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A Fuzzy TOPSIS Approach for Evaluating the Quality of Breast Cancer Information on the Internet

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Abstract

Breast cancer, a worldwide disease that typically affects women, is among the most ubiquitous types of malignant tumors and is the result of abnormal growth of breast cells. Despite heavy reliance on the internet to obtain breast cancer information, the credibility of provided information remains unclear. Inaccurate information causes detrimental consequences to the public. Evaluating the quality of online information on breast cancer is a challenge and therefore requires a rational and systematic evaluation method. This study aimed to evaluate the quality of online information on breast cancer based on fuzzy TOPSIS with the application of linguistic variables, which assists expert decision making in terms of uncertainty and subjectivity. The results can then be used to identify credible websites that can educate the public, including breast cancer patients, on breast cancer issues. Moreover, this study assists in validating the quality of online information on breast cancer. The results obtained from this study were compared to the results obtained using VIKOR, which is a beneficial tool for evaluating the quality of online information on other health issues as well.

Keywords: MCDM, fuzzy TOPSIS, online information quality, breast cancer

INTRODUCTION

The internet is considered a primary information source. Information on health issues, which was initially exclusive to only medical professionals, has become freely accessible. Moreover, the public conveniently relies on the internet to obtain this information with their portable smart devices using high-speed broadband or wireless networks. Online information on health issues largely comes from authoritative sources, such as federal agencies, medical institutions, practitioners, product vendors, and research organizations. However, there are numerous dubious sources as well. Despite the presence of good intention, information provided by dubious sources is likely to be misinformative and misleading [1], thus causing distrust and raising credibility issues over which information to seek. Furthermore, finding quality online health-related information can be difficult due to the speed and uncontrolled manner of information accumulation.

There are numerous studies on the quality of online health-related information. Most of these studies proposed evaluation criteria and framework in evaluating information quality [2, 3, 4, 5]. For instance, Afful-Dadzie et al. [1, 6] proposed a framework based on fuzzy VIKOR to evaluate domain-specific online information quality specifically on diabetes and HIV in Swaziland. A comprehensive search of relevant literature revealed there has been no evaluation on the quality of online information on breast cancer, particularly in Saudi Arabia.

Therefore, this study aimed to evaluate the quality of online information on breast cancer in Saudi Arabia based on a multi-criteria decision-making (MCDM) technique in a fuzzy environment, namely, fuzzy TOPSIS.

The structure of this paper is as follows: Section II introduces both fuzzy MCDM and fuzzy TOPSIS; Section III explains the framework of fuzzy TOPSIS used in this study; Section IV presents the results and discussion of this study; and Section V concludes the study and suggests future directions.

FUZZY MCDM

As a modeling and methodological tool, multi-criteria decision-making (MCDM) addresses complex decision-making problems. Over the years, MCDM has become one of the widely known methods for decision making [7, 8] in diverse fields. Fuzzy logic is recognized as an effective integration for MCDM in cases of natural language expressions when thoughts and judgments may provide inaccurate or subjective data. Thus, Bellman and Zadeh [9] recommended decision making in a fuzzy environment. Hence, numerous applications and theories in addressing various forms of MCDM have been postulated.

In fact, most MCDM techniques, such as (1) Analytic Hierarchy Process (AHP), (2) Analytic Network Process (ANP), (3) Elimination and Choice Expressing Reality (ELECTRE), (4) Grey Relational Analysis (GRA), (5) Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE), (6) Weighted Product Model, (7) VIsekriterijumska optimizacija I KOmpromisno Resenje (VIKOR), and (8) Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), apply fuzzy logic.

A. FUZZY TOPSIS

TOPSIS, which was originally introduced in 1981 by Hwang and Yoon [10], is a technique that ranks possible alternatives based on the measurement of their similarities to the ideal solution. The underlying logic behind this technique is to select the best possible alternative that has the nearest distance from the positive ideal solution and furthest distance from the negative ideal solution. Accordingly, the positive ideal solution denotes maximum benefit criteria with minimum conflicting criteria while the negative ideal solution implies otherwise—maximum conflicting criteria with minimum benefit criteria.

