GROUP FUZZY TOPSIS METHODOLOGY IN COMPUTER SECURITY SOFTWARE SELECTION

DavoudGoli[1]

[1]Department of Industrial Engineering, KNT University of Technology, Tehran, Iran
dvd_goli@yahoo.com

ABSTRACT

In today's interconnected world, the risk of malwares is a major concern for users. Antivirus software is a device to prevent, discover, and eliminatemalwares such as, computer worm, trojan horses,computer viruses,spyware and adware. In the competitive IT environment, due to availability of many antivirus software and their diverse features evaluating them is an arguable and complicated issue for users which has a significant impact on the efficiency of computers defense systems. The anti-virus selection problem can be formulated as a multiple criteria decision making problem. This paper proposes an antivirus evaluation model for computer users based on group fuzzy TOPSIS. We study a real world case of antivirus software and define criteria for antivirus selection problem. Seven alternatives were selected from among the most popular antiviruses in the market and seven criteria were determined by the experts. The study is followed by the sensitivity analyses of the results which also gives valuable insights into the needs and solutions for different users in different conditions.

KEYWORDS

Antivirus software, Fuzzy TOPSIS, Group multiple criteria decision making

1. INTRODUCTION

In today's interconnected world, the risk of malwares is a major concern for users. Antivirus software is a device to prevent, discover, and eliminate malwares such as, computer worm, trojan horses, computer viruses, spyware and adware.

Digital threats are incessantly growing, with latest security risks appearing very hour. Beyond just an enlargement in amount ofmenaces, malware is becoming more indefinable, variable and costly. Today, an insecure computer isn't merely susceptible, it's possibly formerly infected. Freshtrojans,spyware, worms, viruses, and other malware are designed daily. New threats are disguised to bypass other protection measures, and in particular madeto catch you and your computer off guard. The virus view has also altered; viruses that used to be irritating pranks have developed into destructive threats able to not only damaging your computer, but taking your data and identity.

The advantages of installing a protection solution on your PC are evident, but the costs in reducing system's speed used to make it tough to bear. Fortunately, up to date antivirus software have not just upgraded their level of protection, they've extensively developed resource efficiency and total speed. Users can have ultimate protection without consuming much of system resources. With superior technologies and uncomplicated usability, antivirus software is more efficient than ever, and doesn't need regular protection. Current antivirus programs deliver constant protection.
The last generation of antivirus software uses advanced heuristic detection. Continuing to Progress, the latest antivirus software often integrate further upgraded proactive security with enhanced performance inspection and even file status analysis. While we have had antivirus

DOI : 10.5121/ijfls.2013.3203

software for decades, how they operate has considerably changed over the years. Nowadays antivirus software applications integrate advanced heuristic recognition to proactively recognize malware with behavioral examination. Another latest progress is the alter to cloud security, which permits security sellers to host the volume of the essential data online, considerably falling system impact and accelerating quicker updates.

Evaluating protection software is a complicated process and many opposing criteria must be considered to make a decision. Evaluating protection software is not a straightforward technical action but a decision procedure where prejudice and ambiguity are present without any chance of random reduction. Diversity in type and quality of information about such decision problems calls for methods and techniques that can assist in information processing. Ultimately, multiple criteria decision making method may lead to better decisions. As defined by the International Society on Multiple Criteria Decision Making, ***Multi-Criteria Decision Making or MCDM*** *is the study of procedures and methods by which multiple conflicting criteria can be systematically incorporated into the management planning process*.

The anti-virus selection problem can be formulated as a multiple criteria decision making problem. The most commonly used method for evaluating software is weighted average sum. Another commonly used MCDM technique is AHP (Mamaghani, 2002; Kabir&Hasin, 2011) where priorities come from the eigen values of the pairwise evaluation matrix of a set of elements when statedon ratio scales.

In this paper we are seeking solutions for the problem of antivirus software selection and present an evaluation model based on group fuzzy TOPSIS. The motivation of this work is the unmet demand in the antivirus software market for analysis and comparison of antiviruses, in a way that helps users to choose antiviruses based on their needs and limitations. In this work we will study a real world case and define the main criteria for antivirus selection problem.

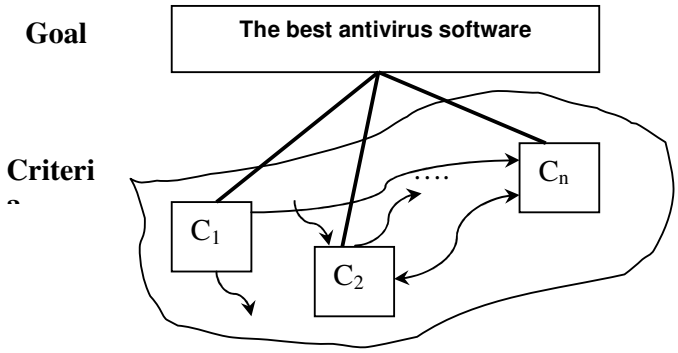

Fig.1. A framework for antivirus software selection problem

Since the information available for use in multiple criteria decision making is usually uncertain, vague, or imprecise, linguistic values and fuzzy numbers will be used to capture the vague and imprecise nature of decision makers' judgments. To obtain less biased judgments we adopt a group decision making approach.

The rest of this paper is organized as follows. In Section 2, some basics associated with the offered approach are addressed. Section 2.1 review basics of fuzzy sets and fuzzy numbers. Section 2.2 provides an introduction and a literature review on TOPSIS. Section 2.3 introduces

Fuzzy TOPSIS and group Fuzzy TOPSIS and reviews the associated literature with a focus on the latest researches on the topic. In section 3 the application of the group fuzzy TOPSIS on the case of antivirus software is studied which is followed by sensitivity analyses and discussions in section 4. We conclude this paper in Section 5, with some suggestions for future research.

2. PRELIMINARIES

2.1. Fuzzy Set and FuzzyNumber

In this section we review some basic notions of fuzzy sets; as follows:

Definition1. A fuzzy set $\tilde{A}$ in a universe of discourse *X* is shown by a membership function $\mu_{\tilde{A}}(x)$which associates a real number in the interval [0,1]with each element x in *X*. The function value $\mu_{\tilde{A}}(x)$ is termed the grade of membership of $x$in$\tilde{A}$.

Definition2. A positive triangular fuzzy number (PTFN) $\tilde{n}$ can be defined as (n_1, n_2, n_3) shown in Fig. 2. The membership function $\mu_{\tilde{n}}(x)$ is defined as (Kaufmann & Gupta, 1991):

$$\mu_{\tilde{n}}(x) = \begin{cases} 0, & x < n_1 \\ \frac{x-n_1}{n_2-n_1}, & n_1 \leq x \leq n_2 \\ \frac{x-n_3}{n_3-n_2}, & n_2 \leq x \leq n_3 \\ 0, & x > n_3 \end{cases} \tag{1}$$

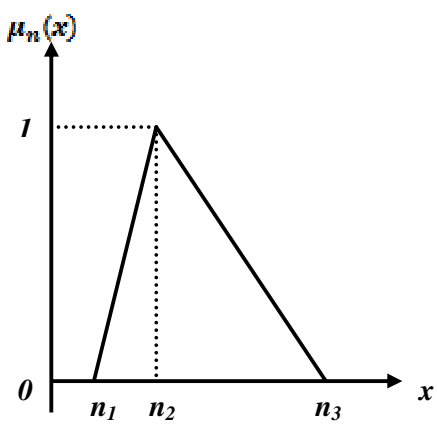

Fig.2. Triangular fuzzy number $\tilde{n}$.

