \big(1 - \nu_{\tilde{A}_S}^2 - \pi_{\tilde{A}_S}^2\big)^{\lambda}\Big)^{1/2}\Big\} \lambda > 0 \quad (8)$$

Definition 3: For these SFS $\tilde{A}_S = (\mu_{\tilde{A}_S}, \nu_{\tilde{A}_S}, \pi_{\tilde{A}_S})$ and$\tilde{B}_S = (\mu_{\tilde{B}_S}, \nu_{\tilde{B}_S}, \pi_{\tilde{B}_S})$, the followings are valid under the condition$\lambda, \lambda_1, \lambda_2 > 0$.

$$\tilde{A}_S \oplus \tilde{B}_S = \tilde{B}_S \oplus \tilde{A}_S \quad (9)$$

$$\tilde{A}_S \otimes \tilde{B}_S = \tilde{B}_S \otimes \tilde{A}_S \quad (10)$$

$$\lambda(\tilde{A}_S \oplus \tilde{B}_S) = \lambda\tilde{A}_S \oplus \lambda\tilde{B}_S \quad (11)$$

$$\lambda_1\tilde{A}_S \oplus \lambda_2\tilde{A}_S = (\lambda_1 + \lambda_2)\tilde{A}_S \quad (12)$$

$$(\tilde{A}_S \otimes \tilde{B}_S)^{\lambda} = \tilde{A}_S^{\lambda} \otimes \tilde{B}_S^{\lambda} \quad (13)$$

$$\tilde{A}_S^{\lambda_1} \otimes \tilde{A}_S^{\lambda_2} = \tilde{A}_S^{\lambda_1 + \lambda_2} \quad (14)$$

Definition 4: Spherical Weighted Arithmetic Mean (SWAM) with respect to $w = (w_1, w_2 \ldots\ldots, w_n); w_i \in [0,1]; \sum_{i=1}^{n} w_i = 1$, SWAM is defined as;

$$SWAM_w(A_{S1}, \ldots\ldots, A_{Sn}) = w_1A_{S1} + w_2A_{S2} + \ldots\ldots + w_nA_{Sn}$$

$$= \Big\{\Big[1 - \textstyle\prod_{i=1}^{n}(1 - \mu_{A_{S_i}}^2)^{w_i}\Big]^{1/2}, \prod_{i=1}^{n} \nu_{A_{S_i}}^{w_i}, \Big[\prod_{i=1}^{n}(1 - \mu_{A_{S_i}}^2)^{w_i} - \prod_{i=1}^{n}(1 - \mu_{A_{S_i}}^2 - \pi_{A_{Si}}^2)^{w_i}\Big]^{1/2}\Big\} \quad (15)$$

Definition 5: Spherical Weighted Geometric Mean (SWGM) with respect to $w = (w_1, w_2 \ldots\ldots, w_n); w_i \in [0,1]; \sum_{i=1}^{n} w_i = 1$, SWGM is defined as;

$$SWGM_w(A_1, \ldots\ldots, A_n) = A_{S1}^{w_1} + A_{S2}^{w_2} + \ldots\ldots + A_{Sn}^{w_n}$$

$$= \Big\{\textstyle\prod_{i=1}^{n} \mu_{A_{Si}}^{w_i}, \big[1 - \prod_{i=1}^{n}(1 - \nu_{A_{Si}}^2)^{w_i}\big]^{1/2}, \big[\prod_{i=1}^{n}(1 - \nu_{A_{Si}}^2)^{w_i} - \prod_{i=1}^{n}(1 - \nu_{A_{Si}}^2 - \pi_{A_{Si}}^2)^{w_i}\big]^{1/2}\Big\} (16)$$

2.2. Spherical Fuzzy AHP

This section covers the steps of the Spherical fuzzy AHP method. Figure 1 represents the steps of the method.

Step 1. Build the hierarchical structure

Step 1 includes establishing a hierarchical structure. The hierarchical structure includes at least 3 levels; aim, which is at the top, attributes identified in the middle and alternatives at the bottom.

Step 2. Establish pairwise comparisons using spherical fuzzy judgment matrices. Table 1 represents the linguistic terms with spherical numbers. After establishing the pairwise comparisons matrices, matrices need to be checked for consistency. For this purpose, linguistic terms are converted to their corresponding score indices, as seen in Table 1. After constructing pairwise comparison matrices, consistency formula, developed by Saaty [22], is applied.

