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Multi-Criteria Decision Making for Computer Antivirus Software using Fuzzy AHP Approach

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Abstract: Nowadays, there are many antiviruses software developed by the information sectors to ensure the security of computer systems. As a result, consumers and information professionals are always debating whether antivirus software provides the best protection on a given criterion. However, there are various types of security software out there that can influence users' decisions. In addition, the determination of the appropriate antivirus software can be classified as a multi-criteria decision-making (MCDM) problem. Several methods could be used to determine the multi-criteria problem such as the method of Fuzzy Analytic Hierarchy Process (FAHP), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), and using an advanced method of Neutrosophic set. Hence, in this study, the method of Fuzzy Analytic Hierarchy Process (FAHP), one of the most powerful MCDM methods is employed for the selection of the appropriate antivirus software. Four criteria, twelve sub-criteria, and five alternatives of selection antivirus software are the main MCDM structures that need to be solved using the proposed method. A group of experts was invited to provide a rating of performance values of criteria and alternatives using a linguistic scale. The result has shown that Kaspersky Antivirus is the most preferred antivirus software that meets the criteria. This result will help users, especially computer software technicians in a certain organization to choose the preferred Antivirus to suggest to their employer. Furthermore, suggestions for further work are also provided for future study.

Keywords: Antivirus software, decision making, Fuzzy AHP

1 Introduction

Recently, there are many different threats to computer safety, such as malware and spam, and many other ways used by someone to steal peoples' data or infect their computer system. Malware is referring to malicious software. It is software that is established by cyber hackers and described as a computer virus. Such viruses migrate from one computer to another computer system to software coding, and these viruses do not directly affect specific machines. Still, they may affect the opposite resources, such as storage space and memory. Antivirus software is extremely useful in stopping, monitoring, destroying viruses, and any program of viruses that can affect computer components from within two files of the operating system. The antivirus acts to secure the computers by observing and reviewing the contents of the file. It can prevent viruses from entering the laptop by warning, hence asking for a deletion order, and taking precautions.

Therefore, these issues have been a concern in each country, especially in university requirements. This is important to prevent hackers or enemies from getting the data or access to university information, especially in getting students' and staff's private data. So, the implementation of a network security system is crucial for protecting critical information assets. Computer security is data system protection from theft or damage to the hardware, software, knowledge of them, and disruption or misdirection of the service they supply.

There are various types of antivirus software brands out there that can influence users' decisions according to different opinions and suggestions from those who are experts in that area.

However, most of the data or information obtained from real-world experts included uncertainty and vagueness about the decision's environment, imprecise human judgments, and incomplete information. One might consider a few criteria before making such a decision. Therefore, in this study, multi-criteria decision-making (MCDM) methods namely the Fuzzy Analytic Hierarchy Process (FAHP) method, also known as the most powerful MCDM method are proposed in solving the selection of antivirus software. This method is used since FAHP could handle various parameters, is simple to understand, and efficiently handle qualitative and quantitative data. MCDM applies to obtain the best decisions from all possible options in the face of several, typically contradictory, decision-making criteria. MCDM approaches, together with fuzzy set theory, have been commonly used to solve ambiguity in the computer antivirus software selection environment. That is because it offers an appropriate language for dealing with imprecise parameters and can combine qualitative and quantitative analysis of variables. Fuzzy AHP results are ranked explicitly according to normalized weights.

This paper aims to show the most preferred antivirus software that meets the criteria chosen. The organization of this paper is as follows: In section 2, we wrote some basic views of fuzzy AHP and some chosen criteria from the previous study. In section 3, we introduce the detailed methodology of fuzzy AHP. In section 4, we apply the introduced method to Antivirus software selection, and we discuss in detail the result obtained. In section 5, the conclusion is given. Lastly, all the references are given.

2 Literature Review

According to Jadhav and Sonar [1], computer evaluation can be conceived as a Multiple Criteria Decision Making (MCDM) issue. A study by Goli [2] found that evaluating software for protection is a complex process, and many of the opposing considerations need to be considered to make a decision. Assessing security software is not a simple technical tool, but a decision-making mechanism in which bias and uncertainty are present without random reduction possibilities.

AHP is technical decision-making when someone wants to choose the appropriate alternatives from various criteria and alternatives. AHP was first used by Saaty [3] to help decision-makers find a decision-making alternative that best suits their objectives. The decision is made using the weight derived from the evaluation of criteria. According to Kumar et al. [4], assessment is performed in the AHP technique by pair-wise judgments on a ratio scale. It is also used through initial views, feelings, and assumptions to simplify decision-making into a multilevel categorization cycle that affects the domain of decisions. Based on Anderluh et al. [5], the central concept of the AHP is to break the complex problem into its constituent elements and then turn all these elements into a hierarchical working system. More information on the technique in applying Fuzzy AHP in MCDM can be found in the literature [5-19]. Furthermore, some previous applications in the selection of Antivirus security software could be seen in [1, 2, 4, 17, 20-23].