For a triangular fuzzy number $\tilde{n} - (n_1, n_2, n_3)$. A non-fuzzy number r can be indicated as (r, r, r, r). By the extension principle, the fuzzy sum $\oplus$and fuzzy subtraction $\ominus$ of any two triangular fuzzy numbers are also triangular fuzzy numbers; but the multiplication $\otimes$of any two triangular

fuzzy numbers is only an approximate triangular fuzzy number. Given any two positive triangular fuzzy numbers, $\tilde{m}=(m_1, m_2, m_3)$, $\tilde{n}=(n_1, n_2, n_3)$ and a positive real number r, some main operations of fuzzy numbers $\tilde{m}$ and $\tilde{n}$ can be expressed as follows (Hwang &Lin,1987):

$$\tilde{m} \oplus \tilde{n} = [m_1 + n_1, m_2 + n_2, m_3 + n_3] \tag{2}$$

$$\tilde{m} \ominus \tilde{n} = [m_1 - n_3, m_2 - n_2, m_3 - n_1] \tag{3}$$

$$\tilde{m} \otimes r = [m_1 r, m_2 r, m_3 r];\ r \geq 0 \tag{4}$$

$$\tilde{m} \otimes \tilde{n} \cong [m_1 n_1, m_2 n_2, m_3 n_3] \tag{5}$$

Definition3. A matrix $\tilde{D}$ is called a fuzzy matrix if it contains at least one fuzzy number.

Definition4. A linguistic variable is a one whose values are determined using linguistic terms. The notion of a linguistic variable is very helpful in dealing with conditions, which are too complicated or not well described to be plausibly described in conventional numerical expressions (Zimmermann, 1991). For instance, ‘‘weight’’ is a linguistic variable whose values are very high, high, medium, low, very low, and so forth. Fuzzy numbers can also indicate these linguistic values.

Definition5. If $\tilde{m}=(m_1, m_2, m_3)$ and $\tilde{n}=(n_1, n_2, n_3)$ be two triangular fuzzy numbers. Then the distance between them can be calculated by using the vertex method as (Chen, 2000):

$$d_v(\tilde{m}, \tilde{n}) = \sqrt{\frac{1}{3}[(m_1 - n_1)^2 + (m_2 - n_2)^2 + (m_3 - n_3)^2]} \tag{6}$$

The vertex method is an effective and simple method to calculate the distance between two triangular fuzzy numbers. According to the vertex method, two triangular fuzzy numbers $\tilde{m}$ and $\tilde{n}$ are identical if and only if $d_v(\tilde{m}, \tilde{n})=0$. Let $\tilde{m}, \tilde{n}$ *and* $\tilde{o}$ be three fuzzy numbers. Fuzzy number $\tilde{n}$ is closer to fuzzy number $\tilde{m}$ than the other fuzzy number $\tilde{p}$ if and only if $d_v(\tilde{m}, \tilde{n}) < d_v(\tilde{m}, \tilde{p})$ (Chen, 2000).

Definition6. If $\tilde{x}_{ij} = (\alpha_{ij}, \beta_{ij}, \gamma_{ij})$ be a traiangular fuzzy number denote value of criteria *j* in alternative *i*; then:

$$\tilde{r}_{ij} = \left(\frac{\alpha_{ij}}{\gamma_j^*}, \frac{\beta_{ij}}{\gamma_j^*}, \frac{\gamma_{ij}}{\gamma_j^*}\right) \text{ ; if j} \in \textit{Benefit} \text{ type criteria ;} \gamma_j^* = max_i \gamma_{ij}$$
$$\tilde{r}_{ij} = \left(\frac{\alpha_j^-}{\gamma_{ij}}, \frac{\alpha_j^-}{\beta_{ij}}, \frac{\alpha_j^-}{\alpha_{ij}}\right) \text{ ; if j} \in \text{Cost type criteria ; } \alpha_j^- = min_i \alpha_{ij} \tag{7}$$

2.2. TOPSIS

MADM approach is frequently applied to solve a variety of decision making and/or selection challenges.This approach often needs the decision makers to present qualitative and/or quantitative evaluations for determining the score of each alternative regarding each criterion, with the relative value of evaluation criteria considering the total objective. The TOPSIS was first introduced by Hwang and Yoon (1981) and ranks the alternatives with respect to their distances from two points, the positive ideal and the negative ideal solution. In other words, the best option has the shortest distance from the ideal answer and the farthest distance from the negative ideal answer. The ideal solution is identified with a "hypothetical alternative" that has the best values for all considered criteria whereas the negative ideal solution is identified with a "hypothetical alternative" that has the worst criteria values. In practice, TOPSIS has been successfully applied to solve selection/evaluation problems with a finite number of alternatives because it is intuitive and easy to understand and implement. Furthermore, TOPSIS has a sound logic that represents the rationale of human choice and has been proved to be one of the best methods in addressing the issue of rank reversal. Real evaluation problems involve assessment of qualitative/quantitative criteria. Moreover, the aggregating function of the TOPSIS method does not produce results such that the highest ranked alternative is simultaneously the closest to the ideal solution and the furthest from the negative ideal solution since these criteria can be conflicting. This issue is faced rather arbitrarily by the original TOPSIS method through the use of the notion of relative closeness which is a measure of the relative distance between a certain alternative and ideal and negative ideal solutions.

According to Kim et al. (1997), four TOPSIS advantages are addressed:
(I) a sound logic that represents the rationale of human choice;
(II) a scalar value that accounts for both the best and worst alternatives simultaneously;
(III) a simple computation process that can be easily programmed into a spreadsheet;
(IV) the performance measures of all alternatives on criteria can be visualized on a polyhedron and at least for any two dimensions.

These benefits make TOPSIS an important MADM technique in comparison with other techniques, e.g. analytical hierarchical process (AHP) and elimination and choice expressing reality (ELECTRE). In fact, TOPSIS is a utility based technique that compares alternatives directly regarding the data in the evaluation matrices and weights (Sasikumar Kannan, 2008).
Since MADM is a useful method for selection and ranking of several alternatives, its applications are numerous. TOPSIS has been considered one of the main decision making methods in the Asian Pacific area. In recent years, TOPSIS has been effectively applied to the fields of human transportation, resources management, quality control, product design, water management, manufacturing, , and location analysis. In addition, TOPSIS has also been linked to group decision making and multi-objective decision making. TOPSIS is able to accommodate more extension to make better comparison sin various conditions. Shanian and Savadogo (2006) proposed an application of the TOPSIS technique to solve the problem of material selection in the case of metallic bipolar plates in polymer electrolyte fuel cell (PEFC), which often includes multiple and conflicting objectives. Olson (2004) considered several applications of TOPSIS using various weighting schemes and distance metrics; then compared the outcomes of different weight sets applied to a set of multiple criteria data. Deng et al. (2000) formulated the inter-company comparison process as a multi-criteria analysis model in their paper, and presented an effective approach by modifying TOPSIS for solving the problem. Jahanshahlooet al. (2009) in their paper proposed an innovative TOPSIS technique for ranking decision making units (DMUs) with interval data resulting in the interval score for each option.

2.3. Fuzzy TOPSIS and Group Fuzzy TOPSIS

Under many conditions, crisp data are insufficient to model real situations. Human decisions are often unclear and cannot assess his preference with a precise quantative value. A more practical approach is to apply linguistic assessments rather than numerical values, i.e. to assume that the weights and ratings of the criteria in a problem are measured through linguistic variables.
If the evaluation values are recognized to have a variety offorms of vagueness or subjectiveness, the classical decision making methods are not practical.

Usually real evaluation problems are not crisply defined because human judgments are uncertain and thus many researchers have proposed fuzzy extensions of the TOPSIS method in order to grasp the vagueness that is inherent in the corresponding evaluation problems.