Step 3. Compute the criteria and alternatives' local weights including spherical information.

In this step, Equation (17) is utilized to get local weight of each alternative.

$$SWAM_w(A_{S1},\ldots\ldots,A_{Sn}) = w_1A_{S1} + w_2A_{S2} + \ldots\ldots + w_nA_{Sn} =$$

$$\left\langle [1-\prod_{i=1}^{n}(1-\mu_{A_{S_i}}^2)^{w_i}]^{1/2}, \prod_{i=1}^{n} v_{A_{S_i}}^{w_i}, [\prod_{i=1}^{n}(1-\mu_{A_{S_i}}^2)^{w_i} - \prod_{i=1}^{n}(1-\mu_{A_{S_i}}^2-\pi_{A_{Si}}^2)^{w_i}]^{1/2} \right\rangle \quad (17)$$

where $w = 1/n$.

Step 4. Calculate the spherical global weights.

In this step, Equation (18) is utilized to get Spherical fuzzy global weights.

$$\prod_{j=1}^{n} \tilde{A}_{S_{ij}} = \tilde{A}_{S_{i1}} \otimes \tilde{A}_{S_{i2}} \ldots \otimes \tilde{A}_{S_{in}} \ \forall i$$

$$i.e.\, \tilde{A}_{S_{11}} \otimes \tilde{A}_{S_{12}} = \left\langle \mu_{\tilde{A}_{S_{11}}}\mu_{\tilde{A}_{S_{12}}}, \left(v_{\tilde{A}_{S_{11}}}^2 + v_{\tilde{A}_{S_{12}}}^2 - v_{\tilde{A}_{S_{11}}}^2 v_{\tilde{A}_{S_{12}}}^2\right)^{1/2}, \left(\left(1-v_{\tilde{A}_{S_{12}}}^2\right)\pi_{\tilde{A}_{S_{11}}}^2 + \left(1-v_{\tilde{A}_{S_{11}}}^2\right)\pi_{\tilde{A}_{S_{12}}}^2 - \pi_{\tilde{A}_{S_{11}}}^2\pi_{\tilde{A}_{S_{12}}}^2\right)^{1/2} \right\rangle \quad (18)$$

Then, the final score of each alternative is determined via Equation (19).

$$\tilde{F} = \sum_{j=1}^{n} \tilde{A}_{S_{ij}} = \tilde{A}_{S_{i1}} \oplus \tilde{A}_{S_{i2}} \ldots \oplus \tilde{A}_{S_{in}} \forall i$$

$$i.e.\, \tilde{A}_{S_{11}} \oplus \tilde{A}_{S_{12}} = \left\langle \left(\mu_{\tilde{A}_{S_{11}}}^2 + \mu_{\tilde{A}_{S_{12}}}^2 - \mu_{\tilde{A}_{S_{11}}}^2\mu_{\tilde{A}_{S_{12}}}^2\right)^{1/2}, v_{\tilde{A}_{S_{11}}}v_{\tilde{A}_{S_{12}}}, \left(\left(1-\mu_{\tilde{A}_{S_{12}}}^2\right)\pi_{\tilde{A}_{S_{11}}}^2 + \left(1-\mu_{\tilde{A}_{S_{11}}}^2\right)\pi_{\tilde{A}_{S_{12}}}^2 - \pi_{\tilde{A}_{S_{11}}}^2\pi_{\tilde{A}_{S_{12}}}^2\right)^{1/2} \right\rangle \quad (19)$$

Table 1 Linguistic Scale

Linguistic Expression	$(\boldsymbol{\mu}, \boldsymbol{v}, \boldsymbol{\pi})$	**Score Index (SI)**
Extremely preferred (ExP)	(0.9,0.1,0.0)	9
Very strongly preferred (VSP)	(0.8,0.2,0.1)	7
Strongly preferred (SP)	(0.7,0.3,0.2)	5
Moderately preferred (MP)	(0.6,0.4,0.3)	3
Equally preferred (EP)	(0.5,0.4,0.4)	1
Moderately low preferred (MLP)	(0.4,0.6,0.3)	1/3
Low preferred (LP)	(0.3,0.7,0.2)	1/5
Very low preferred (VLP)	(0.2,0.8,0.1)	1/7
Extremely low preferred (ELP)	(0.1,0.9,0.0)	1/9