According to Naie and Teymournejad [20], each of the anti-virus products has different scanning due to various reasons. Consumers need to choose the best antivirus in the world according to the criteria to protect their work based on their preferences and limitations. So, many researchers have ranked the best antivirus based on the criteria. Naie and Teymournejad [20] used 20 anti-viruses, Goli [2] used 13 anti-viruses and Nurhayati et al. [16]. The criteria that have been considered in their previous studies are shown in table 1. According to these criteria, in this paper, the criteria selected to rank the appropriate antivirus among Kaspersky Antivirus, Avast Pro Antivirus, SMADAV, Avira Antivirus, and AVG are cost, security, performance, and usability.

3 Methodology

A Fuzzy Analytical Hierarchy Process (FAHP)

This approach merges fuzzy logic based on the linguistic terms and statements, and the well-known AHP methodology established by Saaty [3]. This study agreed to precisely use this approach because of its directness. As Zadeh [25] claims, it is not very easy to express the significance of the criterion by numerical values; thus, the notation of the linguistic term is needed. A Triangular Fuzzy Number (TFN) represents the linguistic term in fuzzy logic. The necessary steps are explained in detail and shown as follows:

Table 1: The list of selected criteria from the previous study

Criteria/ Author	Kirilmaz et al. [21]	Naie & Teymournejad [20]	Nurhayati et al. [16]	Agrawal et al. [22]	Mamaghani [23]	Jadhav & Sonar [1]	Chang & Hung [24]
Cost			/			/	/
Security	/			/	/		/
Usability	/			/		/	/
Performance	/	/	/		/		
Operation					/		
Vendor							
Strategy						/	/

Step 1: Define the problems, criteria, sub-criteria, and alternatives
Obtain the criteria and sub-criteria through a review of literature and experts' opinions regarding this problem.

Step 2: Generating the Pair-wise Comparison Matrix
The decision-maker uses specified fuzzy numbers on the right side of the linguistic scale according to the relevant linguistic terms. The pairwise comparison of the criteria in the form of a matrix is shown in Eq. (1).

$$\tilde{p}^k = \begin{bmatrix} \tilde{d}_{11}^k & \tilde{d}_{12}^k & \cdots & \tilde{d}_{1j}^k \\ \tilde{d}_{21}^k & \tilde{d}_{22}^k & \cdots & \tilde{d}_{2j}^k \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{d}_{i1}^k & \tilde{d}_{i2}^k & \cdots & \tilde{d}_{ij}^k \end{bmatrix} \tag{1}$$

where, $\tilde{d}_{ij}^k$ indicates the k^{th} decision makers' preferences of i^{th} criterion over j^{th}, via fuzzy triangular numbers. Here the "tilde" symbol represents the triangular number demonstration.

Step 3: Calculate the average preference ratings of the decision-makers
Preferences of each decision-maker, $\tilde{d}_{ij}^k$ are averaged if there is more than one decision-maker and $\tilde{d}_{ij}^k$ is calculated as shown in Eq. (2).

$$\tilde{d}_{ij} = \sum_{k=1}^{k} \frac{\tilde{d}_{ij}^k}{k} \tag{2}$$

Step 4: Compute the Fuzzy Synthetic Extent values
In this step, Chang's Extent Analysis as used by Sirisawat & Kiatcharoenpol [17] were applied.

According to Chang's approach, each element is considered, and the extent analysis for each goal g_i is carried out. Thus, for each element, there is m_i a range of extent analysis values that can be obtained from the following Eq. (3):

$$M_{gi}^1, M_{gi}^2, M_{gi}^j, \ldots, M_{gi}^m \tag{3}$$

where $i = 1,2,3,\ldots,n$ and $M_{gi}^j \left(j = 1,2,3,\ldots,m \right)$ are triangular fuzzy numbers. The values of the fuzzy synthetic extent concerning i^{th} criterion can be defined by Eq. (4).

$$S_i = \sum_{j=1}^{m} M_{gi}^i \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^i \right]^{-1} \tag{4}$$

To obtain the expression $\sum_{j=1}^{m} M_{g_i}^i$ perform the fuzzy addition operation of *m* extent analysis, along with:

$$\sum_{j=1}^{m} M_{gi}^i = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j \right) \tag{5}$$

Hence, compute the inverse of the vector using Eq. (6).

