Proceedings of the 2014 Federated Conference on
Computer Science and Information Systems pp. 183–190

DOI: 10.15439/2014F203
ACSIS, Vol. 2

FUZZY VIKOR APPROACH: EVALUATING QUALITY OF INTERNET HEALTH INFORMATION

Eric Afful-Dadzie
Faculty of Applied Informatics
Tomas Bata University in Zlin
Czech Republic
Email: afful@fai.utb.cz

Stephen Nabareseh
Faculty of Management and Economics.
Tomas Bata University in Zlin.
Czech Republic
Email: nabareseh@fame.utb.cz

Zuzana Komínková Oplatková
Faculty of Applied Informatics
Tomas Bata University in Zlin
Czech Republic
Email: oplatkova@fai.utb.cz

Abstract—Proliferation of health related information on the internet is both welcoming and a concern. For instance when solicited information goes wrong, it tends to have dire consequences on the general public. Assessing the quality of internet health information is often difficult but a rational and systematic approach can be useful in evaluating the quality of the services they render to the public. The paper proposes a fuzzy VIKOR framework for evaluating and ranking internet health information providers under a fuzzy environment where uncertainties and subjectivities are catered for with linguistic variables. Linguistic variables with triangular fuzzy numbers (TFN) are used to evaluate weights of the evaluation criteria and the rankings of each internet health information provider. A numerical example is demonstrated using HIV/AIDS online information providers in the most adult prevalent country in the world. The proposed method is compared with TOPSIS and can be applied in evaluating the quality of other specific internet health information providers.

I. Introduction

HEALTH information, until the advent of the internet, was the exclusive preserve of medical professionals. Today, with high-speed broadband, smart mobile devices and wireless networks, more people rely on the internet for a range of health information support [1], [2]. Users often read about specific medical conditions, communicate in real-time with health care providers via chat rooms and answer health assessment questionnaires online [3], [4]. Majority of the people who search online for health advice do so to be better informed and prepared when consulting their physicians or just to reassure themselves of the status of their health. However, while most of the internet health information comes from authoritative sources such as governmental agencies, research institutions, product vendors, medical centres and individual professionals [45], a lot more of them also come from sources who though well-intentioned, tends to misinform and mislead users. This phenomenon breeds mistrust and presents issues of credibility regarding the source or the websites from which information is sought.

In Korea and China where online health information assists the aged in particular to take good care of themselves by adhering to personal care practices and avoiding illnesses [5], [6] misinformation can be fatal to their health. In the US, there are increasing numbers of citizens managing their health mainly from the information they seek online [7], [8] especially those who are unable to access certain health insurance supports. Such people are vulnerable to misleading information.

The growth in the number of people searching for health related information online has seen a corresponding increase with unregulated sites offering unprofessional advice. Additionally, a study in [9] found that health anxious individuals often do not care about the credibility of an online health information forum provided the information is reassuring and allays their fears. Health anxiety [10], [11], raises fears and often misconception about potential severity of ones' illnesses. In another study on changes occurring in the use of e-health services [12], two thirds of the respondents never checked for assurance of privacy of websites visited and 23% could not recollect the specific name of the site used. Whiles this is frightening, more worrying is that majority of the authors of online health information are not health professionals nor trained to author health information [13], [14], [15].

Subsequently, a number of studies have come out with models and frameworks for assessing the quality of online health information. Some of the notable criteria used in evaluating the quality of internet health information are accuracy, authority, currency, disclaimer, design, and security among others. This study makes a contribution by using fuzzy mathematics and VIKOR multi-criteria decision making (MCDM) technique to demonstrate how online health information providers could be ranked on a number of established criteria. The purpose is to guide users in their choice of websites for health related information. The concept and steps in fuzzy VIKOR are explained and a numerical example is performed using the websites of top 4 HIV/AIDS support organizations in Swaziland to show the usefulness of the technique in ranking health related information providers in any topical area.

II. Fuzzy MCDM

Multi-criteria decision making (MCDM) as a modelling and methodological tool is used to deal with complex decision making problems. MCDM has over the years become one of the most well-known branches of decision making [16], [17] applied in many disciplines. Fuzzy logic has proven to be a useful and efficient way in approaching MCDM in situations of imprecise or subjective data in our natural language expression of thoughts and judgements. Since Bellman and Zadeh [18] proposed decision making in fuzzy environment, many extended theories and applications have been carried out to tackle various forms of MCDM. Among few of the Fuzzy MCDM applications are [19] where fuzzy Entropy and t-norm based fuzzy compromise programming is used in locating nuclear power plants in Turkey. In [20], a fuzzy linear programming MCDM model is used in allocating orders to suppliers in a supply chain under uncertainty environment, [21] employed fuzzy MCDM to measure the possibility of successful knowledge management. A hybrid fuzzy MCDM approach based on DEMATEL, ANP and TOPSIS is proposed by [22] to evaluate green suppliers and in [23] a conjunctive MCDM approach also based on DEMATEL, fuzzy ANP, and TOPSIS is modelled as an innovation support system for Taiwanese higher education.

Fuzzy logic has been extended to almost all other MCDM techniques such as Analytic Hierarchy Process (AHP), Analytic Network Process (ANP), ELimination and Choice Expressing REality (ELECTRE), Grey Relational Analysis (GRA), Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Weighted Product Model and VIsekriterijumska optimizacija i KOmpromisno Resenje (VIKOR).

III. FUZZY VIKOR METHOD

VIKOR is a compromise ranking method introduced by Opricovic [24]. The VIKOR method first establishes (1) a compromise ranking-list, (2) a compromise solution, and (3) the weight stability intervals for the compromise solution [24], [25]. It then determines the positive-ideal solution and the negative-ideal solution to aid in ranking and selection [26]. The underlying principle of the VIKOR MCDM method is to deal with ranking and selection of alternatives which have multi-conflicting or non-commensurable criteria [27].

As is usual of most MCDM techniques, the VIKOR method was also extended to accommodate subjectivity and imprecise data under fuzzy environment [28]. A number of applications from various disciplines have been carried out using the fuzzy VIKOR method. In [29], fuzzy VIKOR is used in selecting insurance companies in a group decision making process whiles [30] employed fuzzy VIKOR to resolve multi-criteria decision-making problems. The method is used by [31], [32] for supplier selection problems. In [32], however, the method is modified using entropy measure for objective weighting. In [33] fuzzy VIKOR is utilized for optimized partners' choice in IS/IT outsourcing projects. In [34] the compromise method is used to select renewable energy project in Spain. Similarly in [35] an integrated fuzzy VIKOR and AHP methodology is used to plan renewable energy in Istanbul. In [36] a combined form of fuzzy VIKOR and GRA techniques is utilized to evaluate service quality of airports, [37] applied fuzzy VIKOR for material selection and [38] used fuzzy VIKOR in a robot selection. Again in [39], fuzzy VIKOR based on DEMATEL and ANP is utilized in assessing information security risk control. The literature reviewed portrays the underlying principle of the VIKOR method for selecting and ranking problems but seldom applied in evaluation of service quality.