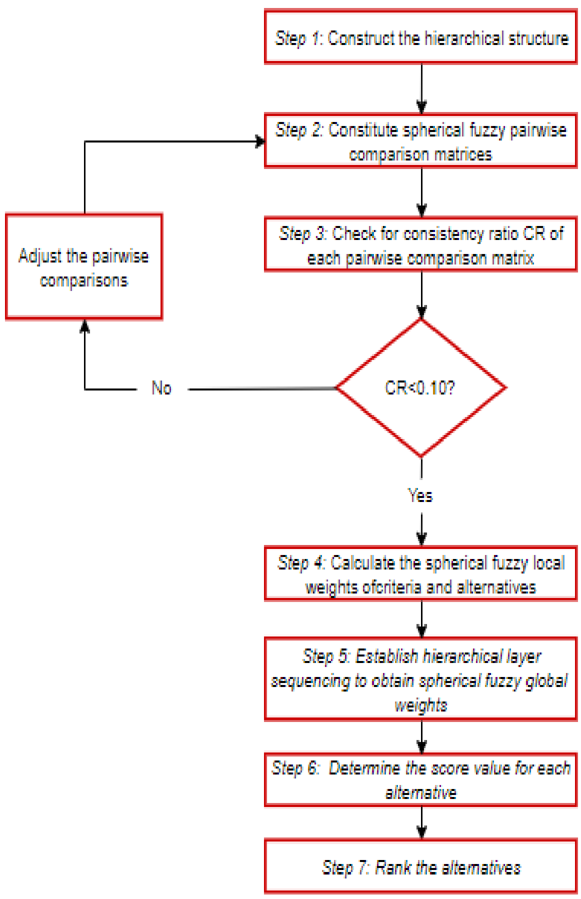

Figure 1 The steps of the Spherical fuzzy AHP [33]

Step 5. The final score of each alternative is defuzzified by using the score function by Equation (20).

$$S(\tilde{w}_j^s) = \sqrt{\left|100 * \left[\left(3\mu_{\tilde{A}_s} - \frac{\pi_{\tilde{A}_s}}{2}\right)^2 - \left(\pi_{\tilde{A}_s} - \frac{v_{\tilde{A}_s}}{2}\right)^2\right]\right|} \quad (20)$$

Step 6. At the last step, the alternatives are ordered according to their defuzzified final scores in descending order.

3. THE RESEARCH FINDINGS AND DISCUSSION

In this part of the paper, the mask selection problem is handled by spherical AHP method. As the determined criteria contains both tangible and intangible data, we use Spherical data in mask selection problem. Moreover, the mask selection problem is handled with hierarchical structure. Therefore, using Spherical AHP method is useful to overcome the mask selection problem.

First, the masks are determined for public consumption. The determined four different alternatives are as follows; A_1: N95 mask, A_2: Cloth mask, A_3: FFP1 mask, A_4: Surgical mask. After a literature review, six criteria have been determined. Criteria are Fluid Resistance (C_1), Breathability (C_2), Reusability (C_3), and Ergonomic design (C_4), Bacterial filtration (C_5), Particulate filtration (C_6). Pairwise comparison matrices are fulfilled by us after gathering data from different mask users' experience.

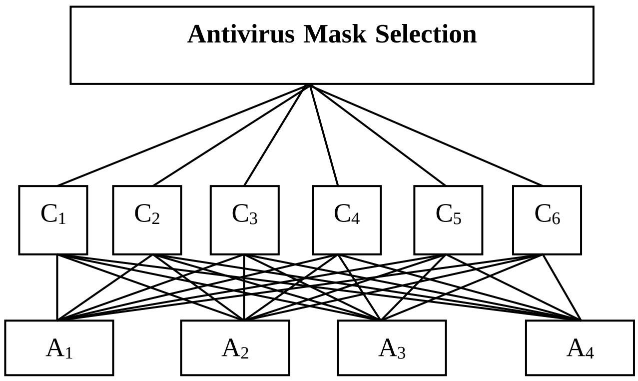

Figure 2 The hierarchical structure

Step 1. The hierarchical structure is established as seen in Figure 2.