In real decision making problems, it is necessary to involve several decision makers and experts from different functional areas in the process. Efficient communication between different experts is essential because the better the parties are informed about consultant, the higher the probability that the parties will be committed to supporting this selection. The more different perspectives are initially taken into account and the greater the complexity of convergence, the smaller the chances of addressing the wrong problem and reaching an inadequate solution. There are several "group-based" research methodsfor determining the perceptions or views of individuals about specific topics. The goal of such work is to expand the depth and scale of discussion, wide coverage of viewpoints, and involve members in the selection of priorities and seeking consensus or agreement on the subject in question.Brainstorming, Nominal Group Technique(NGT) and Delphi Focus Groups are formal and practical group management methods. It is not unusual for certain groups to frequently make complicated decisions within institutes. However, for applying any MADM method for instance, TOPSIS, it is generally supposed that the decision statistics is provided by a task group or a team.

A fuzzy multi-criteria decision model was proposed by Seçme et al. (2009) to evaluate the performances of banks. In this model fuzzy AHP (FAHP) and TOPSIS methods are integrated. Afterward the weights for several criteria are determined based on the views of experts via the FAHPtechnique, these weights are inputs to the TOPSIS technique to rank the banks. Gumus (2009) developed a two-step procedure to evaluate hazardous waste transportation firms including the techniques of FAHP and TOPSIS. Yurdakula and Tansel (2009) proposed fuzzy MCDM models to deal with the vagueness and imprecision inherent in the machine tool selection problem. Chamodrakas et al. (2009) applied a new class of fuzzy methods for evaluating customers. In their paper they applied aninnovative model for the aggregation function of TOPSIS that represents the closeness to the ideal and the negative ideal solutionsusing fuzzy numbers. Celik et al. (2009)presented an integratedapproach to ensuring the competitiveness requirements for main Turkish container ports by applying Fuzzy TOPSIS methodologies and fuzzy axiomatic design (FAD) to handle strategic decision-making with insufficient information. Izadikhah(2008) extended the TOPSIS method for dealing with fuzzy data and an algorithm to determine the most preferable choice among all possible choices, when data was fuzzy, was also presented. In this study, to identify the fuzzy ideal solution and fuzzy negative ideal solution one of the Yagers indices which is used for ordering fuzzy quantities in [0, 1] is applied. Mahdavi et al. (2008)utilized a different measurement of fuzzy distance value with a reduced bound of options. In their paper similarity extent of each choiceto fuzzy positive and negative ideal solutions was utilized for ranking the alternatives. Jahanshahloo et al. (2006)expanded the TOPSIS technique to decision-making challenges with fuzzy data. In their paper, the ranking of

each solution and the weight of criteria were stated in triangular fuzzy numbers. The normalized fuzzy numbers were calculated by using the concept of α-cuts. Wang and Elhag(2006) proposed a Fuzzy TOPSIS method in their paper based on alpha level sets and presented a nonlinear programming (NLP) solution procedure. Chen (2000)applied linguistic terms illustrated by triangular fuzzy numbers to determine the rating of each solution and the weight of criteria. Chen et al. (2005)applied linguistic values to measure the ratings and weights of qualitative and quantitative factors. In their work a closeness coefficient is proposed to determine the rankings of suppliers by evaluating the distances to the both FNIS and FPIS concurrently. Wang and Chang (2007) applied the fuzzy MCDM method in their paper to determine the importance weights of evaluation criteria and to synthesize the ratings of candidate aircraft. Deviren et al. (2008) developed an evaluation model based on AHP and TOPSIS method which is handled with linguistic values parameterized by triangular fuzzy numbers. Wang and Lee (2009)presented a novel Fuzzy TOPSIS for assessing alternatives by integrating the subjective and objective weights. They normalized the subjective weights assigned by DMs into a comparable scale and used Shannon's entropy theory to adopt end-user ratings as an objective weight. A closeness coefficient is describedto determine the suitability order of alternatives by evaluating the distances to ideal solutions . TOPSIS method combined with intuitionistic fuzzy set was proposed by Boran et al. (2009) to select appropriate supplier in a group decision making. He used intuitionistic fuzzy weighted averaging (IFWA) operator to aggregate all individual decision makers' opinions for rating importance of criteria and alternatives. Wang and Lee (2007) generalized TOPSIS to fuzzy multiple-criteria group decision-making (FMCGDM) in a fuzzy environment. They presented two operators Up and Lo to ensure the partial ordering relation of fuzzy numbers for the generalizing TOPSIS. Chu and Lin (2009)presented a Fuzzy TOPSIS model, where rankings of options under the criteria and weights of criteria are evaluated in linguistic values illustrated by fuzzy numbers. Rankings of alternatives against criteria and their weights are normalized prior to multiplication. The membership function of each fuzzy weighted rating has been developed by interval arithmetic of fuzzy numbers.

Shih et al. (2007) investigated an extension of TOPSIS technique to a group decision environment. In this study they offered a few alternatives for the operations, such as distance measures, normalization and mean operators, at each of the matching steps of TOPSIS. The preferences of more than one decision maker were also internally aggregated into the TOPSIS procedure. Saremi et al. (2009) proposed a systematic decision process for selecting external consultant. Their proposed method is based on TOPSIS method in fuzzy environment and decision criteria are obtained from the nominal group technique (NGT).

Kahraman et al. (2009) considered an Information systems outsourcing decision problem and proposed an interactive group decision-making methodology to rank Information systems providers. They obtained the group and the individual evaluations using a Fuzzy TOPSIS approach. They applied the proposed methodology in the largest office furniture manufacturer in Konya-Turkey. They also provided Sensitivity analyses to see the effects of parameter changes on the final decision. Önüt et al. (2009) developed a supplier evaluation model based on ANP and TOPSIS methods under fuzzy environment. Contrary to conventional Fuzzy ANP (FANP) methodology, they used triangular fuzzy numbers in all pairwise comparison matrices in the FANP. They applied their model to help a telecommunication company in the GSM sector in Turkey to evaluate and select suppliers involving six main evaluation criteria that the company had determined. Their work was concluded by sensitivity analyses.

Gligoric et al. (2010) considered used Fuzzy TOPSIS method for the multi-criteria evaluation of the location of the base of the shaft location selection at deep multiple ore body deposit in a

problem of strategic planning for underground mine development system design. They used network optimization utilizing Kruskal's algorithm and considering Steiner points to recognize candidate points oralternatives. Awasthi et al. (2010) presented Fuzzy TOPSIS approach for evaluating environmental performance of suppliers. They organized a sensitivity analysis to assess the impact of criteria weights on the evaluation of suppliers' environmental performance. Kara (2011) combined Fuzzy TOPSIS method with a two-stage stochastic programming model for supplier selection problem. She used Fuzzy TOPSIS for ranking potential suppliers considering qualitative data under fuzzy environment then a group of ranked potential suppliers are included in a two-stage stochastic programming model for evaluation. The author considered the model in multi-product, multi-period and multi-sourcing environment. Awasthiet al. (2011) proposed a hybrid method using Fuzzy TOPSIS and SERVQUAL for assessing service quality of metropolitan transportation systems. They presented an application of their methodfor assessment of service quality of subway in Montreal. Kelemenis et al. (2011) proposed a group Fuzzy TOPSIS technique for selecting managers based on their skills regarding the organizational goals. They also applied their model on a case of selecting a middle level manager in a large IT Greek firm. Singh and Benyoucef(2011) proposed a method for solving the e-sourcing problem of sealed bid, multi-attribute reverse auction in which the sales item is characterized by several attributes, the auctioneer is the buyer , and the bidders are the suppliers . They considered both qualitative and quantitative attributes and modeled the winner determination problem as a multi criteria decision making problem. They applied TOPSIS methodology in conjunction with entropy method to compute the weights of the attributes automatically without participation of decision makers. Chamodrakas and Martakos(2011) presented a Fuzzy Set Representation TOPSIS method that takes into account user preferences, network conditions, QoS and energy consumption requirements in order to select the optimal heterogeneous wireless network which seeks to find a balance between performance and energy consumption. They employed utility functions for the elimination of the ranking abnormality problem. They conducted simulations assess suitability and effectiveness of their model. Kaya and Kahraman(2011) presented a revised Fuzzy TOPSIS method for selecting the best energy technology. Fuzzy pairwise comparison matrices determine The weights of the selection criteria. They applied their method to an energy planning decision-making problem. Zeydan et al. (2011) proposed a combined methodology supplier selection and performance evaluation. They considered both qualitative and quantitative variables in evaluating performance for selection of suppliers based on efficiency and effectiveness in one of the biggest car manufacturing factory in Turkey, they performed qualitative performance evaluation by using fuzzy AHP in finding criteria weights and then utilized Fuzzy TOPSIS to obtain the ranking of suppliers. They concluded that the proposed method in comparison with the present system of the car factory, has some benefits and superiorities in buying the suitable car luggage side part (panel) by selecting the appropriateprovider(s) in an automotive factory in Turkey.