IV. FUZZY SET THEORY

The human language is filled with imprecision, subjectivities and vagueness when used to judge, describe and communicate information. In view of this, Zadeh [24] introduced the fuzzy set theory to model human judgements. The following are some useful definitions of the fuzzy set theory.

Definition 1: Fuzzy Set. Let X be a nonempty set, the universe of discourse $X = \{x_1, x_2, ..., x_n\}$. A fuzzy set A of X is a set of ordered pairs: $\{(x_1, f_A(x_1)), (x_2, f_A(x_2)), \ldots, (x_n, f_A(x_n))\}$, characterized by a membership function $f_A(x)$ that maps each element x in X to a real number in the interval $[0,1]$. The function value $f_A(x)$ stands for the membership degree of x in A. To capture the vagueness and variations in the subjective ratings of a decision maker, a fuzzy number is used. A Fuzzy number is an expression of membership functions of a linguistic term and ascribe a rating set between the interval [0, 1] for subjective ratings. The two most popular fuzzy numbers are the trapezoidal and triangular fuzzy numbers. In this paper we use the Triangular Fuzzy Number (TFN).

Definition 2: Triangular fuzzy number. A triangular fuzzy number (TFN) is expressed as a triplet (a,b,c). The membership function $f_A(x)$ of a triangular fuzzy number is as defined in Eqn. 1

$$f_A(x) = \begin{cases} 0 & x < a, x > b \\ \dfrac{x-a}{b-a}, & a \le x \le b \\ \dfrac{c-x}{c-b}, & b \le x \le c \end{cases} \tag{1}$$

Fuzzy models that use TFNs prove to be effective for solving decision-making problems where the available information is subjective and vague [19, 20].

Definition 3: Basic TFN Operations: Assuming $A = (a,b,c)$ and $B = (a_1, b_1, c_1)$ are two TFNs, the basic operations on these two fuzzy triangular numbers are as follows:

$$A \oplus B = (a,b,c) + (a_1,b_1,c_1) = (a + a_1, b + b_1, c + c_1) \tag{2}$$

$$A - B = (a,b,c) - (a_1,b_1,c_1) = (a - c_1, b - b_1, c - a_1) \tag{3}$$

$$A \times B = (a,b,c) \times (a_1,b_1,c_1) = (aa_1, bb_1, cc_1) \tag{4}$$

$$A \div B = (a,b,c) \div (a_1,b_1,c_1) = \left(\frac{a}{c_1}, \frac{b}{b_1}, \frac{c}{a_1}\right) \tag{5}$$

V. EVALUATING QUALITY OF INTERNET HEALTH INFORMATION

The growing interests and efforts at assessing the quality of health information on the Internet have generated several sets of criteria from a number of sources with little research work on standardizing such criteria. This study first proposes a new set of criteria for evaluating quality of internet health information culled from several sources [40], [41], [42], [43], [44], [45], [46], [47], [48], [49] as shown in Fig. 1. Secondly, the criteria are used to construct a framework for evaluating the quality of internet health information using fuzzy VIKOR method. We propose that the decision makers be composed of consumer health information experts, self-help group representatives, clinical specialists, general practitioners, lay medical publishers, community health Association representatives, health journalists and information security experts. The criteria used in this study are grouped into four main clusters namely: (a) credibility (b) content (c) design and (d) security. With each cluster having a set of sub-criteria, the total criteria used in this study are fifteen (15). The rationale for selecting the four clusters and their sub-criteria are explained below.

A. Credibility

This cluster examines users' trust in online health information [42], [49]. There are four indicators to measure the credibility of a website providing health information. These are the source, context, relevance and disclosure. The most important criterion for judging the credibility of an online health information provider is the source since it helps to defuse user doubts about the credibility of the information accessed.

B. Content

The content of a website providing health related information is equally deemed important for winning users trust. The sub-criteria are accuracy, currency, disclaimer and authority [43], [45]. Accuracy is often regarded the most important criteria for evaluating "content" and seeks for the scientific validity of the information provided. Users expect proven solutions that are rooted in scientific theory [49].

C. Design

Design defines the quality features and the ease of use of a health information website [43]. Though design does not contribute directly to the quality of information on a website, it is a necessary requirement to ensure frequent delivery of information to users. This is made possible through logical organization of the website information for user understanding [45]. The sub-criteria are accessibility, attractiveness and links.

D. Security

Security is essential in a website providing health related information because of the sensitive and confidential information shared in real-time interactions [49]. Some websites provide chat rooms where users seek advice on a range of issues. It is incumbent on the internet health information provider to assure users of their confidentiality. In this proposed framework, security is measured using caveat together with the CIA triad of confidentiality, integrity and availability. Caveat looks at a website's ability to assure consumers through statements that personal information would not be transferred to third parties or even stored [45]. CIA triad [46], [47] is a widely applied model designed to guide and evaluates information systems security policies. The most obvious element of the CIA triad is confidentiality which ensures that data or an information system is accessed only by authorized persons. Confidentiality is achieved through the protection of user Id's and passwords and other policy based security measures [45].

VI. PROPOSED FUZZY FRAMEWORK

The fuzzy VIKOR approach used in this study is organized in the following order. First, the importance weights of the evaluation criteria are determined and then the performance rating matrix is constructed. Second is the computation of the fuzzy best and worst values of the criteria. Normalized fuzzy difference and the separation values are also computed. Lastly, the triangular fuzzy numbers are defuzzified into crisp values to determine rankings of the alternatives and consequently a compromise solution is proposed.

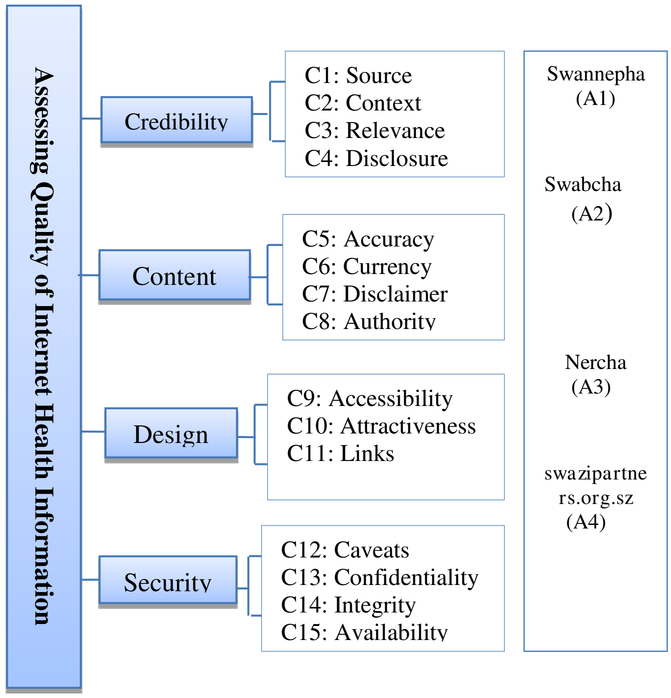

Fig. 1: A framework for evaluating quality of internet Health Information

Step 1: Determining linguistic Variables

The first step in the fuzzy VIKOR method is to determine the linguistic variables; the criteria for evaluating the quality of internet health information. Linguistic terms transformed into fuzzy numbers are used by the experts to rate each linguistic variable. Linguistic terms are qualitative words or phrases of a natural language that reflect the subjective view of an expert about the criteria per each alternative under consideration [50]. In this study, triangular fuzzy numbers are used as shown in Table I and Table II respectively to capture the ratings of the criteria and alternatives on a scale of 0-1.