Step 2. Pairwise comparisons are established as seen in Tables 2-8. Tables 2-8 also includes spherical weights ($\tilde{w}^s$) and crisp weights ($\bar{w}^s$), and consistency ratios (CR).

Table 2 Pairwise comparison of criteria

Criteria	**C_1**	**C_2**	**C_3**
C_1	EP	MP	VSP
C_2	MLP	EP	MP
C_3	VLP	MLP	EP
C_4	MLP	EI	VSP
C_5	EP	MP	VSP
C_6	MLP	MP	SP
Criteria	**C_4**	**C_5**	**C_6**
C_1	MP	EP	MP
C_2	EP	MLP	MLP
C_3	VLP	VLP	LP
C_4	EP	MLP	MLP
C_5	MP	EP	MP
C_6	MP	MLP	EP
	$\tilde{w}^s$	$\bar{w}^s$	**CR**
C_1	(0.36, 0.72, 0.26)	0.207	0.055
C_2	(0.27, 0.79, 0.25)	0.147	
C_3	(0.18, 0.87, 0.17)	0.080	
C_4	(0.32, 0.76, 0.24)	0.182	
C_5	(0.35, 0.71, 0.28)	0.204	
C_6	(0.31, 0.76, 0.25)	0.179	

Table 3 Pairwise comparison of alternatives according to C_1

C_1	**A_1**	**A_2**	**A_3**	**A_4**
A_1	EP	VSP	SP	SP
A_2	VLP	EP	MLP	MLP
A_3	LP	MP	EP	LP
A_4	LP	MP	SP	EP
	$\tilde{w}^s$		$\bar{w}^s$	**CR**
A_1	(0.70, 0.29, 0.22)		0.345	0.027
A_2	(0.39, 0.58, 0.30)		0.180	
A_3	(0.45, 0.53, 0.30)		0.212	
A_4	(0.59, 0.40, 0.26)		0.288	

Table 4 Pairwise comparison of alternatives according to C_2

C_2	**A_1**	**A_2**	**A_3**	**A_4**
A_1	EP	MP	ExP	VSP
A_2	MLP	EP	MP	SP
A_3	ELP	MLP	EP	MLP
A_4	VLP	LP	MP	EP
	$\tilde{w}^s$		$\bar{w}^s$	**CR**
A_1	(0.76, 0.24, 0.206)		0.379	0.096
A_2	(0.57, 0.41, 0.30)		0.273	
A_3	(0.39, 0.60, 0.31)		0.176	
A_4	(0.44, 0.55, 0.29)		0.206	

Table 5 Pairwise comparison of alternatives according to C_3

C_3	**A_1**	**A_2**	**A_3**	**A_4**
A_1	EP	MP	LP	MLP
A_2	MLP	EP	VLP	LP
A_3	SP	VSP	EP	MP
A_4	MP	SP	MLP	EP
	$\tilde{w}^s$		$\bar{w}^s$	**CR**
A_1	(0.47, 0.51, 0.31)		0.219	0.043
A_2	(0.37, 0.61, 0.28)		0.170	
A_3	(0.67, 0.31, 0.25)		0.331	
A_4	(0.57, 0.41, 0.30)		0.273	

Table 6 Pairwise comparison of alternatives according to C_4

C_4	**A_1**	**A_2**	**A_3**	**A_4**
A_1	EP	SP	VSP	MP
A_2	LP	EP	MP	LP
A_3	VLP	MLP	EP	LP
A_4	MLP	SP	SP	EP
	$\tilde{w}^s$		$\bar{w}^s$	**CR**
A_1	(0.67, 0.31, 0.25)		0.331	0.086
A_2	(0.45, 0.53, 0.30)		0.212	
A_3	(0.37, 0.61, 0.28)		0.170	
A_4	(0.60, 0.38, 0.27)		0.292	

Table 7 Pairwise comparison of alternatives according to C_5

C_5	**A_1**	**A_2**	**A_3**	**A_4**
A_1	EP	SP	VSP	SP
A_2	LP	EP	MLP	MLP
A_3	VLP	MP	EP	EP
A_4	VLP	MP	EP	EP
	$\tilde{w}^s$		$\bar{w}^s$	**CR**
A_1	(0.70, 0.29, 0.23)		0.345	0.081
A_2	(0.41, 0.56, 0.31)		0.187	
A_3	(0.48, 0.48, 0.33)		0.223	
A_4	(0.49, 0.46, 0.34)		0.228	