Figure 3 illustrates complete and detailed procedure of the group Fuzzy TOPSIS methodology adopted in this work.

A. Arrange the decision-making group.
m possible alternatives: $A=\{A_1,A_2,\ldots,A_m\}$, *K decision makers:* $D=\{D_1,D_2,\ldots,D_k\}$.

B. Define and describe a finite set of relevant attributes.
n Criteria: $C=\{C_1,C_2,\ldots,C_n\}$.

C. Establish a decision matrix for alternative performance for each decision maker the relative importance of attributes.

$\tilde{w}_j^k = (\alpha_j^k, \beta_{ij}^k, \gamma_{ij}^k)\ \tilde{x}_{ij}^k = (\alpha_{ij}^k, \beta_{ij}^k, \gamma_{ij}^k)$

$$\tilde{D}^k = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_i \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccccc} x_1 & x_2 & \cdots & x_j & \cdots & x_n \end{array} \\ \begin{bmatrix} \tilde{x}_{11}^k & \tilde{x}_{12}^k & \cdots & \tilde{x}_{1j}^k & \cdots & \tilde{x}_{1n}^k \\ \tilde{x}_{21}^k & \tilde{x}_{22}^k & \cdots & \tilde{x}_{2j}^k & \cdots & \tilde{x}_{2n}^k \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots \\ \tilde{x}_{i1}^k & \tilde{x}_{i2}^k & \cdots & \tilde{x}_{ij}^k & \cdots & \tilde{x}_{in}^k \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots \\ \tilde{x}_{m1}^k & \tilde{x}_{m2}^k & \cdots & \tilde{x}_{mj}^k & \cdots & \tilde{x}_{mn}^k \end{bmatrix} \end{array}$$

D. Aggregate fuzzy ratings of alternatives with respect to each criterion $\tilde{x}_{ij}$ and fuzzy weights of each criterion $\tilde{w}_j$

$\tilde{X}_{ij} = (\alpha_{ij}, \beta_{ij}, \gamma_{ij})$; $\alpha_{ij} = \frac{1}{k}\sum_{j=1}^{k} \alpha_{ij}^k$

$$\beta_{ij} = \frac{1}{k}\sum_{j=1}^{k} \beta_{ij}^k$$

$$\gamma_{ij} = \frac{1}{k}\sum_{j=1}^{k} \gamma_{ij}^k$$

$\tilde{w}_j = (w_{j1}, w_{j2}, w_{j3})$; $w_{j1} = \frac{1}{k}\sum_{j=1}^{k} w_{j1}^k$

$$w_{j2} = \frac{1}{k}\sum_{j=1}^{k} w_{j2}^k$$

$$w_{j3} = \frac{1}{k}\sum_{j=1}^{k} w_{j3}^k$$

E. Establish final decision matrix for alternative performance.

$$\tilde{D} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mn} \end{bmatrix}$$

F. Establish the normalized decision matrix.

$\tilde{r}_{ij} = \left(\frac{\alpha_{ij}}{\gamma_j^*}, \frac{\beta_{ij}}{\gamma_j^*}, \frac{\gamma_{ij}}{\gamma_j^*}\right)$; if $j \in B$; $\gamma_j^* = max_i \gamma_{ij}$; $\tilde{r}ij = \left(\frac{\alpha_j^-}{\gamma_{ij}}, \frac{\alpha_j^-}{\beta_{ij}}, \frac{\alpha_j^-}{\alpha_{ij}}\right)$; if $j \in C$; $\alpha_j^- = min_i \alpha_{ij}$

G. Construct weighted normalized decision matrix. $\tilde{v}_{ij} = \tilde{r}_{ij} \otimes \tilde{w}_j$

H. Determine FPIS and FNIS as follow:

$A^* = (\tilde{v}_1^*, \tilde{v}_2^*, \tilde{v}_3^*, \ldots, \tilde{v}_n^*)$; $A = (\tilde{v}_1, \tilde{v}_2, \tilde{v}_3, \ldots, \tilde{v}_n)$; $v_j^* = max_i(v_{ij3}^*)$; $v_j^- = min_i(v_{ij1}^-)$

$i = 1,2,\ldots,m$; $j = 1,2,\ldots,n$

I. Calculate the distance of each alternative from FPIS and FNIS

$d_i^* = \sum_{j=1}^{n} d_v(\tilde{v}_{ij}, \tilde{v}_j^*)$; $d_i^- = \sum_{j=1}^{n} d_v(\tilde{v}_{ij}, \tilde{v}_j^-)$; $i = 1,2,\ldots,m$

J. Calculate the relative closeness to the ideal solution.

$Cc_i = \frac{d_i^-}{d_i^* + d_i^-}$ *Where* Cc_i *range belongs to the closed interval [0, 1] and i = 1,2 , … , m*

K. Rank the alternatives in descending order. *A set of alternatives can now be preference ranked according to the descending order of* Cc_i, *and the one with the maximum value of* Cc_i *is the best.*

Fig.3. The procedure of group fuzzy TOPSIS

3. APPLICATION OF THE MODEL: A CASE STUDY

The aforesaid decision-making methodology has been applied to a case of antivirus software selection. Seven alternatives were chosen from among the most popular single client antivirus software in the market. Table 1 lists the alternatives

Antivirus software
1. Norton Antivirus (Home)
2. ESET Nod32 Antivirus (Home)
3. Kaspersky Antivirus (Home)
4. Bitdefender Antivirus Pro
5. Avira Antivir Premium (Home)
6. AVG Anti-Virus (Home)
7. Avast Pro Antivirus

Table 1- Antivirus software chosen for evaluation (Alternatives)

As we adopted a group decision making approach, three decision makers (DMs) were chosen for weighting the criteria and examination of alternatives against the criteria. The DMs are IT experts who have substantial experience in computer security issues. Seven criteria were identified by DMs for decision-making on antivirus software as given in table 2.

Criteria	**Explanation**
Power (C1)	Ability to prevent viruses, spyware, malware
Low System Resources Consumption (C2)	Low impact on the performance of the computer and resources usage
Ease of use (C3)	User friendly interface
Avoiding unwanted deletion (C4)	Low false positive chances which leads to deletion of non-malware files
Updates (C5)	Frequent download of updates files; Easy and rapid updates.
Scanning Speed (C6)	The time taken for scanning the system.
Price (C7)	The price of the specific version in the market (converted to $)

Table 2-Criteria used for the selection of antivirus software

Descriptions of the chosen criteria are provided below:

Power of antivirus is generally referred to as ability to prevent viruses, spyware, malware, and so on. The broader approach encompasses scope of protection and effectiveness of the antivirus. The most suitable antivirus solutions will have traditional protection against worms, Trojans, viruses and spyware, but should also include defense against phishing scams rootkits, email-borne threats, and key loggers. Although antiviruses are not full-blown internet protection suites, they should defend as many risks on as many fronts as they can. Antivirus is specifically designed to protect computers and nothing can make up for poor performance. We try to find the best software and evaluate it effectiveness.

Users have always suffered from the system slow-down caused by installed software. This makes the user experience of working with the system tiring and painful. Slow system performance is so

intolerable for users that may lead to permanently abandoning software with a highly negative perception. Thus the antivirus products are forced to reduce the system resources usage and cause the lowest impact on the system performance.