Table I. Linguistic Scale for the importance of criteria

Linguistic terms	Triangular fuzzy number
Very Low (VL)	(0.0,0.1,0.3)
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)	(0.7,0.9,1.0)

Table III. Linguistic scale for ratings of alternatives

Linguistic terms	Triangular fuzzy number
Very Poor (VP)	(0.0,0.0,0.2)
Poor (P)	(0.0,0.2,0.4)
Fair (F)	(0.2,0.4,0.6)
Good (G)	(0.4,0.6,0.8)
Very Good (VG)	(0.6,0.8,1.0)
Excellent (E)	(0.8,0.1,1.0)

Step 2: Determining importance weight of criteria

The evaluation criteria for determining the quality of internet health information providers are supposed to have different importance weights. To determine the importance weight of each criterion, the decision makers rate each criterion using the linguistic terms in Table I. This is expressed in Eq. 6 as vector $\tilde{W}$: $\tilde{W} = [\tilde{w}_1, \tilde{w}_2, ..., \tilde{w}_n]\ j = 1,2,...,n$ (6)

where $\tilde{w}_j$ represents the weight of the jth criterion based on the linguistic preference assigned by a decision maker. Each weight $\tilde{w}_j^k = (w_{j1}^k, w_{j2}^k, w_{j3}^k)$ is expressed as a TFN. These preferences signify the importance attributed to a criterion by a decision maker. The study uses the graded mean integration method [51] to aggregate the decision makers' opinions. The fuzzy importance weight $\tilde{w}_j$ for criterion C_j is computed as:

$$\tilde{w}_j^k = \left(w_{j1}, w_{j2}, w_{j3}\right) \text{ where, } w_{j1} = \min_k \left\{w_{jk1}\right\},\ w_{j2} = \frac{1}{k}\sum_{k=1}^{k} w_{jk2},$$
$$w_{j3} = \max_k \left\{w_{jk3}\right\} \text{ for } i = 1,2,...,m;\ j = 1,2,...,n \quad (7)$$

Step 3: Constructing the fuzzy decision matrix

Consider a group of k decision-makers $(D_1, D_2, ..., D_k)$ presented with m alternatives $(A_1, A_2, ..., A_m)$ against n set of criteria $(C_1, C_2, ..., C_n)$ in a typical MCDM problem. A fuzzy multi-criteria decision-making is formally expressed as:

$$\tilde{D} = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mn} \end{bmatrix} \end{array} i = 1,2,...,m;\ j = 1,2,...,n \quad (8)$$

where, $\tilde{x}_{mn}$ is the rating of alternative A_m with respect to criterion C_j. Note that for a decision maker k, $\tilde{x}_{ij}^k = (a_{ij}^k, b_{ij}^k, c_{ij}^k)$ is a TFN. Similarly as in step 2, the graded mean integration method is used to aggregate the opinions of the decision makers concerning the ratings of the alternatives (websites).This is formally expressed as $\tilde{x}_{ij}^k = \left(a_{ij}^k, b_{ij}^k, c_{ij}^k\right)$ where,

$$a_{ij} = \min_k \left\{a_{ij}^k\right\}, b_{ij} = \frac{1}{k}\sum_{k=1}^{k} b_{ij}^k, c_{ij} = \max_k \left\{c_{ij}^k\right\}\ i = 1,2,...,m; j = 1,2,...,n \quad (9)$$

Step 4: Fuzzy best value f_i^* and fuzzy worst value f_i°

The fuzzy best value $f_i^* = \left(a_i^*, b_i^*, c_i^*\right)$ and the fuzzy worst values $f_i^\circ = \left(a_i^\circ, b_i^\circ, c_i^\circ\right)$ are computed respectively using Eq. 10 and 11 below [25], [30].

$$\tilde{f}_i^* = \max_j \tilde{f}_{ij},\ \tilde{f}_i^\circ = \min_j \tilde{a}_{ij}, \text{ for } i \in B \quad (10)$$

$$\tilde{f}_i^* = \min_j \tilde{f}_{ij},\ \tilde{f}_i^\circ = \max_j \tilde{a}_{ij}, \text{ for } i \in C \quad (11)$$

where B is the benefit criteria and C , the cost criteria.

Step 5: Normalized fuzzy difference $\tilde{d}_{ij}$

To obtain the fuzzy difference $\tilde{d}_{ij}$, it is computed as below:

$$\tilde{d}_{ij} = (\tilde{f}_i^* - \tilde{x}_{ij})/(c_i^* - a_i^\circ) \quad \text{for } i \in B \quad (12)$$

$$\tilde{d}_{ij} = (\tilde{x}_{ij} - \tilde{f}_i^*)/(c_i^\circ - a_i^*) \quad \text{for } i \in C \quad (13)$$

where B is the benefit criteria and C , the cost criteria

Step 6: Computing separation Measures $\tilde{S}_j$ and $\tilde{R}_j$

The next step computes the separation $\tilde{S}_j$ of alternative A_j from the fuzzy best value f_i^*. Similarly, the separation of $\tilde{R}_j$ of alternative A_j from the fuzzy worst value f_i° is also computed. These are respectively measured using Eq. 14 and 15:

$$\tilde{S}_j = \sum_{i=1}^{n} (\tilde{w}_j \otimes \tilde{d}_{ij}) \quad (14)$$

$$\tilde{R}_j = \max_i (\tilde{w}_j \otimes \tilde{d}_{ij}) \quad (15)$$

where $\tilde{S}_j = (S_j^a, S_j^b, S_j^c)$ is a fuzzy weighted sum of the separation measure of A_j from the best value f_i^* [27]. Similarly, $\tilde{R}_j = (R_j^a, R_j^b, R_j^c)$ is a fuzzy MAX which refers to the separation measure of A_j from the worst value f_i° where w_j is the importance weight of criterion C_j.