$$\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^i \right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} \sum_{j=1}^{m} u_i}, \frac{1}{\sum_{i=1}^{n} \sum_{j=1}^{m} m_i}, \frac{1}{\sum_{i=1}^{n} \sum_{j=1}^{m} l_i} \right) \tag{6}$$

Step 5: Calculation of the sets of weight values of fuzzy AHP
Based on the method of extent analysis proposed by Chang [19], the degree of possibility of

$$S_j = \left(l_j, m_j, u_j \right) \geq S_i = \left(l_i, m_i, u_i \right)$$

is defined as

$$V\left(S_j \geq S_i \right) = \sup_{y \geq x} \left[\min\left(\mu_{sj}\left(y \right), \mu_{si}\left(x \right) \right) \right]$$

which can be expressed as follows:

$$V\left(S_j \geq S_i \right) = hgt\left(S_i \cap S_j \right) = \mu_{sj}\left(d \right) \tag{7}$$

$$V\left(S_j \geq S_i \right) = \begin{cases} 1, & if \quad m_j \geq m_i \\ 0, & if \quad l_i \geq u_j \\ \dfrac{l_i - u_j}{\left(m_j - u_j \right) - \left(m_i - l_i \right)}, & if \quad otherwise \end{cases} \tag{8}$$

where the highest intersection μ_{S_j} and μ_{S_i} as shown in Figure 1. To compare S_i and S_j, it is requiring us to have both values of $V\left(S_i \geq S_j \right)$ and $V\left(S_j \geq S_i \right)$.

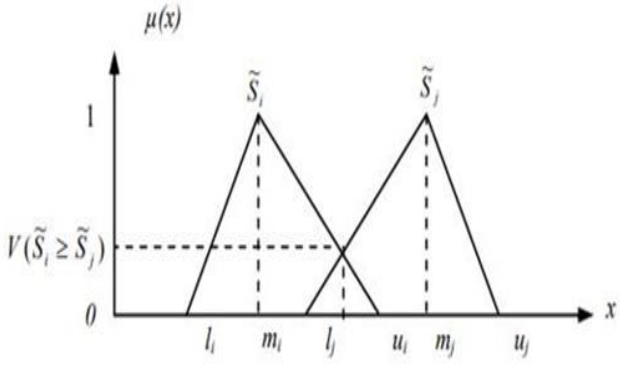

Figure 1: The degree of possibility of $(\tilde{S}_i \geq \tilde{S}_j)$

The degree of possibility of a convex fuzzy number to be greater than k convex fuzzy numbers $S_i\left(i=1,2,3,\ldots,S_k\right)$ can be defined as Eq. (9)

$$V\left(S \geq S_1, S_2, S_3, \ldots, S_k\right) = V\left[\left(S \geq S_1\right),\left(S \geq S_2\right),\left(S \geq S_3\right),\ldots,\left(S \geq S_k\right)\right]$$
$$= \min\left(S \geq S_i\right), i=1,2,3,\ldots,k \tag{9}$$

Assume that Eq. (10) is

$$d'\left(A_i\right) = \min V\left(S_i \geq S_k\right), k=1,2,3,\ldots,n; k \neq i \tag{10}$$

Then, the weight vector is given by Eq. (11) as follows

$$W' = \left(d'\left(A_1\right), d'\left(A_2\right), d'\left(A_3\right),\ldots, d'\left(A_n\right)\right)^T \tag{11}$$

Where $A_i = \left(i=1,2,3,\ldots,n\right)$ are n elements.

Step 6: Normalize the weight vectors of decision elements
By normalization in Eq. (11) to reduce each value of elements to the range $[0,1]$, the normalized weight vectors are given by Eq. (12):

$$W = \left(d\left(A_1\right), d\left(A_2\right), d\left(A_3\right),\ldots, d\left(A_n\right)\right)^T \tag{12}$$

where W is not a fuzzy number calculated for each comparison matrix.

Step 7: Compute global performance and rank the alternatives
The global performance of each alternative will be calculated using Eq. (13), and the alternatives will be ranked.

$$\sum_{i=1}^{n} d'\left(A_{iC_j}\right) \times d'\left(C_j\right) \tag{13}$$

4 Application in Selection of Antivirus Software

In this study, we apply the fuzzy AHP method to rank the best alternative, which are Kaspersky Antivirus (A1), Avast Pro Antivirus (A2), SMADAV (A3), Avira Antivirus (A4), and AVG (A5). Then, five experts (DM1, DM2, DM3, DM4, and DM5) are selected for the decision-making process.