Fuzzy TOPSIS is an extension of TOPSIS in a fuzzy environment with both values of attributes and weights being triangular fuzzy numbers [11]. Fuzzy TOPSIS has been extensively applied in diverse fields for selection and ranking [12, 13, 14, 15], evaluation of credit risk [16], performance analysis [17], and quality assessment of online shopping websites [18]. However, the application of fuzzy TOPSIS for the evaluation of online information quality remains scarce.

FUZZY TOPSIS FRAMEWORK

For this study, the fuzzy TOPSIS approach was implemented as follows:

Step 1: The alternatives, criteria, and decision makers were specifically determined.

Step 2: Both weights and ratings of linguistic term sets were identified.

Step 3: The individual linguistic preferences were gathered for both criteria and alternatives prior to their transformation into fuzzy weights and a fuzzy decision matrix. It was assumed that there were m possible alternatives known as $A = \{A_1, A_2, \ldots, A_m\}$ that were assessed against n criteria known as $C = \{C_1, C_2, \ldots, C_n\}$.

The weights of criteria were expressed as w_i, $i = 1, 2, \ldots, n$. It was assumed that there are K persons for the group of decision makers. Therefore, the rating of each alternative with reference to each criterion was determined based on the following:

$$\tilde{x}_{ij} = \frac{1}{K}[\tilde{x}_{ij}^1 + \tilde{x}_{ij}^2 + \cdots + \tilde{x}_{ij}^K] \tag{1}$$

where $\tilde{x}_{ij}^K$ indicates the rating of an alternative (A_i) with reference to a criterion (C_j) according to Kth decision maker and $\tilde{x}_{ij} = (a_{ij}^K, b_{ij}^K, c_{ij}^K)$.

The aggregated fuzzy weights of criteria were obtained based on the following:

$$\tilde{w}_j = \frac{1}{K}[\tilde{w}_j^1 + \tilde{w}_j^2 + \cdots + \tilde{w}_j^K] \tag{2}$$

Meanwhile, the fuzzy decision matrix was constructed as below:

$$\tilde{D} = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mn} \end{bmatrix} \end{array} \tag{3}$$

Step 4: The weighted fuzzy decision matrix was determined based on the following:

$$\tilde{V} = [\tilde{v}_{ij}]_{mxn} \quad i = 1,2,\cdots,m; j = 1,2,\cdots,n \tag{4}$$

where $\tilde{v}_{ij} = \tilde{x}_{ij} \otimes \tilde{w}_{ij}$.

Step 5: The distances from the fuzzy positive ideal solution (FPIS) and fuzzy negative ideal solution (FNIS) for every alternative were computed. With respect to the weighted fuzzy decision matrix, FPIS (A^+) and FNIS (A^-) were defined by the following equations:

$$A^+ = (\tilde{v}_1^+, \tilde{v}_2^+, \cdots, \tilde{v}_n^+) \tag{5}$$

$$A^- = (\tilde{v}_1^-, \tilde{v}_2^-, \cdots, \tilde{v}_n^-) \tag{6}$$

where $\tilde{v}_j^+ = (1,1,1)$, and $\tilde{v}_j^- = (0,0,0), j = 1, 2, \cdots, n$. Referring to the following equations, the distances from FPIS (A^+) and FNIS (A^-) for every alternative were computed:

$$d_i^+ = \sum_j^n d(\tilde{v}_{ij}, \tilde{v}_j^+), i = 1,2,\cdots,m \tag{7}$$

$$d_i^- = \sum_j^n d(\tilde{v}_{ij}, \tilde{v}_j^-), i = 1,2,\cdots,m \tag{8}$$

where *d(.,.)* is the calculated distance between two triangular fuzzy numbers using the vertex method. Assuming $\tilde{a} = (\tilde{a}_1, \tilde{a}_2, \tilde{a}_3)$ and $\tilde{b} = (\tilde{b}_1, \tilde{b}_2, \tilde{b}_3)$ as triangular fuzzy numbers, the distance between both numbers was determined as follows:

$$d(\tilde{a}, \tilde{b}) = \sqrt{\frac{1}{3}[(\tilde{a}_1 - \tilde{b}_1)^2 + (\tilde{a}_2 - \tilde{b}_2)^2 + (\tilde{a}_3 - \tilde{b}_3)^2]} \tag{9}$$