Step 7: Computing the value of $\tilde{Q}_j$

The value $\tilde{Q}_j = (a_j, b_j, c_j)$ expressed in a triangular fuzzy number is computed as following:

$$\tilde{Q}_j = v(\tilde{S}_j - \tilde{S}^*)/(S^{\circ c} - S^{*a}) \oplus (1-v)(\tilde{R}_j - \tilde{R}^*)/(R^{\circ c} - R^{*a}) \quad (16)$$

where $\tilde{S}^* = MIN_j \tilde{S}_j$, $S^{\circ c} = MAX_j S_j^{\ c}$, $\tilde{R}^* = MIN_j \tilde{R}_j$ $R^{\circ c} = MAX_j R_j^{\ c}$ and $v(v = n+1/2n)$ is taken as a weight for the strategy of "majority criteria" (or "maximum utility"), where $1-v$ represents the weight of the individual regret [28]. The best values of S and R are respectively $\tilde{S}^*$ and $\tilde{R}^*$.

Step 8: Defuzifying $\tilde{S}_j$, $\tilde{R}_j$ and $\tilde{Q}_j$

In fuzzy logic, defuzzification is the process of converting the fuzzy numbers into crisp values [50]. The defuzzification is computed by locating the Best Non fuzzy Performance (BNP). A range of defuzzification methods such as Center Of Area (COA), mean of maximum and weighted average method [53] can be used. This paper uses the defuzzification method of COA for ranking fuzzy numbers by [52, 53]. The defuzzification process converts $\tilde{S}_j$, $\tilde{R}_j$ and $\tilde{Q}_j$ into crisp values S , R and Q.

Step 9: Ranking the alternatives

This step ranks the alternatives by sorting the values of S, R and Q in descending order resulting in three ranking lists $\{A\}_S$, $\{R\}_S$ and $\{Q\}_S$ respectively. The index Q_i is the separation measure of A_i from the best alternative. Consequently, the smaller Q_i, the better the alternative.

Step 10: Proposing a Compromise solution

A compromised solution is proposed at this stage where alternative $(A^{(1)})$ is the best ranked by the measure Q (minimum) if the following two conditions are satisfied:

[Condition 1]: Acceptable advantage:

$$Q(A^{(2)} - Q(A^{(1)}) \geq DQ \tag{17}$$

where $A^{(2)}$ represents the alternative with second position in the ranking list $\{A\}_Q$. Additionally, the threshold $DQ = 1/(n-1)$ where n indicates the number of feasible alternatives.

[Condition 2]: Acceptable stability in decision-making:

The alternative $A^{(1)}$ must be the best ranked by S or/and R. Here if one of these conditions is not satisfied, then a set of compromise solution is proposed consisting of:

1. Alternatives $A^{(1)}$ and $A^{(2)}$ if only condition 2 is not satisfied, or
2. Alternatives $A^{(1)}$, $A^{(2)}$,…, $A^{(M)}$ if condition 1 is not satisfied; $A^{(M)}$ is determined by the relation $Q(A^{(M)}) - Q(A^{(1)}) \leq DQ$ for maximum M (the positions of these alternatives are in "closeness").

VII. Numerical Example

This section demonstrates how the fuzzy VIKOR method can be used to evaluate and rank online health information providers. The numerical example in this paper assumes an 8-member decision making team evaluating and ranking the websites of four HIV/AIDS organizations in Swaziland. Swaziland has the world's highest HIV/AIDS adult prevalent rates [54]. The rise in internet rate in Africa leads to reliance on internet for information. In view of this, the quality of information provided by a website on health is crucial. The four websites used in this demonstration are shown in Fig 1. In the following steps, Fuzzy VIKOR is used to demonstrate how to arrive at decision-makers' preferable compromise solution or alternative. The computational illustration of this numerical example is shown as follows:

Step 1: Determining linguistic Variables

The linguistic variables and the alternatives are as shown in Fig. 1. The linguistic terms for the importance weight criteria and the ratings for the alternatives per each criterion used in this paper are as subsequently shown in Table I and Table II.

Step 2: Determining importance weight of criteria

The evaluation is organized into four main clusters comprising 15 sub-criteria for the evaluation of the quality of online health information as shown in Fig 1. This second step in the fuzzy VIKOR MCDM process offers evaluators the chance to choose by rating the most important criteria for the evaluation guided by the linguistic terms in Table I. The linguistic preferences for our assumed eight decision makers concerning the importance attached to each criterion is as shown in Table III below.

Table III. Importance weight of criteria

	D1	D2	D3	D4	D5	D6	D7	D8
C1	VL	M	H	VL	L	L	M	L
C2	M	H	M	M	M	H	H	H
C3	VH	M	H	H	H	VH	M	H
C4	VH	M	H	M	H	M	M	VH
C5	VH	H	VH	VH	VH	H	VH	H
C6	VH	M	H	VH	VH	M	VH	VH
C7	M	M	VH	H	VH	VH	H	VH
C8	L	L	M	H	M	VL	L	L
C9	M	M	H	H	M	L	M	VL
C10	H	M	M	H	H	M	L	H
C11	H	M	H	M	M	H	H	L
C12	H	M	VH	H	VH	VH	M	VH
C13	M	M	M	H	H	H	M	VH
C14	M	H	H	VH	M	L	M	VH
C15	VH	M	M	VH	VH	M	H	H

The graded mean integration method defined in Eq. 7 is used to aggregate the decision makers' opinions regarding the importance weightings of each criterion. The result of such aggregation is shown in Table IV. To determine the importance of each criterion by ranking, the fuzzy numbers are defuzzified. The paper uses the COA (center of area) method in computing the Best Non-Fuzzy Performance value (BNP) to rank the order of importance of each criterion. The BNP value of the fuzzy number $W_k = (L_{wk}, M_{wk}, U_{wk})$ is calculated using the expression in Eq. 18.

$$BNP_{wk} = L_{wk} + [(U_{wk} - L_{wk}) + (M_{wk} - L_{wk})]/3 \tag{18}$$

Table IV. Fuzzy aggregated weights of criterion

	TFN	BNP	Rank
C1	(0.0, 0.35, 0.9)	0.417	15
C2	(0.3, 0.60, 0.9)	0.600	10
C3	(0.3, 0.70, 1.0)	0.667	5
C4	(0.3, 0.65, 1.0)	0.650	7
C5	(0.5, 0.83, 1.0)	0.775	1
C6	(0.3, 0.78, 1.0)	0.692	2
C7	(0.3, 0.74, 1.0)	0.679	4
C8	(0.0, 0.38, 0.9)	0.425	14
C9	(0.0, 0.48, 0.9)	0.458	13
C10	(0.1, 0.58, 0.9)	0.525	11
C11	(0.1, 0.58, 0.9)	0.525	11
C12	(0.3, 0.75, 1.0)	0.683	3
C13	(0.3, 0.63, 1.0)	0.642	8
C14	(0.1, 0.75, 1.0)	0.617	9
C15	(0.3, 0.70, 1.0)	0.667	5

For example, the BNP value for criteria 1 (C1) is computed as follows:

$$=0.0 + [(0.90-0.0) + (0.35-0.0)]/3 = 0.417 \tag{19}$$

By the BNP value computation, the major influential criteria out of the 15 are C5 with a rank of 1 and (C6, C12 and C7) with a rank of 2, 3 and 4 respectively. The least important criterion would be C1 with a rank of 15.