A The implementation of the Fuzzy AHP Method

The criteria and sub-criteria affecting the ranking of the selected antivirus software were obtained by review of the literature and obtaining the experts' opinions. Therefore, in this study, the four main criteria, twelve sub-criteria, and five alternatives will be considered as shown in Table 2 and Figure 2. The linguistic variables presented in Table 3 were used by decision-makers to comparatively evaluate the weight of the criteria and the ratings of the alternatives. Following [18], TFN was used to specify the linguistic values of these variables. Table 4 presents the comparative judgments of the weights of the criteria made by the five decision-makers involved already converted into TFN. The results of aggregation of these fuzzy values are presented in Table 5.

Table 2: Proposed criteria and sub-criteria

Criteria	Sub-criteria
Usability (C1)	● Effectiveness (C11) ● False alarm (C12) ● Easy to use (C13)
Performance (C2)	● User friendly (C21) ● Scanning speed (C22) ● Installing and uninstalling apps (C23)
Cost (C3)	● Installing and implementation (C31) ● Upgrading cost (C32) ● Cost of hardware (C33)
Security (C4)	● Confidentially (C41) ● Integrity (C42) ● Malware removal (C43)

Table 3: Linguistic variable for importance level of each criterion and alternatives

Linguistic terms	Triangular fuzzy number (TFN)	Reciprocal Triangular fuzzy number (RTFN)
Extreme importance (EI)	$\left(\frac{5}{2},3,\frac{7}{2}\right)$	$\left(\frac{2}{7},\frac{1}{3},\frac{2}{5}\right)$
Very strong importance (VS)	$\left(2,\frac{5}{2},3\right)$	$\left(\frac{1}{3},\frac{2}{5},\frac{1}{2}\right)$
Strong importance (SI)	$\left(\frac{3}{2},2,\frac{5}{2}\right)$	$\left(\frac{2}{5},\frac{1}{2},\frac{2}{3}\right)$
Moderate importance (MI)	$\left(1,\frac{3}{2},2\right)$	$\left(\frac{1}{2},\frac{2}{3},1\right)$
Equal importance (EI)	$(1,1,1)$	$(1,1,1)$