Ease of use is a critical feature for every IT tool. Users cannot spend much time on learning how specific software works. Installing and implementing antivirus software should be quick and easy. The most suitable security programs have all the attributes security specialists want, but are just as simply used by a novice and have a friendly interface. The best antivirus software is flexible enough for experts to do exactly what they want to, accessible enough for the rest of users and robust enough for everyone.

Deleting a legitimate file as a consequence of a false positive by the antivirus is again very disappointing and leads to a very bad user experience. Users prefer that the antivirus act under their control and avoid deleting files without user's permission. Antivirus features should be quickly turned off whenever desired.

Security programs are only as useful as their newest update. Viruses are being identified and added to signature databases all the time, so it's important that the virus definition list updates accordingly in short periods. Modern antivirus software is equipped with automatic updates that perform regularly enough that users get faster updates that don't slow down your system. The best security providers even "push" updates to users as soon as they're available.

Time is the most critical limitation of today's user. A well-developed antivirus scans the system as fast as possible. With growing size of data and information stores on computers the scanning speed is becoming more and more important. A time-consuming scanning process is painful for users and eventually leads to disuse of the product.

Finally users may have budget limitations and prefer a cheaper product that can still maintain the security standards. This is especially true for individuals in developing countries whose income is limited.

For each criterion a fuzzy importance weight ($\tilde{W}_j$) is defined. The decision-makers use the linguistic weighting variables to assess the importance of the criteria (Table 3); the ratings of alternatives are represented by linguistic rating variables (Table 4). The linguistic variables used by the DMs are transformed into triangular fuzzy numbers.

Linguistic data	**Triangular fuzzy number (TFN)**
Very low (VL)	(0,0.1,0.3)
Low (L)	(0.1,0.3,0.5)
Medium (M)	(0.3,0.5,0.7)
High (H)	(0.5,0.7,0.9)
Very high (VH)	(0.7,0.9,1)

Table 3-Linguistic variables for importance of the criteria

Linguistic data	Triangular fuzzy number (TFN)
Very poor (VP)	(0,0.1,0.2)
Poor (P)	(0,0.2,0.4)
Medium (M)	(0.2,0.4,0.6)
Good (G)	(0.4,0.6,0.8)
Very good (VG)	(0.6,0.8,1)
Excellent(E)	(0.8,0.9,1)

Table 4-Linguistic variables for ratings of the alternatives

Both the weights of the criteria and the performance ratings of alternatives against the criteria are determined by these three decision-makers and aggregated into triangular fuzzy numbers (table 5, 6).

Criteria	Decision makers			Aggregate Weight ($\tilde{w}_j$)
	D1	D2	D3	
Power	VH	H	VH	(0.63,0.83,0.97)
Low System Resources Consumption	H	H	VH	(0.57,0.77,0.93)
Ease of use	L	L	L	(0.1,0.3,0.5)
Avoiding unwanted deletion	M	H	L	(0.3,0.5,0.7)
Updates	M	L	L	(0.17,0.37,0.57)
Scanning Speed	M	M	H	(0.37,0.57,0.77)
Price	VH	VH	H	(0.63,0.83,0.97)

Table 5- Weights of criteria solicited from three decision makers ($\tilde{W}_j$)

Criteria	Alternatives	Decision-makers			Aggregate Fuzzy Performance Rate ($\tilde{x}_{ij}$)
		D1	D2	D3	
C1	A1	H	H	VH	(0.47,0.67,0.87)
	A2	L	L	M	(0.07,0.27,0.47)
	A3	E	E	VH	(0.73,0.87,1)
	A4	M	M	M	(0.2,0.4,0.6)
	A5	H	H	H	(0.4,0.6,0.8)
	A6	M	L	L	(0.07,0.27,0.47)
	A7	VH	VH	VH	(0.6,0.8,1)
C2	A1	L	M	L	(0.07,0.27,0.47)
	A2	E	E	E	(0.8,0.9,1)
	A3	VL	L	L	(0,0.17,0.33)
	A4	VL	L	VL	(0,0.13,0.27)
	A5	M	M	H	(0.27,0.47,0.67)
	A6	L	M	L	(0.07,0.27,0.47)
	A7	H	M	M	(0.27,0.47,0.67)
C3	A1	VL	L	L	(0,0.17,0.33)
	A2	H	VH	VH	(0.53,0.73,0.93)
	A3	M	L	M	(0.13,0.33,0.53)
	A4	L	M	VL	(0.07,0.23,0.4)

	A5	H	M	VH	(0.4,0.6,0.8)
	A6	VL	L	M	(0.07,0.23,0.4)
	A7	M	M	L	(0.13,0.33,0.53)
C4	A1	H	M	M	(0.27,0.47,0.67)
	A2	VH	VH	VH	(0.6,0.8,1)
	A3	E	E	H	(0.67,0.8,0.93)
	A4	M	L	VL	(0.07,0.23,0.4)
	A5	M	H	H	(0.33,0.53,0.73)
	A6	L	L	VL	(0,0.17,0.33)
	A7	H	H	H	(0.4,0.6,0.8)
C5	A1	L	VL	L	(0,0.17,0.33)
	A2	M	L	L	(0.07,0.27,0.47)
	A3	L	L	M	(0.07,0.27,0.47)
	A4	L	L	M	(0.07,0.27,0.47)
	A5	H	H	H	(0.4,0.6,0.8)
	A6	VH	VH	E	(0.67,0.83,1)
	A7	VH	VH	H	(0.53,0.73,0.93)
C6	A1	L	L	M	(0.07,0.27,0.47)
	A2	H	M	H	(0.33,0.53,0.73)
	A3	L	L	VL	(0,0.17,0.33)
	A4	L	VL	VL	(0,0.13,0.27)
	A5	M	M	H	(0.27,0.47,0.67)
	A6	H	M	M	(0.27,0.47,0.67)
	A7	H	H	M	(0.33,0.53,0.73)

Table 6-Performance rates of alternatives

The seventh criterion (Price) is deterministic and inquired of the clients. Thus the prices are presented as crisp numbers that can easily be transformed into triangular fuzzy numbers and treated as TFN in Fuzzy-TOPSIS procedures.

Alternative	A1	A2	A3	A4	A5	A6	A7
Price (C7)	50	47	50	40	35	45	50

Table 7- Price of the Alternatives

Once the weights of the criteria and ratings of the criteria are obtained, group Fuzzy TOPSIS procedures (Figure 3) are applied to transform the data into closeness coefficients as an aggregated measure for selecting the best antivirus software. Table 8 presents the normalized performance rates.

Criteria	Alternatives			
	A1	**A2**	**A3**	**A4**
C1	(0.47,0.67,0.87)	(0.07,0.27,0.47)	(0,0.18,0.36)	(0.27,0.47,0.67)
C2	(0.07,0.27,0.47)	(0.8,0.9,1)	(0.57,0.79,1)	(0.6,0.8,1)
C3	(0.73,0.87,1)	(0,0.17,0.33)	(0.14,0.36,0.57)	(0.67,0.8,0.93)

C4	(0.2,0.4,0.6)	(0,0.13,0.27)	(0.07,0.25,0.43)	(0.07,0.23,0.4)
C5	(0.4,0.6,0.8)	(0.27,0.47,0.67)	(0.43,0.64,0.86)	(0.33,0.53,0.73)
C6	(0.07,0.27,0.47)	(0.07,0.27,0.47)	(0.07,0.25,0.43)	(0,0.17,0.33)
C7	(0.6,0.8,1)	(0.27,0.47,0.67)	(0.14,0.36,0.57)	(0.4,0.6,0.8)

Table 8-Normalized Performance Rates $\tilde{r}_{ij}$

The normalized performance rates are then multiplied by the weight of criteria to give weighted normalized performance rates (table 9).