Step 3: Constructing the fuzzy decision matrix

Similarly as in step 2, the decision makers rate the various online health information providers using linguistic terms in Table II. These linguistic judgments would represent the opinions of the evaluators in rating and ranking the four HIV/AIDS organizations. Table V demonstrates assumed ratings of evaluators which have been aggregated using Eq. 9.

Table V. Aggregated fuzzy decision matrix

	A1	A2	A3	A4
C1	(3.18,5.18,7.18)	(4.01,6.01,8.01)	(4.48,6.68,8.68)	(2.46,4.46,6.46)
C2	(3.26,5.18,7.18)	(4.51,6.51,8.43)	(5.34,7.34,9.18)	(2.68,4.68,6.68)
C3	(2.19,4.19,6.19)	(3.85,5.85,7.78)	(4.19,6.19,8.19)	(3.02,5.02,7.02)
C4	(3.21,5.21,7.21)	(4.52,6.50,8.42)	(4.10,6.02,7.85)	(2.19,4.02,6.02)
C5	(3.19,5.19,7.19)	(4.85,6.85,8.69)	(4.53,6.53,8.44)	(3.02,5.02,7.02)
C6	(3.02,5.02,7.02)	(4.69,6.69,8.52)	(5.19,7.19,9.02)	(1.85,3.69,5.69)
C7	(3.10,5.02,7.02)	(4.69,6.69,8.60)	(4.35,6.35,8.35)	(2.85,4.85,6.85)
C8	(4.69,6.69,8.44)	(3.51,5.34,7.34)	(2.51,4.34,6.34)	(2.09,4.01,6.01)
C9	(4.70,6.70,8.61)	(4.36,6.36,8.28)	(3.03,5.03,7.03)	(1.70,3.53,5.53)
C10	(3.08,5.10,7.08)	(4.91,6.91,8.75)	(4.59,6.59,8.50)	(3.25,5.25,7.25)
C11	(3.12,5.12,7.12)	(4.79,6.79,8.62)	(5.29,7.29,9.12)	(1.95,3.79,5.79)
C12	(3.14,5.06,7.06)	(4.73,6.73,8.71)	(4.39,6.39,8.39)	(2.89,4.89,6.89)
C13	(2.58,4.42,6.42)	(2.17,4.09,6.09)	(4.78,6.78,8.52)	(3.58,5.42,7.42)
C14	(3.09,5.09,7.09)	(4.42,6.42,8.34)	(4.76,6.76,8.67)	(1.76,3.59,5.59)
C15	(2.73,5.49,7.34)	(4.45,7.12,8.36)	(2.53,3.78,5.59)	(4.79,6.79,8.68)

Step 4: Fuzzy best value f_i^* and fuzzy worst value f_i°

The study utilizes Eqs. 10 and 11 to determine the fuzzy best and fuzzy worst values for the evaluation criteria. The result of this process is shown in Table VI.

Table VI. Fuzzy best value f_i^* and fuzzy worst value f_i°

Criteria	f_i^*	f_i°
C1	(4.48,6.68,8.68)	(2.46,4.46,6.46)
C2	(5.34,7.34,9.18)	(2.68,4.68,6.68)
C3	(4.19,6.19,8.19)	(2.19,4.19,6.19)
C4	(4.52,6.50,8.42)	(2.19,4.02,6.02)
C5	(4.53,6.53,8.44)	(3.02,5.02,7.02)
C6	(5.19,7.19,9.02)	(1.85,3.69,5.69)
C7	(4.69,6.69,8.60)	(2.85,4.85,6.85)
C8	(4.69,6.69,8.44)	(2.09,4.01,6.01)
C9	(4.70,6.70,8.61)	(1.70,3.53,5.53)
C10	(4.91,6.91,8.75)	(3.08,5.10,7.08)
C11	(5.29,7.29,9.12)	(1.95,3.79,5.79)
C12	(4.73,6.73,8.71)	(2.89,4.89,6.89)
C13	(4.78,6.78,8.52)	(2.58,4.42,6.42)
C14	(4.76,6.76,8.67)	(1.76,3.59,5.59)
C15	(4.79,6.79,8.68)	(2.53,3.78,5.59)

Step 5: Normalized fuzzy difference $\tilde{d}_{ij}$

In this step, the normalized fuzzy difference $\tilde{d}_{ij}$ is computed using Eqs. 12 and 13. For example, $\tilde{d}_{A1}$ is computed as below.

$$\tilde{d}_{A1} = \frac{[(4.48,6.68,8.68)-(3.18,5.18,7.18)]}{8.68\text{-}2.46} \tag{20}$$

$$= \frac{[(4.48\text{-}7.18),(6.68\text{-}5.18),(8.68\text{-}3.18)]}{6.22} = (-0.434, 0.241, 0.884)$$

The rest of the normalized fuzzy differences are calculated in the same manner.

Step 6: Computing separation Measures $\tilde{S}_j$ and $\tilde{R}_j$

The separation measures of $\tilde{S}_j$ and $\tilde{R}_j$ of alternative A_j from the fuzzy best and worst values respectively are computed using Eqs. 14 and 15. The resulting Table VII is as shown below:

Table VII. Index $\tilde{S}_j$ and $\tilde{R}_j$

	A1	A2	A3	A4
C1	(0,0.084,0.795)	(0.0,0.037,0.67)	(0.0,0.0,0.61)	(0.0,0.12,0.90)
C2	(-0.085,1.99,1.0)	(-0.14,0.08,0.65)	(-0.177,0.0,0.53)	(-0.062,0.24,0.9)
C3	(-1.0,2.33,1.0)	(-0.18,0.04,0.72)	(-0.2,0.0,0.67)	(-0.14,0.136,0.86)
C4	(-0.13,0.13,0.84)	(-0.19,0.0,0.63)	(-0.16,0.05,0.69)	(-0.072,0.26,1.0)
C5	(-0.25,0.21,0.97)	(-0.38,-0.05,0.66)	(-0.36,0.0,0.72)	(-0.23,0.23,1.0)
C6	(-0.08,0.24,0.84)	(-0.14,0.05,0.6)	(-0.16,0.0,0.53)	(-0.021,0.38,1.0)
C7	(-0.12,0.21,0.96)	(-0.2,0.0,0.68)	(-0.19,0.04,0.74)	(-0.11,0.24,1.0)
C8	(0.0,0.0,0.53)	(-0.0,0.08,0.7)	(0.0,0.14,0.84)	(0.0,0.16,0.90)
C9	(0.0,0.0,0.51)	(-0.0,0.024,0.55)	(0.0,0.116,0.73)	(0.0,0.22,0.90)
C10	(-0.04,0.185,0.9)	(-0.068,0.0,0.61)	(-0.06,0.03,0.66)	(-0.04,0.17,0.87)
C11	(-0.30,0.17,0.75)	(-0.05,0.04,0.54)	(-0.05,0.0,0.48)	(-0.006,0.28,0.9)
C12	(-0.12,0.21,0.96)	(-0.20,0.0,0.68)	(-0.188,0.04,0.74)	(-0.11,0.288,1.0)
C13	(-0.08,0.25,1.0)	(-0.066,0.28,1.06)	(-0.188,0.0,0.63)	(-0.13,0.14,0.83)
C14	(-0.03,0.18,0.81)	(-0.05,0.04,0.62)	(-0.056,0.0,0.56)	(-0.012,0.34,1.0)
C15	(-0.12,0.14,0.97)	(-0.17,-0.03,0.68)	(-0.039,0.34,1.0)	(-0.189,0.0,0.63)
$\tilde{S}_j$	(-1.185,2.46,12.6)	(-1.84,0.58,10.07)	(-1.84,0.77,10.14)	(-1.13,3.22,13.70)
$\tilde{R}_j$	(0.0,0.25,1.0)	(0.0,0.285,1.07)	(0.0,0.34,1.0)	(0.0,0.38,1.0)