Table 8 Pairwise comparison of alternatives according to C_6

C_6	**A_1**	**A_2**	**A_3**	**A_4**
A_1	EP	EP	SP	MP
A_2	EP	EP	MLP	MLP
A_3	VLI	SMI	EP	MLP
A_4	MLP	MP	MP	EP
	$\tilde{w}^s$		$\bar{w}^s$	**CR**
A_1	(0.59, 0.37, 0.32)		0.279	0.047
A_2	(0.45, 0.49, 0.35)		0.206	
A_3	(0.47, 0.51, 0.31)		0.219	
A_4	(0.54, 0.44, 0.32)		0.252	

Step 3. Spherical fuzzy local weights of alternatives are calculated as seen Table 9.

Table 9 Spherical fuzzy weighted matrix

Alternatives	**C_1**	**C_2**
A_1	(0.25, 0.75, 0.29)	(0.20, 0.80, 0.27)
A_2	(0.14, 0.83, 0.29)	(0.15, 0.83, 0.29)
A_3	(0.16, 0.81, 0.30)	(0.10, 0.87, 0.27)
A_4	(0.21, 0.77, 0.30)	(0.12, 0.86, 0.27)
	C_3	**C_4**
A_1	(0.08, 0.91, 0.21)	(0.21, 0.79, 0.28)
A_2	(0.07, 0.92, 0.19)	(0.14, 0.83, 0.27)
A_3	(0.12, 0.89, 0.20)	(0.12, 0.86, 0.26)
A_4	(0.10, 0.90, 0.21)	(0.19, 0.80, 0.28)
	C_5	**C_6**
A_1	(0.25, 0.74, 0.31)	(0.18, 0.80, 0.31)
A_2	(0.14, 0.81, 0.31)	(0.14, 0.82, 0.31)
A_3	(0.17, 0.79, 0.33)	(0.15, 0.83, 0.29)
A_4	(0.17, 0.78, 0.33)	(0.17, 0.81, 0.30)

Step 4 and Step 5. Spherical fuzzy global preference weights and defuzzified values of final scores of each alternative can be seen in Table 10.

Table 10 Defuzzified final score values and ranking of alternatives

	Total	**Total**	**Ranking**
A_1	(0.48, 0.25, 0.72)	7.379	1
A_2	(0.32, 0.35, 0.47)	3.965	3
A_3	(0.33, 0.35, 0.47)	4.159	4
A_4	(0.39, 0.30, 0.46)	5.498	2

Step 6. Alternatives are ranked in descending order according to the defuzzified final scores

Alternative 1 > Alternative 4 > Alternative 3 > Alternative 2

Alternative 1 is chosen the best according to the ranking scores.

4. ENTROPY BASED SPHERICAL FUZZY AHP

In this section of the paper, we insert the entropy theory into the Spherical fuzzy AHP method. In decision-making problems, entropy theory is used to determine how much useful information the existing data have. We used a combination of fuzzy logic and entropy theory to determine the value of information in a spherical fuzzy environment in this article. We propose to use entropy theory to find criteria weight. Therefore, we proposed the entropy formula and weighting formula.

$$E(A_i) = \frac{1}{n}\sum_{i=1}^{n} \frac{\pi_{\tilde{A}_S}^2(u_i)+1-\left|\mu_{\tilde{A}_S}^2(u_i)-v_{\tilde{A}_S}^2(u_i)\right|}{\pi_{\tilde{A}_S}^2(u_i)+1+\left|\mu_{\tilde{A}_S}^2(u_i)-v_{\tilde{A}_S}^2(u_i)\right|}, \forall_i \quad (21)$$

$$d_i = 1 - E(A_i), \forall_i \quad (22)$$

$$w_i = \frac{d_i}{\sum_{i=1}^{n} d_i}, \forall_i \quad (23)$$

The suggested spherical AHP's steps are as follows.

Step 1 and Step 2. The computation algorithm of these steps is similar with Spherical fuzzy AHP.

Step 3 The criteria's weights are determined using Eq. (23). Alternatives' local weights are computed by using Eq. (17).