Criteria	**Alternatives**			
	A1	**A2**	**A3**	**A4**
C1	(0.3,0.56,0.84)	(0.04,0.2,0.44)	(0,0.05,0.18)	(0.08,0.23,0.47)
C2	(0.04,0.22,0.45)	(0.45,0.69,0.93)	(0.06,0.24,0.5)	(0.18,0.4,0.7)
C3	(0.46,0.72,0.97)	(0,0.13,0.31)	(0.01,0.11,0.29)	(0.2,0.4,0.65)
C4	(0.13,0.33,0.58)	(0,0.1,0.25)	(0.01,0.08,0.21)	(0.02,0.12,0.28)
C5	(0.25,0.5,0.77)	(0.15,0.36,0.62)	(0.04,0.19,0.43)	(0.1,0.27,0.51)
C6	(0.04,0.22,0.45)	(0.04,0.2,0.44)	(0.01,0.08,0.21)	(0,0.08,0.23)
C7	(0.38,0.67,0.97)	(0.15,0.36,0.62)	(0.01,0.11,0.29)	(0.12,0.3,0.56)

Table 9-Weighted Normalized Performance Rates $\tilde{v}_{ij} = \tilde{r}_{ij} \otimes \tilde{w}_j$

Now we can calculate the fuzzy positive and negative ideal solutions (FPIS and FNIS) by using the weighted normalized performance rates matrix (table 10).

Ideal Solutions	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**
A^*	(0.97,0.97,0.97)	(0.93,0.93,0.93)	(0.5,0.5,0.5)	(0.7,0.7,0.7)	(0.57,0.57,0.57)	(0.77,0.77,0.77)	(0.97,0.97,0.97)
A^-	(0.04,0.04,0.04)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0.44,0.44,0.44)

Table 10-Positive and negative ideal solutions

For each alternative its distances to FPIS and FNIS are calculated. Then closeness coefficients (CC_j) are calculated for each alternative which is the final measure of suitability of the alternatives. Finally the alternatives are ranked based on their CC_j. (table 11)

Alternatives	**Distance D^{*+}**	**Distance D^{*-}**	**CC_j**	**Rank**
Norton Antivirus (Home)	3.540	1.835	0.341	6
ESET Nod32 Antivirus (Home)	2.936	2.640	0.473	3
Kaspersky Antivirus (Home)	3.328	2.068	0.383	4
Bitdefender Antivirus Pro	3.839	1.445	0.273	7
Avira Antivir Premium (Home)	2.856	2.693	0.485	1
AVG Anti-Virus (Home)	3.577	1.863	0.342	5
Avast Pro Antivirus	2.904	2.661	0.478	2

Table 11-The distances of alternatives to positive/negative ideal solutions, the related closeness coefficients (CCj) and the rankings

As observed in table 11, with this set of criteria weights the most suitable antivirus software would be Avira Antivirus Premium (Home).

4. SENSITIVITY ANALYSIS

When conditions of uncertainty exist for parameters, sensitivity analyses are performed. One-at-a-time procedures investigate the sensitivity of the measure of effectiveness to changes in a single parameter (Kahraman et al., 2009)
In each step of analyses we change the weight of a criterion from very low to very high while keeping the weights acquired from the decision makers for other criteria. Since in different conditions of users the importance of the power, low system resource consumption and price varies significantly we implement the sensitivity analysis on these three criteria. In the following section we are seeking to find how the closeness coefficients and the ratings of the alternatives will change when the weightings of the selected criteria change.

The initial ranking obtained in earlier sections could be considered as a general solution applicable to all situations. On the other hand in specific conditions such as when using a personal computer with sufficient resources, a laptop computer with limited resources, a computer in an organization on which no important data is stored and so on, the needs vary and the weights of the criteria will differ. The changes in importance of the criteria in sensitivity analyses can be considered as switching between these conditions. The authors believe that the results of the analyses gives valuable insight into understanding the security needs in different situations and selecting the best solution for each situation.

4.1. Sensitivity AnalysisFor Power

In this section we analyze the sensitivity of the rankings and CC_j to the weight of power. The initial fuzzy weight of the power criterion, solicited from the decision makers and aggregated, was (0.63, 0.83, 0.97). We change this weight from very low, i.e. (0,0.1,0.2) to very high, i.e. (0.8,0.9,1) at each step and calculated rankings while keeping the weights of the other criteria as solicited from the decision makers. Figure 4 illustrates the results.

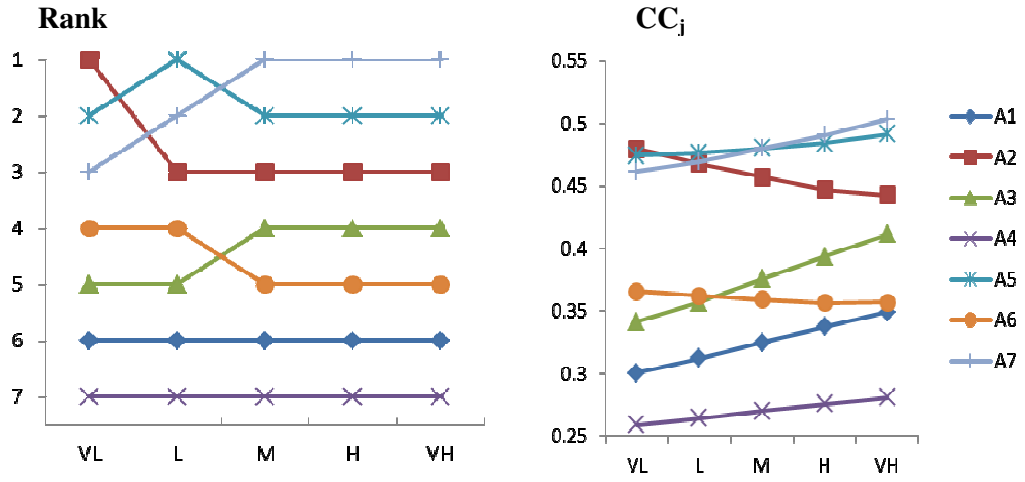

Fig. 4. One-at-a-time sensitivity analysis for power.

As we see the rankings vary when the importance of power changes. When the weight of power is very low A2 is ranked first. In comparison with A5 and A7 this alternative performs particularly well in low system resource consumption while not very well in power; thus when the importance of power increases, the CC_j of A2 decreases significantly. A7 does a little better in power compared to A5, thus in lower power weights A5 is superior and in higher power weights A7 ranks higher. Also A3 is well-known for its power while not performing well in other criteria especially in low system resource consumption. This, results in a lower rank compared to A7, A5 and A3 but significant increase in CC_j by increasing the power weight. This is also true for A1 to a lower extent.

Note that when power is medium important A5 and A7 score the same and A7 is more sensitive to power; which implies that the two alternatives are generally performing the same and the weight of power can make a significant difference between them and determines the best one.
By extrapolating the trends in the chart it can be deducted that in conditions that power is extremely more important than other criteria the best solution would be A3. This condition is especially applicable to individual and organizational computer users who want to maintain a higher security margin while not compromising other factors significantly.

4.2. Sensitivity AnalysisFor Low System Resources Consumption

In this section we analyze the sensitivity of the rankings and CC_j to the weight of low system resources consumption. The initial fuzzy weight of this criterion, solicited from the decision makers and aggregated, was (0.57, 0.77, 0.93). Figure 6 illustrates the results.