Step 7: Computing the value of $\tilde{Q}_j$

$\tilde{S}^* = (-1.850, 0.588, 10.078)$; $\tilde{R}^* = (0.00, 0.25, 1.00)$, $S^{oc} = 13.69885$; $R^{oc} = 1.069024$.

For example $\tilde{Q}_{jA1}$ is computed using Eq.16 as shown below:

$$\tilde{Q}_{jA1} = \{0.5[(-1.18-10.08, 2.46-0.59, 12.64+1.84)]/(13.69+1.84)\}$$
$$+\{1-0.5[0-1, 0.25-0.25, 1-0]/(1.06-0)\}$$
$$= (-0.82995, 0.06028, 0.93366)$$

By same calculation, the values of the other alternatives are

$\tilde{Q}_{jA2}$=(−0.85130,0.01637,0.88359), $\tilde{Q}_{jA3}$=(−0.85116,0.04898,0.85327)

$\tilde{Q}_{jA4}$=(−0.82831,0.14579,0.96772)

Step 8: Defuzifying $\tilde{S}_j$, $\tilde{R}_j$ and $\tilde{Q}_j$

The defuzzification process converts $\tilde{S}_j$, $\tilde{R}_j$ and $\tilde{Q}_j$ into crisp numbers S, R and Q. The results are shown in Table VIII.

Table VIII. Defuzzified values of S, R and Q

	A1	A2	A3	A4
Q	0.54661	0.016218	0.017031	0.095065
S	4.63946	2.939804	3.021934	5.263415
R	0.416768	0.451442	0.447534	0.460251

Step 9: Ranking the alternatives

The crisp value of the alternatives for Q is ranked from the smallest value to the highest value. The alternatives are ranked as shown in Table IX below.

Table IX. Rank for alternatives

	A1	A2	A3	A4
Q	0.54661	0.016218	0.017031	0.095065
Rank	3	1	2	4

Step 10: Proposing a Compromise solution

In Table IX, the best ranked alternative is A2 which happens to be the best compromise solution. According to the values of Q_j and S_j as shown in Table VIII, the ascending rank of the four HIV/AIDS online information providers in Swaziland is $Q_{A2} \succ Q_{A3} \succ Q_{A1} \succ Q_{A4}$ and $S_{A2} \succ S_{A3} \succ S_{A1} \succ S_{A4}$

Now by the ascending rank order, the HIV/AIDS support organization known as Swabcha (A2), which had the minimum of Q_j and S_j, would be said to have the best quality in terms of provision of online HIV/AIDS information in Swaziland.

VIII. COMPARISON WITH FUZZY TOPSIS

This stage compares the fuzzy VIKOR results from the study with another popular MCDM method called the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). Fuzzy VIKOR and TOPSIS are both widely used for various selection and ranking solutions. The TOPSIS technique was proposed by [55] but extended to fuzzy TOPSIS by [56]. The technique introduces the shortest distance from the Fuzzy Positive Ideal Solution (FPIS) and the farthest distance from the Fuzzy Negative Ideal Solution (FNIS) simultaneously for the best rank.

In view of this, Fuzzy TOPSIS technique was found ideal in comparison with fuzzy VIKOR since both methods arrive at a scalar (crisp) value in their ranking that considers the best and worst fuzzy values in calculation [56],[57]. They are both found also to be theoretically robust [56]. In Table X, the ranking of the alternatives for both the fuzzy TOPSIS method and the fuzzy VIKOR are presented. The results show that both methods yielded the same order of ranking of the alternatives based on the same data used. Note that in TOPSIS unlike VIKOR, the bigger the value of the relative closeness coefficient, the better the alternative.

Table X: Compared ranking of fuzzy VIKOR and fuzzy TOPSIS results

Alternatives	Fuzzy VIKOR		Fuzzy TOPSIS	
	Results (Q)	Rank	Results (CC_i)	Rank
A1	0.05466	3	0.4600	3
A2	0.0162	1	0.4928	1
A3	0.0170	2	0.4719	2
A4	0.0951	4	0.4085	4

IX. IMPLICATIONS

The growth of the internet means an increase in consumers of online information for a range of purposes. One critical use of the internet is seeking for health information which hitherto was the exclusive preserve of health professionals. Health delivery challenges and shortage of medical professionals in some parts of the world especially in Africa could let people become overly dependent on online health information. To ensure that users access quality online information for improved health, providers of such health related information must be evaluated regularly. To lead in this direction, the proposed fuzzy VIKOR framework could prove handy in ranking health information providers to among other things (1) help users or self-help groups know which websites have the mandate and the competence to educate the public on topical health issues (2) aid health information consumer groups and associations in their resolve to ensuring quality of health information on the internet (3) create competition among specific area health information providers. For example, the evaluation and ranking could introduce competition among diabetes online health information providers or malaria information providers to improve upon their website content and design.

X. CONCLUSION

In this paper, a fuzzy VIKOR framework is proposed for evaluating and ranking internet health information providers. To demonstrate how the framework can be used, a numerical example is carried out using HIV/AIDS organizations in Swaziland who provide internet information related to HIV/AIDS for the Swazis. The organizations used in the study are real organizations providing HIV/AIDS support information and care in Swaziland but the results of the ranking in this paper is just for demonstration purposes.

The study first proposes a new set of criteria for evaluating quality of internet health information. A fuzzy VIKOR framework is then used to demonstrate how this can be carried out experimentally. The results show a methodology that can prove effective in evaluating online health information on any topic. The outcome of results compare favorably to the fuzzy TOPSIS technique justifying its reliability.