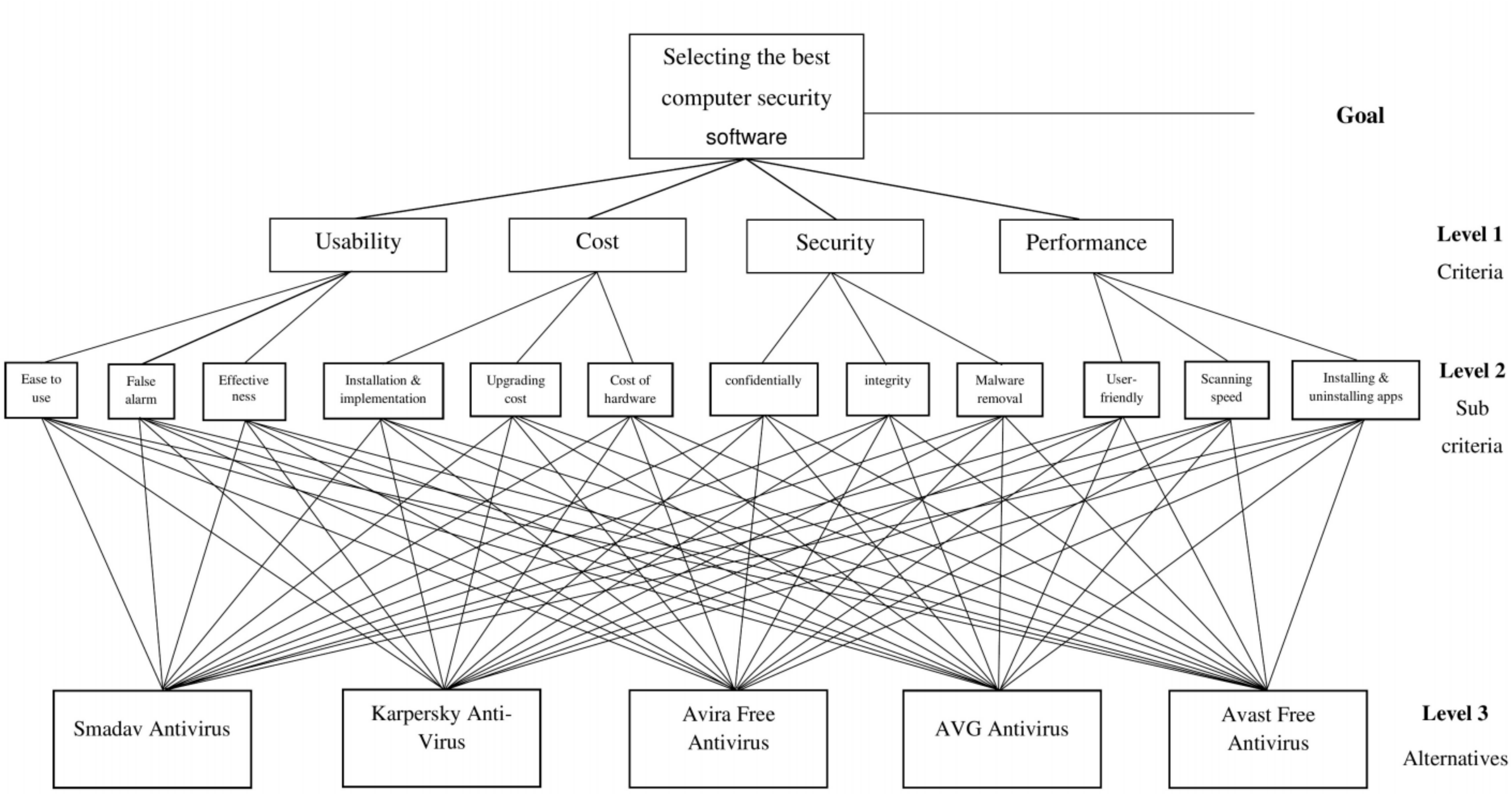

Figure 2: The hierarchy of criteria, sub-criteria, and alternative

The fuzzy synthetic extent value S_i concerning the i^{th} criterion for criteria, sub-criteria, and the alternative is calculated using equation (4). The values of the fuzzy synthetic extent for the criteria matrix are:

$$S_1=\left(\frac{1061}{525},\frac{67}{30},\frac{64}{25}\right)\otimes\left(\frac{5}{124},\frac{150}{3167},\frac{525}{9278}\right)=(0.0815,0.1058,0.1449)$$

$$S_2=\left(\frac{2111}{525},\frac{713}{150},\frac{139}{25}\right)\otimes\left(\frac{5}{124},\frac{150}{3167},\frac{525}{9278}\right)=(0.1621,0.2251,0.3146)$$

$$S_3=\left(\frac{2774}{525},\frac{967}{150},\frac{1147}{150}\right)\otimes\left(\frac{5}{124},\frac{150}{3167},\frac{525}{9278}\right)=(0.2131,0.3053,0.4327)$$

$$S_4=\left(\frac{476}{75},\frac{192}{25},\frac{271}{30}\right)\otimes\left(\frac{5}{124},\frac{150}{3167},\frac{525}{9278}\right)=(0.2559,0.3638,0.5112)$$

Table 4: Comparative judgments of the importance of the criteria made by decision-makers

		C1	**C2**	**C3**	**C4**
DM1	**C1**	$(1,1,1)$	$\left(\frac{1}{3},\frac{2}{5},\frac{1}{2}\right)$	$\left(\frac{3}{2},2,\frac{5}{2}\right)$	$\left(\frac{3}{2},2,\frac{5}{2}\right)$
	C2	$\left(2,\frac{5}{2},3\right)$	$(1,1,1)$	$\left(\frac{2}{7},\frac{1}{3},\frac{2}{5}\right)$	$\left(\frac{1}{3},\frac{2}{5},\frac{1}{2}\right)$
	C3	$\left(\frac{2}{5},\frac{1}{2},\frac{2}{3}\right)$	$\left(\frac{5}{2},3,\frac{7}{2}\right)$	$(1,1,1)$	$\left(\frac{2}{5},\frac{1}{2},\frac{2}{3}\right)$
	C4	$\left(\frac{2}{5},\frac{1}{2},\frac{2}{3}\right)$	$\left(2,\frac{5}{2},3\right)$	$\left(\frac{3}{2},2,\frac{5}{2}\right)$	$(1,1,1)$
DM2	**C1**	$(1,1,1)$	$\left(\frac{1}{3},\frac{2}{5},\frac{1}{2}\right)$	$\left(2,\frac{5}{2},3\right)$	$\left(\frac{5}{2},3,\frac{7}{2}\right)$
	C2	$\left(2,\frac{5}{2},3\right)$	$(1,1,1)$	$\left(\frac{1}{3},\frac{2}{5},\frac{1}{2}\right)$	$\left(\frac{2}{5},\frac{1}{2},\frac{2}{3}\right)$
	C3	$\left(\frac{1}{3},\frac{2}{5},\frac{1}{2}\right)$	$\left(2,\frac{5}{2},3\right)$	$(1,1,1)$	$\left(\frac{2}{5},\frac{1}{2},\frac{2}{3}\right)$
	C4	$\left(\frac{2}{7},\frac{1}{3},\frac{2}{5}\right)$	$\left(\frac{3}{2},2,\frac{5}{2}\right)$	$\left(\frac{3}{2},2,\frac{5}{2}\right)$	$(1,1,1)$
DM3	**C1**	$(1,1,1)$	$\left(\frac{1}{3},\frac{2}{5},\frac{1}{2}\right)$	$\left(\frac{3}{2},2,\frac{5}{2}\right)$	$\left(\frac{5}{2},3,\frac{7}{2}\right)$
	C2	$\left(2,\frac{5}{2},3\right)$	$(1,1,1)$	$\left(\frac{1}{3},\frac{2}{5},\frac{1}{2}\right)$	$\left(2,\frac{5}{2},3\right)$
	C3	$\left(\frac{2}{5},\frac{1}{2},\frac{2}{3}\right)$	$\left(2,\frac{5}{2},3\right)$	$(1,1,1)$	$\left(\frac{1}{3},\frac{2}{5},\frac{1}{2}\right)$
	C4	$\left(\frac{2}{7},\frac{1}{3},\frac{2}{5}\right)$	$\left(\frac{1}{3},\frac{2}{5},\frac{1}{2}\right)$	$\left(2,\frac{5}{2},3\right)$	$(1,1,1)$
DM4	**C1**	$(1,1,1)$	$(1,1,1)$	$\left(2,\frac{5}{2},3\right)$	$\left(2,\frac{5}{2},3\right)$
	C2	$\left(2,\frac{5}{2},3\right)$	$(1,1,1)$	$\left(\frac{2}{5},\frac{1}{2},\frac{2}{3}\right)$	$\left(\frac{1}{3},\frac{2}{5},\frac{1}{2}\right)$
	C3	$\left(\frac{1}{3},\frac{2}{5},\frac{1}{2}\right)$	$\left(\frac{3}{2},2,\frac{5}{2}\right)$	$(1,1,1)$	$\left(\frac{2}{7},\frac{1}{3},\frac{2}{5}\right)$