Step 4. The spherical global weights are computed by using Eq. (24).

$$\tilde{A}_{S_{ij}} = \bar{w}_j \cdot \tilde{A}_{S_i} = \left\langle \left(1-\left(1-\mu_{\tilde{A}_S}^2\right)^{\bar{w}_j}\right)^{1/2}, v_{\tilde{A}_S}^{\bar{w}_j}, \left(\left(1-\mu_{\tilde{A}_S}^2\right)^{\bar{w}_j} - \left(1-\mu_{\tilde{A}_S}^2-\pi_{\tilde{A}_S}^2\right)^{\bar{w}_j}\right)^{1/2} \right\rangle \forall i \quad (24)$$

Step 5. The final spherical fuzzy AHP scores are obtained by carrying out the spherical fuzzy arithmetic addition by using Eq. (19).

Step 6 and Step 7. The computation algorithm of these steps is similar with Spherical fuzzy AHP.

The calculation steps of the proposed method are clarified as follows.

Step 1 and Step 2. The hierarchical structure is established as seen in Figure 2 and the pairwise comparisons are established as seen in Tables 2-8.

Step 3. The weights of the criteria are computed by using Eq. (23) below. Table 11 represent the Spherical fuzzy weighted matrix of alternatives.

$w_{C1} = 0.129$ $w_{C2} = 0.118$ $w_{C3} = 0.300$
$w_{C4} = 0.154$ $w_{C5} = 0.144$ $w_{C6} = 0.152$

Table 11 Spherical fuzzy weighted matrix

Alternatives	C_1	C_2
A_1	(0.29, 0.85, 0.11)	(0.31, 0.84, 0.11)
A_2	(0.15, 0.93, 0.12)	(0.21, 0.90, 0.13)
A_3	(0.17, 0.92, 0.12)	(0.14, 0.94, 0.12)
A_4	(0.23, 0.89, 0.12)	(0.16, 0.93, 0.11)
	C_3	C_4
A_1	(0.27, 0.82, 0.19)	(0.30, 0.84, 0.13)
A_2	(0.21, 0.86, 0.17)	(0.19, 0.91, 0.13)
A_3	(0.41, 0.71, 0.18)	(0.15, 0.93, 0.12)
A_4	(0.33, 0.77, 0.20)	(0.26, 0.86, 0.14)
	C5	C6
A_1	(0.30, 0.84, 0.12)	(0.25, 0.86, 0.16)
A_2	(0.16, 0.92, 0.13)	(0.19, 0.90, 0.16)
A_3	(0.19, 0.90, 0.15)	(0.19, 0.90, 0.14)
A_4	(0.20, 0.89, 0.15)	(0.22, 0.88, 0.15)

Step 4 and Step 5. Spherical fuzzy global preference weights and defuzzified values of final scores of each alternative can be seen in Table 12.

Table 12 Defuzzified final score values and ranking of alternatives

	Total	Total	Ranking
A_1	(0.64, 0.49, 0.14)	11.213	1
A_2	(0.44, 0.65, 0.22)	5.317	4
A_3	(0.53, 0.57, 0.21)	8.363	3
A_4	(0.55, 0.55, 0.20)	8.954	2

Step 6. Alternatives are ranked in descending order according to the defuzzified final scores

Alternative 1 > Alternative 4 > Alternative 3 > Alternative 2

Alternative 1 is chosen the best according to the ranking scores. As seen in step 6, the ranking of Alternative 3 and Alternative 2 is different in Spherical fuzzy AHP and an entropy based spherical Fuzzy AHP method. We discuss the reason of this situation in Section 6.

5. SENSITIVITY ANALYSIS

We applied sensitivity analysis in this section to illustrate how our model is susceptible to changes in criteria weights. We assign different weights to the criteria and observe the changes in ranking results of alternatives. The various crisp weights of parameters as seen in Table 13 and Figure 3 illustrates the results of the sensitivity analysis.