ACKNOWLEDGMENT

This work was supported by Internal Grant Agency of Tomas Bata University IGA/FAI/2014/037, IGA/FaME/2014/007 and by the European Regional Development Fund under the project CEBIA-Tech No. CZ.1.05/2.1.00/03.0089.

REFERENCES

[1] A. Suziedelyte, “How does searching for health information on the Internet affect individuals' demand for health care services?.” Social science & medicine, vol. 75, no. 10, pp. 1828-1835, Nov. 2012. DOI: 10.1016/j.socscimed.2012.07.022

[2] K. M AlGhamdi, and N.A. Moussa. “Internet use by the public to search for health-related information.” International journal of medical informatics, vol. 81, no. 6, pp. 363-373, June 2012. DOI: 10.1016/j.ijmedinf.2011.12.004

[3] S. Fox, and M. Duggan. “Health online 2013.” Health, Jan. 2013

[4] Rozmovits, Linda, and Sue Ziebland. “What do patients with prostate or breast cancer want from an Internet site? A qualitative study of information needs.” Patient education and counselling, vol. 53, no. 1 pp. 57-64, April 2004. DOI: 10.1016/S0738-3991(03)00116-2

[5] S.J Chang, and I. E.O Im. “A path analysis of Internet health information seeking behaviors among older adults.” Geriatric Nursing, Nov.2013. DOI: 10.1016/j.gerinurse.2013.11.005

[6] A. Leung, P. Ko, K.S. Chan, I. Chi, and N. Chow. “Searching health information via the web: Hong Kong Chinese older adults' experience.” Public Health Nursing, vol. 24, no. 2, pp. 169-175, Feb. 2007. DOI: 10.1111/j.1525-1446.2007.00621.x

[7] R.A Cohen and B. Stussman. “Health information technology use among men and women aged 18–64: early release of estimates from the National Health Interview Survey, January–June 2009.” National Center for Health Statistics, 2010.

[8] Centers for Disease Control and Prevention. “Health Information Technology Use among US Adults”, retrieved from: http://www.cdc.gov/features/dshealthinfo/index.html, Oct. 2010.

[9] S.E Baumgartner and T. Hartmann. “The role of health anxiety in online health information search.” Cyberpsychology, Behavior, and Social Networking, vol. 14, no. 10, pp. 613-618, Oct. 2011. DOI: 10.1089/cyber.2010.0425

[10] G. J. G Asmundson, S. Taylor, and B. J. Cox. Health anxiety: Clinical and research perspectives on hypochondriasis and related conditions. Chichester, 2001.

[11] P.M Salkovskis, K.A. Rimes, H. M. C. Warwick, and D. M. Clark. “The Health Anxiety Inventory: development and validation of scales for the measurement of health anxiety and hypochondriasis.” Psychological medicine, vol. 32, no. 5, pp. 843-853, July, 2002. http://dx.doi.org/10.1017/S0033291702005822

[12] E. Sillence, P. Briggs, P. Harris, and L. Fishwick. “Changes in online health usage over the last 5 years.” In CHI'06 Extended Abstracts on Human Factors in Computing Systems, pp. 1331-1336. ACM, 2006. DOI:10.1145/1125451.1125698

[13] M.S Eastin. “Credibility assessments of online health information: The effects of source expertise and knowledge of content. *“Journal* of Computer-Mediated Communication, vol. 6, no. 4, pp. 0-0, Jun, 2001. DOI: 10.1111/j.1083-6101.2001.tb00126.x

[14] Eachus, P. “Health information on the Internet: is quality a problem?.” International journal of health promotion and education, vol. 37, no. 1, pp. 30-33, 1999. DOI:10.1080/14635240.1999.10806089.

[15] L. Theodosiou, and J. Green. “Emerging challenges in using health information from the internet. “Advances in Psychiatric treatment, vol. 9, no. 5, pp. 387-396, 2003. DOI: 10.1192/apt.9.5.387

[16] C. Kahraman. Fuzzy multi-criteria decision making: theory and applications with recent developments. Vol. 16. Springer, 2008.

[17] J. Lu, G. Zhang, and D. Ruan. Multi-objective group decision making: methods, software and applications with fuzzy set techniques. Imperial College Press, 2007.

[18] R.E. Bellman and L.A. Zadeh. “Decision-making in a fuzzy environment.” Management science, vol. 17, no. 4, pp. B-141, Dec. 1970. http://dx.doi.org/10.1287/mnsc.17.4.B141.

[19] İ. Erol, S. Sencer, A. Özmen, and C. Searcy. “Fuzzy MCDM framework for locating a nuclear power plant in Turkey.” Energy Policy, vol. 67, pp. 186-197, Apr. 2013. DOI: 10.1016/j.enpol.2013.11.056.

[20] Haleh, H., and A. Hamidi. "A fuzzy MCDM model for allocating orders to suppliers in a supply chain under uncertainty over a multi-period time horizon." Expert Systems with Applications, vol. 38, no. 8, pp. 9076-9083, Aug. 2011. DOI: 10.1016/j.eswa.2010.11.064.

[21] T.H Chang, and T.C. Wang. “Using the fuzzy multi-criteria decision making approach for measuring the possibility of successful knowledge management.” Information Sciences, vol. 179, no. 4, pp. 355-370, Feb. 2009. DOI: 10.1016/j.ins.2008.10.012.

[22] G. Büyüközkan, and G. Çifçi. “A novel hybrid MCDM approach based on fuzzy DEMATEL, fuzzy ANP and fuzzy TOPSIS to evaluate green suppliers.” Expert Systems with Applications, vol. 39, no. 3, pp. 3000-3011, Feb. 2012. DOI: 10.1016/j.eswa.2011.08.162.

[23] J.K. Chen, and I. Chen. “Using a novel conjunctive MCDM approach based on DEMATEL, fuzzy ANP, and TOPSIS as an innovation support system for Taiwanese higher education.” Expert Systems with Applications, vol. 37, no. 3, pp. 1981-1990, Mar. 2010. DOI: 10.1016/j.eswa.2009.06.079.

[24] S. Opricovic. “Multicriteria optimization of civil engineering systems.” Faculty of Civil Engineering, Belgrade, vol. 2, no. 1, pp. 5-21, 1998.

[25] S. Opricovic, and G.H. Tzeng. “Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS.” European Journal of Operational Research, vol. 156, no. 2, pp. 445-455, Jul. 2004. DOI: 10.1016/S0377-2217(03)00020-1.

[26] M. Wu, and Z. Liu. “The supplier selection application based on two methods: VIKOR algorithm with entropy method and Fuzzy TOPSIS with vague sets method.” International Journal of Management Science and Engineering Management, vol. 6, no. 2, pp. 109-115, May, 2013. DOI:10.1080/17509653.2011.10671152.

[27] T.H. Chang. “Fuzzy VIKOR method: A case study of the hospital service evaluation in Taiwan.” Information Sciences, 2014. DOI: 10.1016/j.ins.2014.02.118.