	C4	$\left(\frac{1}{3},\frac{2}{5},\frac{1}{2}\right)$	$\left(2,\frac{5}{2},3\right)$	$\left(\frac{5}{2},3,\frac{7}{2}\right)$	$(1,1,1)$
DM5	**C1**	$(1,1,1)$	$\left(\frac{1}{3},\frac{2}{5},\frac{1}{2}\right)$	$\left(2,\frac{5}{2},3\right)$	$\left(2,\frac{5}{2},3\right)$
	C2	$\left(2,\frac{5}{2},3\right)$	$(1,1,1)$	$\left(\frac{2}{5},\frac{1}{2},\frac{2}{3}\right)$	$\left(\frac{2}{7},\frac{1}{3},\frac{2}{5}\right)$
	C3	$\left(\frac{1}{3},\frac{2}{5},\frac{1}{2}\right)$	$\left(\frac{3}{2},2,\frac{5}{2}\right)$	$(1,1,1)$	$\left(\frac{3}{2},2,\frac{5}{2}\right)$
	C4	$\left(\frac{1}{3},\frac{2}{5},\frac{1}{2}\right)$	$\left(\frac{5}{2},3,\frac{7}{2}\right)$	$\left(\frac{2}{5},\frac{1}{2},\frac{2}{3}\right)$	$(1,1,1)$

Table 5: Fuzzy numbers of the aggregated importance levels of the criteria

	C1	**C2**	**C3**	**C4**
C1	$(1,1,1)$	$\left(\frac{1}{3},\frac{2}{5},\frac{1}{2}\right)$	$\left(\frac{9}{5},\frac{23}{10},\frac{14}{5}\right)$	$\left(\frac{21}{108},\frac{13}{5},\frac{31}{10}\right)$
C2	$\left(2,\frac{5}{2},3\right)$	$(1,1,1)$	$\left(\frac{184}{525},\frac{32}{75},\frac{41}{75}\right)$	$\left(\frac{352}{525},\frac{62}{75},\frac{71}{75}\right)$
C3	$\left(\frac{9}{25},\frac{11}{25},\frac{17}{30}\right)$	$\left(\frac{19}{10},\frac{12}{5},\frac{29}{10}\right)$	$(1,1,1)$	$\left(\frac{613}{1050},\frac{56}{75},\frac{71}{75}\right)$
C4	$\left(\frac{172}{525},\frac{59}{150},\frac{37}{75}\right)$	$\left(\frac{5}{3},\frac{52}{25},\frac{5}{2}\right)$	$\left(\frac{79}{50},2,\frac{73}{30}\right)$	$(1,1,1)$