Table 13 Cases with different criteria weights

Cases	Criteria weights
Case 1	(0.40, 0.15, 0.15, 0.10, 0.10, 0.10)
Case 2	(0.10, 0.40, 0.10, 0.15, 0.10, 0.15)
Case 3	(0.10, 0.10, 0.50, 0.15, 0.05, 0.10)
Case 4	(0.05, 0.05, 0.30, 0.40, 0.10, 0.10)
Case 5	(0.10, 0.10, 0.60, 0.05, 0.05, 0.10)
Case 6	(0.10, 0.05, 0.35, 0.30, 0.10, 0.10)

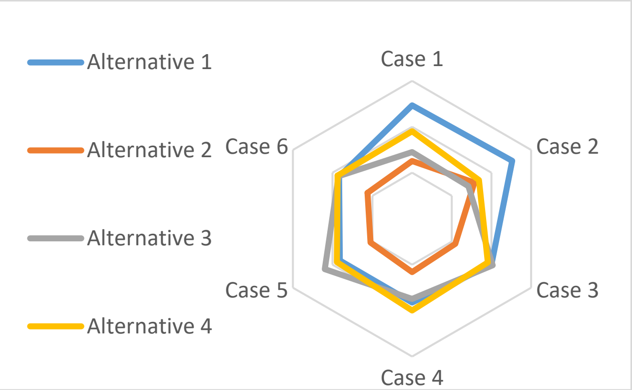

Figure 3 Sensitivity analysis

We get different outcomes for different situations in the sensitivity study. For example, in Case 3, if the third parameter is given the maximum weight, Alternative 3 is ranked first among alternatives, while it is ranked third in Case 1. In Case 4, if the fourth parameter is given the maximum weight, Alternative 4 is ranked first among alternatives, while it is ranked second in Case 1. As seen sensitivity analysis, third and fourth criteria have big impact on ranking alternatives. When we assign large weights to them, Alternative 3 and Alternative 4 can get the first rank. We can infer that the model is susceptible to changes based on the findings of the sensitivity analysis.

6. RESULTS

The COVID-19 is much more contagious, despite sharing common properties with other deadly coronaviruses, and has been the greatest threat to healthcare systems in many nations, including the developed ones with the most modern healthcare facilities. Infection prevention is the key to reducing the harm done by the COVID-19 before vaccines and/or specific medications are available [29]. This can be achieved by isolation, supportive treatment, and self-protection. In this manner, using anti-virus masks plays a major role in protecting against the COVID-19.

The sector in which the person using the mask works is important for the mask selection. Moreover, the mask selection problem not only contains quantitative factors and but also contains qualitative factors. In this paper, we deal with the mask selection problem with qualitative factors. To do this aim, we determined 4 different alternatives and 6 conflicting criteria. We gathered the data under spherical information; therefore, we implemented the Spherical fuzzy AHP method to the problem. Finally, alternatives are ranked according to their final scores and the N95 masks get the first rank according to the criteria. Surgical masks get the second rank, FFP1 masks get the third rank and Cloth masks get the fourth rank.

In this paper, we also proposed an entropy based Spherical fuzzy AHP method to overcome the mask selection problem. First, we utilized entropy theory to get the criteria weights. Then we calculate the final scores of alternatives and rank them. We observe that the proposed method gives same ranking results with Spherical AHP method. However, the proposed method gives more sensitive results by comparison the Spherical AHP method. The reason of this, the entropy theory calculates how much valuable knowledge the current data provide. Therefore, the proposed model more sensitive than the Spherical fuzzy AHP method.

Ultimately, we can summarize the practical benefits of the proposed method as follows i) if the data is gathered under spherical environment ii) if the demonstration of the problem can be structured as a hierarchy iii) if the decision maker needs to calculate the how much valuable knowledge the current data provide, then using the proposed method gives effective and efficient results.

In future studies, new criteria can be determined for the problem, and the Spherical AHP method can be applied by more criteria. Also, new types of fuzzy extensions can be applied to the problem such as neutrosophic fuzzy sets, q-rung orthopair fuzzy, picture fuzzy sets, etc.

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Authors' Contribution

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The Declaration of Ethics Committee Approval

This study does not require ethics committee permission or any special permission.

The Declaration of Research and Publication Ethics

The authors of the paper declare that they comply with the scientific, ethical and quotation rules of SAUJS in all processes of the paper and that they do not make any falsification on the data collected. In addition, they declare that Sakarya University Journal of Science and its editorial board have no responsibility for any ethical violations that may be encountered, and that this study has not been evaluated in any academic publication environment other than Sakarya University Journal of Science.

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