[28] S. Opricovic. “Fuzzy VIKOR with an application to water resources planning.” Expert Systems with Applications, vol. 38, no. 10, pp. 12983-12990, Sept. 2011. DOI: 10.1016/j.eswa.2011.04.097.

[29] G. N. Yücenur, and N.C. Demirel. “Group decision making process for insurance company selection problem with extended VIKOR method under fuzzy environment.” Expert Systems with Applications, vol. 39, no. 3, pp. 3702-3707, Feb. 2012. DOI: 10.1016/j.eswa.2011.09.065.

[30] T.C. Wang and T. H. Chang. “Fuzzy VIKOR as a resolution for multicriteria group decision-making.” In The 11th International Conference on Industrial Engineering and Engineering Management, pp. 352-356. 2005.

[31] A.S. Sanayei, F. Mousavi, and A. Yazdankhah. “Group decision making process for supplier selection with VIKOR under fuzzy environment.” Expert Systems with Applications, vol. 37, no. 1, pp. 24-30, Jan. 2010. DOI: 10.1016/j.eswa.2009.04.063.

[32] A. Shemshadi, H. Shirazi, M. Toreihi, and M. J. Tarokh. “A fuzzy VIKOR method for supplier selection based on entropy measure for objective weighting.” Expert Systems with Applications, vol. 38, no. 10, pp. 12160-12167, Sept. 2011. DOI: 10.1016/j.eswa.2011.03.027.

[33] L.Y. Chen, and T.C. Wang. “Optimizing partners’ choice in IS/IT outsourcing projects: The strategic decision of fuzzy VIKOR.” International Journal of Production Economics, vol. 120, no. 1, pp. 233-242, Jul. 2009. DOI: 10.1016/j.ijpe.2008.07.022.

[34] J.R. San Cristóbal. “Multi-criteria decision-making in the selection of a renewable energy project in Spain: the Vikor method.” Renewable energy vol. 36, no. 2, pp. 498-502, Feb. 2011. DOI: 10.1016/j.renene.2010.07.031.

[35] T. Kaya, and C. Kahraman. “Multicriteria renewable energy planning using an integrated fuzzy VIKOR & AHP methodology: The case of Istanbul.” Energy, vol. 35, no. 6, pp. 2517-2527, Jun. 2010. DOI: 10.1016/j.energy.2010.02.051.

[36] M.S. Kuo, and G.S. Liang. “Combining VIKOR with GRA techniques to evaluate service quality of airports under fuzzy environment.” Expert Systems with Applications, vol. 38, no. 3, pp. 1304-1312, Mar. 2011. DOI: 10.1016/j.eswa.2010.07.003.

[37] A. Jahan, F. Mustapha, M.Y. Ismail, S. M. Sapuan, and M. Bahraminasab. “A comprehensive VIKOR method for material selection.” Materials & Design, vol. 32, no. 3, pp. 1215-1221, Mar. 2011. DOI: 10.1016/j.matdes.2010.10.015.

[38] K. Devi. “Extension of VIKOR method in intuitionistic fuzzy environment for robot selection.” Expert Systems with Applications, vol. 38, no. 11, pp. 14163-14168, Oct. 2011. DOI: 10.1016/j.eswa.2011.04.227.

[39] Y.P Ou Yang, H.M. Shieh, and G.H. Tzeng. “A VIKOR technique based on DEMATEL and ANP for information security risk control assessment.” Information Sciences, vol. 232, pp. 482-500, May. 2013. DOI: 10.1016/j.ins.2011.09.012.

[40] P. Kim, T.R. Eng, M. J. Deering, and A. Maxfield. “Published criteria for evaluating health related web sites: review.” BMJ: British Medical Journal, vol. 318, no. 7184, pp. 647, Mar. 1999. DOI:/10.1136/bmj.318.7184.647

[41] G. Eysenbach, J. Powell, O. Kuss, and E.R Sa. “Empirical studies assessing the quality of health information for consumers on the World Wide Web: a systematic review.” Jama, vol. 287, no. 20, pp. 2691-2700, May, 2002. DOI:10.1001/jama.287.20.2691.

[42] A.R Jadad, and A. Gagliardi. “Rating health information on the Internet: navigating to knowledge or to Babel?.” Jama, vol. 279, no. 8, pp. 611-614, Feb. 1998. DOI:10.1001/jama.279.8.611

[43] Healthcare Research and Quality (HRQ).“Assessing the Quality of Internet Health Information”. U.S. Department of Health & Human Services. 1999.

[44] American Public Health Association. “Criteria for assessing the quality of health information on the Internet.” American Journal of Public Health, vol. 91, no. 3, pp. 513, Mar. 2001.

[45] J. Ambre et al. criteria for assessing the quality of health information on the Internet. Working draft white paper, Oct. 1997.

[46] D.E.R Denning. Information warfare and security. Vol. 4. Reading MA: Addison-Wesley, 1999.

[47] R. Von Solms. “Information security management: why standards are important.” Information Management & Computer Security, vol. 7, no. 1, pp. 50-58, 1999. DOI:10.1108/09685229910255223

[48] Leonard M. Miller School of Medicine. Confidentiality, Integrity and Availability (CIA). University of Miami. Retrieved from : http://it.med.miami.edu/x904.xml

[49] J.M. Moreno, J. M. Cadenas, S. Alonso, and E. Herrera-Viedma. “An Evaluation Methodology of Quality for Health Web Sites based on Fuzzy Linguistic Modelling.” In Proceedings of IPMU, vol. 8, p. 1091.

[50] Klir, George J., and Bo Yuan. Fuzzy sets and fuzzy logic. Vol. 4. New Jersey: Prentice Hall, 1995.

[51] C. Chou. “The canonical representation of multiplication operation on triangular fuzzy numbers”, Computers & Mathematics with Applications, vol. 45, no.10, pp. 1601-1610, May. 2003. DOI: 10.1016/S0898-1221(03)00139-1.

[52] S. Opricovic, G.H. Tzeng. “Defuzzification within a multicriteria decision model”, International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems, vol. 11, no.5, Oct. 2003.

[53] R. Zhao, R. Govind, Algebraic characteristics of extended fuzzy numbers, Information Sciences, 54(1) (1991), 103-130.

[54] Central Intelligence Agency (CIA). “Country Comparison of HIV/AIDS - adult prevalence rates” CIA Library, 2013.

[55] C. L. Hwang, K. Yoon. "Multiple Attribute Decision Making: Methods and Applications, A State of the Art Survey. 1981." Sprinnger-Verlag, New York, NY.

[56] H. Deng, Y. Chung-Hsing, R. J. Willis. "Inter-company comparison using modified TOPSIS with objective weights." Computers & Operations Research 27.10 (2000): 963-973.

[57] H.S. Shih, H.J. Shyur, E. S. Lee. "An extension of TOPSIS for group decision making." Mathematical and Computer Modelling 45.7 (2007): 801-813.