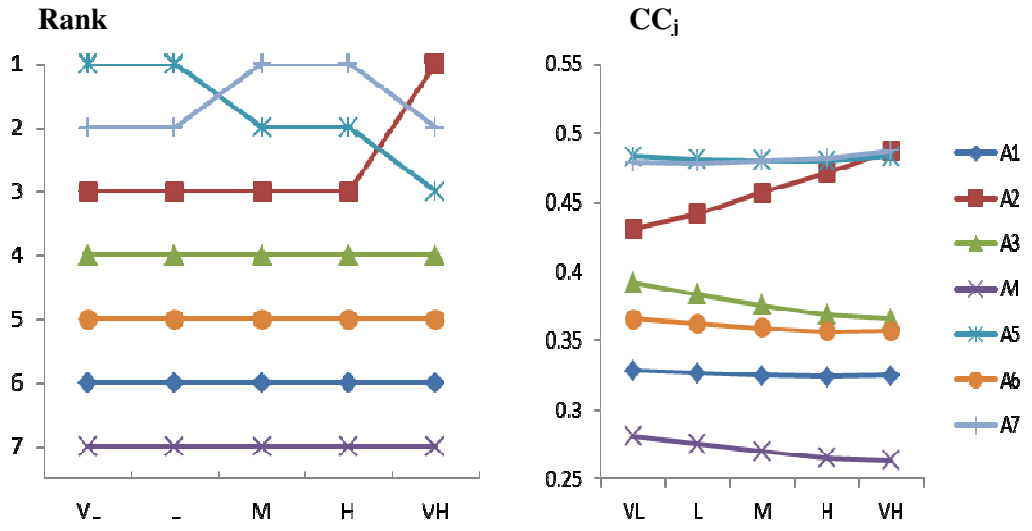

Fig. 5. One-at-a-time sensitivity analysis for low resource consumption.

As we can see the most significant point in the above figure is the increase in CC_j and rank of A2 which over scores other alternatives when the importance of low system resources consumption increases. A decreasing trend is seen in the CC_j of A3 which implies its high impact on the performance of the computer. A5 and A7 obtain almost the same CCj with A7 doing slightly better in low system resources usage which results in over scoring A5 with increase in the weight of this criterion.

By extrapolating the trends in the chart it can be deducted that in conditions that resources are very limited the best solution would be A2. This alternative provides a good security while using low system resources thus it would be closer to the positive ideal and farther from the negative ideal under limited resources. This condition is especially applicable to laptop users.

4.3. Sensitivity AnalysisFor Price

In this section we analyze the sensitivity of the rankings and CC_j to the weight of price. The initial fuzzy weight of this criterion, solicited from the decision makers and aggregated, was (0.63,0.83,0.97). Figure 6 illustrates the results.

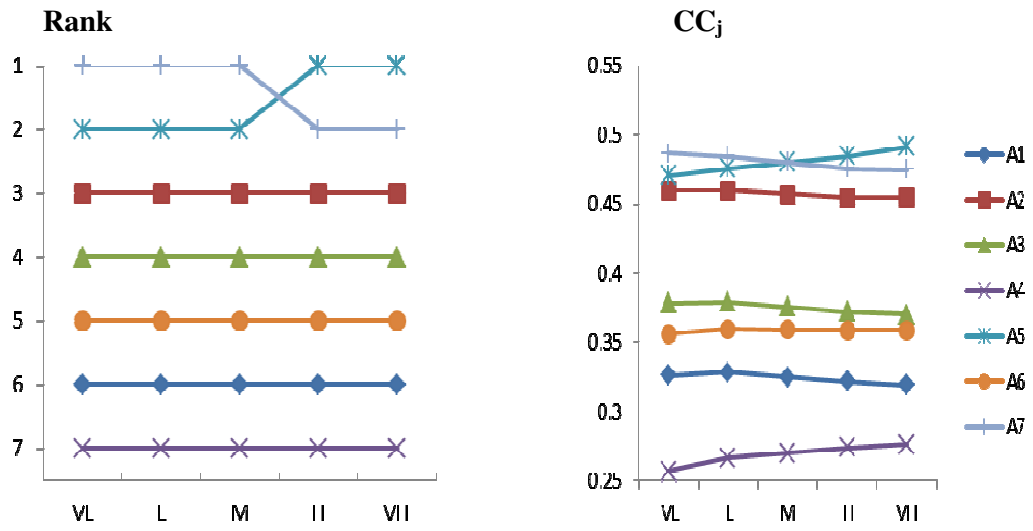

Fig. 6. One-at-a-time sensitivity analysis for price.

As observe in the above figure A5 over scores A7 and ranks first in a condition that price is important, while A5 ranks first when price is not important. This implies that for conditions in which price is determinant the best solution is A5. A7 does well in other criteria while having higher price compared to A5. This leads to a decrease in its suitability and rank when price gets more important. Note that when price is medium important A5 and A7 score the same and A5 is more sensitive to price; which implies that the two alternatives are generally performing the same and the weight of price can make a significant difference between them and determines the best one.

We observed that A2, A5, A7 are always in top three as each does better against specific criteria and worse against others. The user conditions and criteria weights will determine which one is the best.

5. CONCLUSION

Institutes and individuals nowadays need to have an all-inclusive virus protection strategy to face the growing risks of the computer malwares. The risk of malwares is a major concern for users and antivirus software are essential tools to prevent, detect, and remove malwares. They have

significant impact on the efficiency of computers defense systems. Selecting antivirus programshas a considerable impact on the protection of a computer system.
There are many antivirus products available and there are many factors that have impact on the selection of an antivirus thus analyzing their features and valuating them is a complicated issue for users which can be formulated as a multiple criteria decision making problem. The information accessible for utilization in multiple criteria decision making is typically uncertain, vague, or imprecise. Thus linguistic values and fuzzy numbers are used to capture the vague and imprecise nature of decision makers' judgments.
In this work we determined criteria for antivirus selection. This work studied a real world case study in the antivirus market involving seven alternatives and seven criteria determined to choose the most appropriate antivirus software. The most popular antivirus software in the market are short listed and studied to determine how they perform against the introduced criteria.

The paper is followed by the sensitivity analyses of the results. The analysis revealed the impact of changes in the importance of criteria (Power, System resources consumption and Price) on the ranking of alternatives. We observed that A2, A5, A7 are always in top three as each does better against specific criteria and worse against others. The user conditions and criteria weights will determine which one is the best.

This study can be further extended. We used Fuzzy-TOPSIS methodology because of its simplicity and applicability to the problem. Fuzzy-AHP and other multiple attribute decision making methodologies can also be used in this problem. More detailed criteria and sub-criteria can be introduced and the interactions among the criteria and sub-criteria can be encompassed in the model. In this work we studied one-client software while other versions can be studied especially in a network environment.

REFERENCES

[1] A.Awasthi, S.S.Chauhan, & S.K. Goyal, (2010) "A fuzzy multicriteria approach for evaluating environmental performance of suppliers", *International Journal of Production Economics,*Vol. 126, No. 2, pp 370-378.

[2] A.Awasthi,S. S.Chauhan,H.Omrani, &A.Panahi, (2011) "A hybrid approach based on SERVQUAL and Fuzzy TOPSIS for evaluating transportation service quality", *Computers & Industrial Engineering*, In Press, doi:10.1016/j.cie.2011.04.019.

[3] F. E.Boran, M.Kurt, & D. Akay, (2009) "A multi-criteria intuitionistic fuzzy group decision making for selection of supplier with TOPSIS method", *Expert Systems with Applications,*Vol. 36,pp 11363-11368.

[4] M. Celik, S. Cebi, C. Kahraman, & I. DehaEr, (2009) " Application of axiomatic design and TOPSIS methodologies under fuzzy environment for proposing competitive strategies on Turkish container ports in maritime transportation network", *Expert Systems with Applications,* Vol. 36,pp 4541–4557.

[5] I.Chamodrakas, N. Alexopoulou, & D. Martakos, (2009)"Customer evaluation for order acceptance using a novel class of fuzzy methods based on TOPSIS", *Expert Systems with Applications,* Vol. 36,pp 7409–7415.

[6] I.Chamodrakas, & D. Martakos, (2011) " A utility-based Fuzzy TOPSIS method for energy efficient network selection in heterogeneous wireless networks", *Applied Soft Computing,* Vol. 11, No. 4, pp 3734-3743.