The degree of possibility from Eq. (9) and (10) are used to find the highest intersection point. The detailed calculation and comparison are:

$$V(S_1 \geq S_2) = 1.00 \qquad V(S_2 \geq S_2) = 0.59 \qquad V(S_3 \geq S_1) = 0.54 \qquad V(S_4 \geq S_1) = 0.80$$
$$V(S_1 \geq S_3) = 1.00 \qquad V(S_2 \geq S_3) = 1.00 \qquad V(S_3 \geq S_2) = 0.95 \qquad V(S_4 \geq S_2) = 1.00$$
$$V(S_1 \geq S_4) = 1.00 \qquad V(S_2 \geq S_4) = 0.79 \qquad V(S_3 \geq S_4) = 0.74 \qquad V(S_4 \geq S_3) = 1.00$$

Therefore, the weight vector *W'*, computed as in Eq. (11), are:

$$d'(C1) = V(S_1 \geq S_2, S_3, S_4) = \min(1.00, 1.00, 1.00) = 1.00$$
$$d'(C2) = V(S_2 \geq S_1, S_3, S_4) = \min(0.59, 1.00, 0.79) = 0.59$$
$$d'(C3) = V(S_3 \geq S_1, S_2, S_4) = \min(0.54, 0.95, 0.74) = 0.54$$
$$d'(C4) = V(S_4 \geq S_1, S_2, S_3) = \min(0.80, 1.00, 1.000) = 0.80$$

$$W' = (1.00, 0.59, 0.54, 0.80)$$

After normalization, the weight vector is (0.34, 0.20, 0.18, 0.27). Table 6 summarizes the normalized weight vectors of the criteria and alternative.

Table 6: Normalized weights for each criterion towards alternatives

Criteria / Alternatives	A1	A2	A3	A4	A5	Weight of criteria
C1	0.27	0.23	0.25	0.03	0.21	0.34
C2	0.57	0.07	0.16	0.04	0.17	0.20
C3	0.52	0.08	0.25	0.04	0.12	0.18
C4	0.43	0.15	0.15	0.03	0.24	0.27

The results obtained in Table 6, summarize the final weight of the main criteria, while Figure 3 shows a graphical representation of the relative importance of the main criteria used in the study compared to each other. The illustration of the result displays usability (C1) being the most important criteria in selecting the most preferred computer antivirus software since the weight of its criteria is the highest which is 0.34, then followed by security (C4), performance (C2), and cost (C3) where their weight of criteria is 0.27, 0.20 and 0.18 respectively. In addition, the final weight for each sub-criteria are calculated as shown in Table 7.

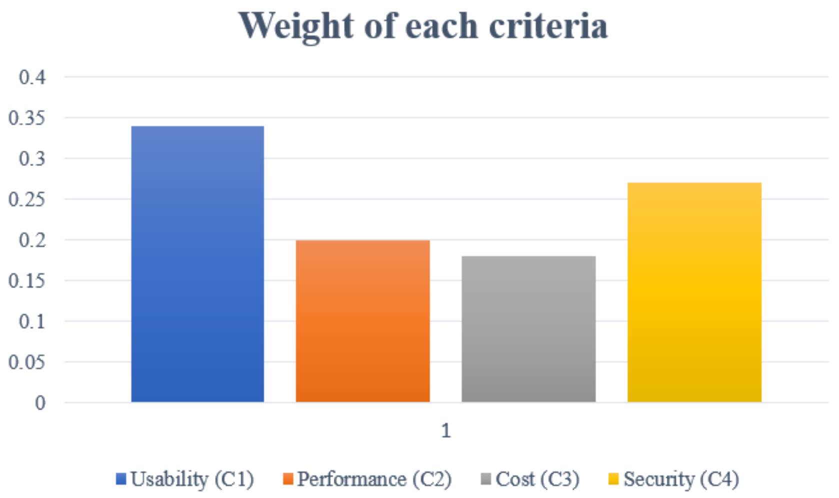

Figure 3: Graphical view of the relative weights of the main criteria

In addition, to rank the preferred Antivirus, the global performance for each alternative A1, A2, A3, A4, and A5 are computed. For alternative A1, its global performance was computed as:

$$\begin{aligned} D(A1) &= \left[d'(Al_{C1}) \times d'(C1) + d'(Al_{C2}) \times d'(C2) + d'(Al_{C3}) \times d'(C3) + d'(Al_{C4}) \times d'(C4) \right] \\ &= (0.34 \times 0.2719) + (0.20 \times 0.5651) + (0.18 \times 0.5164) + (0.27 \times 0.4311) \\ &= 0.42 \end{aligned}$$

The global performance for the other alternative antivirus software (A2, A3, A4, and A5) was computed similarly. Table 8 presents the global performance for all alternatives and their ranking position, while Figure 4 shows a graphical representation of global performance for each alternative. From both representations, alternative A1 is the highest with a global performance value of 0.42. Then followed by alternatives A3, A5, A2, and A4 with their global performance are 0.20, 0.19, 0.15, and 0.03 respectively.

Table 7: Normalized weights of sub-criteria towards the alternatives

Sub-criteria / Alternatives	A1	A2	A3	A4	A5
C11	0.28	0.23	0.25	0.01	0.23
C12	0.28	0.23	0.30	0.08	0.11
C13	0.25	0.24	0.25	0.08	0.18
C21	0.33	0.15	0.12	0.09	0.31
C22	0.51	0.09	0.20	0.11	0.10
C23	0.75	0.01	0.20	0.01	0.05
C31	0.42	0.04	0.30	0.01	0.24
C32	0.67	0.01	0.15	0.01	0.17
C33	0.37	0.15	0.33	0.01	0.08
C41	0.42	0.16	0.16	0.01	0.25
C42	0.33	0.11	0.30	0.01	0.26
C43	0.47	0.13	0.09	0.11	0.21

Table 8: Global performance of alternatives and outranking

Alternatives	Global performance	Rank
A1	0.42	1
A2	0.15	4
A3	0.20	2
A4	0.03	5
A5	0.19	3

Therefore, following this procedure and based on the evaluation done by the five experts, the most preferred antivirus software is Kaspersky Antivirus (A1), followed by SMADAV (A3), AVG (A5), Avast Pro (A2), and Avira (A4).

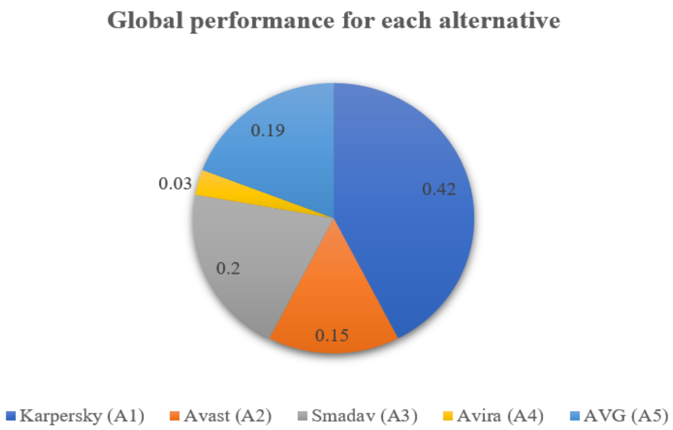

Figure 4: Graphical view of global performance for each alternative.

5 Conclusion

Antivirus software is extremely useful in monitoring, stopping, destroying viruses and any program of viruses that can affect computer components. Choosing the appropriate antivirus software can prevent all the undesirables from happening. Antivirus software protects computers by inspecting and evaluating the contents of files. If it detects viruses on your computer, it warns and asks for your command to delete them, as well as taking your preventative steps. However, choosing and installing safe and secure security software for computer protection is one of the most pressing problems for those who operate with computers. Every day, new computer viruses are created, and it appears that preventing them from destroying current files is unavoidable. However, if you examine the security software market, you will probably be surprised to see such a vast number of antivirus manufacturers, which may make it difficult to choose an appropriate antivirus software.

Therefore, in this study, the selection of the most preferred antivirus software using the Fuzzy AHP was proposed. The study aims to rank the alternatives and choose the best alternatives to Antivirus software. First, criteria and sub-criteria for evaluating antivirus software are examined and it is realized that all the sources applied have four common criteria and twelve sub-criteria. There are various commercial antivirus software, so to limit the alternative set, we choose only 5 security software which is the most preferred by experts. After the identification of criteria, sub-criteria, and alternatives, criteria weights are computed by the fuzzy AHP method. Then, the global performance for each alternative is computed. Finally, rank all the alternatives and select the best one. The study concludes that Kaspersky Antivirus would be the best security software to protect our security system.

There are several limitations to this study, requiring further examination and additional research. First, this study employs fuzzy AHP to compute the weight for each criterion. Future studies can adopt additional fuzzy multi-attribute approaches such as fuzzy TOPSIS and fuzzy outranking methods to estimate the relative weights of each criterion in selection antivirus software. The results of future studies can then be compared with those presented here. Second, the evaluation criteria were selected from a review of the literature on antivirus software, a review that excluded some possible influences on antivirus software effectiveness. Future research can use different methodologies, such as longitudinal studies, focus groups, and interviews to identify other criteria of selection antivirus software. Lastly, this study used a tiny sample size. More complex evaluation analysis would have been possible with a larger sample along with more significance. To improve generalizability, the findings of the study should be confirmed using a larger sample.

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