[7] C.T. Chen, (2000) " Extensions of the TOPSIS for group decision-making under fuzzy environment", *Fuzzy sets and systems,* vol. 114,No. 1,pp 1–9.

[8] C.T. Chen, C.T. Linb, &S.F. Huang, (2005) "A fuzzy approach for supplier evaluation and selection in supply chain management", *International Journal of Production Economics,* Vol. 102, pp289-301.

[9] T.C. Chu, &Y.C. Lin, (2009) " An interval arithmetic based Fuzzy TOPSIS model", *Expert Systems with Applications,* Vol. 36, pp10870-10876.

[10] H.Deng, C.H. Yeh& R.J. Willis, (2000) " Inter-company comparison using modified TOPSIS with objective weights", *Computers & Operations Research,*Vol. 27, pp963-973.

[11] M.D. Deviren, S. Yavuz& N. Kılınç, (2008) "Weapon selection using the AHP and TOPSIS methods under fuzzy environment", *Expert Systems with Applications,* Vol. 36, pp8143-8151.

[12] Z.Gligoric, C. Beljic& V. Simeunovic, (2010) "Shaft location selection at deep multiple orebody deposit by using Fuzzy TOPSIS method and network optimization", *Expert Systems with Applications,* Vol. 37, No. 2, pp 1408-1418.

[13] A.T.Gumus, (2009) "Evaluation of hazardous waste transportation firms by using a two-step fuzzy-AHP and TOPSIS methodology", *Expert Systems with Applications,* Vol. 36, pp4067–4074.

[14] C.L. Hwang& M.J Lin, (1987) *Group Decision Making under Multiple Criteria*, Berlin, Springer-Verlag.

[15] C. L. Hwang &K.Yoon, (1981) *Multiple Attribute Decision Making*, Berlin, Springer-Verlag.

[16] M.Izadikhah, (2008) "Using Hamming distance to extend TOPSIS in fuzzy environment", *Journal of Computational and Applied Mathematics,* Vol. 231, pp200-207.

[17] G.R.Jahanshahloo, F.H. Lotfi, & A.R. Davoodi, (2009) " Extension of TOPSIS for decision-making problems with interval data: Interval efficiency", *Mathematical and Computer Modelling,* Vol. 49, pp1137- 1142.

[18] G.R. Jahanshahloo, F.H. Lotfi& M. Izadikhah, (2006) "Extension of the TOPSIS method for decision-making problems with fuzzy data", *Applied Mathematics and Computation,* Vol. 181, pp1544–1551.

[19] G. Kabir& M. A. A. Hasin, (2011) "Comparative Analysis of AHP and Fuzzy AHP Models for multicriteria inventory classification", *International Journal of Fuzzy Logic Systems*,Vol.1, No.1, pp1-16.

[20] C. Kahraman,O.Engin,Ö.Kabak&İ.Kaya, (2009) "Information systems outsourcing decisions using a group decision-making approach", *Engineering Applications of Artificial Intelligence,* Vol. 22,No. 6, pp832-841.

[21] S.S.Kara, (2011) " Supplier selection with an integrated methodology in unknown environment", *Expert Systems with Applications,* Vol. 38, No. 3, pp2133-2139.

[22] T.Kaya& C. Kahraman, (2011) " Multicriteria decision making in energy planning using a modified Fuzzy TOPSIS methodology", *Expert Systems with Applications,* Vol. 38, No. 6, pp6577-6585.

[23] A. Kaufmann &M.M.Gupta (1991) *Introduction to Fuzzy Arithmetic: Theory and Applications*, New York, Van Nostrand Reinhold.

[24] A. Kelemenis, K. Ergazakis& D. Askounis, (2011) "Support managers' selection using an extension of fuzzy TOPSIS", *Expert Systems with Applications,* Vol. 38, No. 3 , pp2774-2782.

[25] G. Kim, C.S. Park&K.P. Yoon, (1997) "Identifying investment opportunities for advanced manufacturing systems with comparative-integrated performance measurement", *International Journal of Production Economics,* Vol. 50, pp23–33.

[26] I. Mahdavi,A.N.Mahdavi, A. Heidarzade& R. Nourifar, (2008) "Designing a model of Fuzzy TOPSIS in multiple criteria decision making", *Applied Mathematics and Computation,* Vol. 206, pp607–617.

[27] F. Mamaghani, (2002) " Evaluation and selection of an antivirus and content filtering software", *Information management & computer security,* Vol. 10(1), pp28-32.

[28] D.L. Olson, (2004) "Comparison of Weights in TOPSIS Models", *Mathematical and Computer Modelling,* Vol. 40, pp721-727.

[29] S.Önüt, S.S. Kara & E. Işik, (2009) "Long term supplier selection using a combined fuzzy MCDM approach: A case study for a telecommunication company", *Expert Systems with Applications,* Vol. 36, No. 2, pp3887-3895.

[30] M. Saremi, S.F. Mousavi& A. Sanayei, (2009) "TQM consultant selection in SMEs with TOPSIS under fuzzy environment", *Expert Systems with Applications,* Vol. 36, pp2742–2749.

[31] P. Sasikumar, G. Kannan, (2008) " Issues in reverse supply chain, part II: reverse distribution issues – an overview", *International Journal of Sustainable Engineering,* Vol. 1, No. 4, pp234–249.

[32] N.Y. Seçme, A. Bayrakdaroglu& C. Kahraman, (2009) "Fuzzy performance evaluation in Turkish Banking Sector using Analytic Hierarchy Process and TOPSIS", *Expert Systems with Applications,* Vol. 36, 11699-11709.

[33] A.Shanian& O. Savadogo, (2006) " TOPSIS multiple-criteria decision support analysis for material selection of metallic bipolar plates for polymer electrolyte fuel cell", *Journal of Power Sources,* Vol. 159, pp1095 –1104.

[34] H.S. Shih, H.J. Shyurb&E.S. Lee (2007) "An extension of TOPSIS for group decision making", *Mathematical and Computer Modelling,* Vol. 45, pp801–813.

[35] R.K. Singh & L. Benyoucef, (2011) "A Fuzzy TOPSIS based approach for e-sourcing", *Engineering Applications of Artificial Intelligence,* Vol. 24, No. 3, pp437-448.

[36] T.C. Wang & T.H. Chang, (2007) "Application of TOPSIS in evaluating initial training aircraft under a fuzzy environment", *Expert Systems with Applications,* Vol. 33, pp870–880.

[37] Y.M. Wang & T.M.S. Elhag, (2006) "Fuzzy TOPSIS method based on alpha level sets with an application to bridge risk assessment", *Expert Systems with Applications,* Vol. 31, pp309–319.

[38] Y.J.Wang&H.S. Lee, (2007) "Generalizing TOPSIS for fuzzy multiple-criteria group decision-making", *Computers and Mathematics with Applications,* Vol. 53, pp1762–1772.

[39] T.C. Wang &H.D. Lee, (2009) "Developing a Fuzzy TOPSIS approach based on subjective weights and objective weights", *Expert Systems with Applications,* Vol. 36, pp8980–8985.

[40] M. Yurdakul&Y.TanselIç, (2009) "Analysis of the benefit generated by using fuzzy numbers in a TOPSIS model developed for machine tool selection problems", *journal of materials processing technology*, Vol. 209, pp310–317.

[41] M. Zeydan, C. Çolpan& C. Çobanoğlu, (2011) "A combined methodology for supplier selection and performance evaluation", *Expert Systems with Applications,* Vol. 38, No. 3, pp2741-2751.

[42] H.J. Zimmermann, (1991) *Fuzzy set theory and its applications*, (2nd ed.), Boston, Kluwer Academic Publishers.

Authors

DavoudGoli is a graduate researcher at KNT University of Technology. He holds a B.Sc degree in Industrial Engineering from the KNT University. His main field of interest is Decision Making Methodologies. His current research is focused on developing new decision support system for real industrial problems.