Step 6: The closeness coefficients were obtained, and the alternatives were ranked. The closeness coefficient was obtained for every alternative once d_i^+ and d_i^- of each alternative were calculated. Principally, this ranks the alternatives in a specific order. The closeness coefficient of each alternative, CC_i, was determined as follows:

$$CC_i = \frac{d_i^-}{d_i^+ + d_i^-}, i = 1,2,\cdots,m \tag{10}$$

CC_i takes a value between 0 and 1. Based on CC_i values, the alternatives were ranked from the highest value to the lowest value. When the CC_i value approaches 1, the ith alternative approaches FPIS. However, when the CC_i value gets further from 1, the ith alternative approaches FNIS instead. Therefore, the alternative with the maximum CC_i value was selected.

RESULTS

The results of the application of fuzzy TOPSIS in the evaluation of the quality of online information quality on breast cancer and the ranking of online information providers in Saudi Arabia are discussed in this section.

First, the alternatives, criteria, and decision makers were determined. This study adopted 15 criteria (refer to Fig. 1), as proposed by Afful–Dadzie et al. [1], which were then grouped into four primary clusters: (1) credibility, (2) content, (3) design, and (4) security. This study gathered four decision makers to evaluate the quality of online information on breast cancer in Saudi Arabia: (1) medical practitioner, (2) breast cancer specialist, (3) web designer, and (4) information security expert.

Websites on breast cancer were obtained using Alexa with the keyword "breast cancer in Saudi Arabia", which produced 2,620,000 results. This study particularly omitted links to research papers and news. More specifically, this study only considered links that were associated with Saudi Arabia and provided information on breast cancer in the English language. Alamoudi Breast Center (A1), Ministry of Health (A2), Siemens Healthineers (A3), and Zahra (A4) were selected as the most prevalent online information providers on breast cancer in Saudi Arabia.

Second, the weights (L1) and ratings (L2) of linguistic term sets were identified as follows:

- L1 = {Strongly Not Important (SNI) = (0.0, 0.1, 0.3); Not Important (NI) = (0.1, 0.3, 0.5); Medium (M) = (0.3, 0.5, 0.7); Important (I) = (0.5, 0.7, 0.9); Strongly Important (SI) = (0.7, 0.9, 1.0)}
- L2 = {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, 1.0, 1.0)}

Third, individual linguistic preferences for each criterion as well as for each alternative were gathered. Table I presents the evaluated weight for each criterion by decision makers. Subsequently, these linguistic preferences were transformed into triangular fuzzy numbers—L1 was used for weights and L2 was used for alternatives. Subsequently, (1) was utilized to aggregate the fuzzy rating of each alternative, whereas (2) was utilized to aggregate the fuzzy weight of each criterion. Table II displays the aggregated fuzzy weights of criteria while Table III shows the aggregated fuzzy decision matrix.

Following that, the weighted fuzzy decision matrix was determined using (4) and presented in Table IV. Subsequently, the obtained distances from FPIS and FNIS for each alternative in Table V were computed using (9).

Lastly, the closeness coefficients were obtained using (10) prior to the ranking of alternatives, as revealed in Table VI. Conclusively, the four alternatives in this study were ranked based on CC_i values, which revealed the following ranking order: $A2 > A3 > A4 > A1$. Thus, the Ministry of Health (*A2*) was found to be the best online information provider on breast cancer in Saudi Arabia.

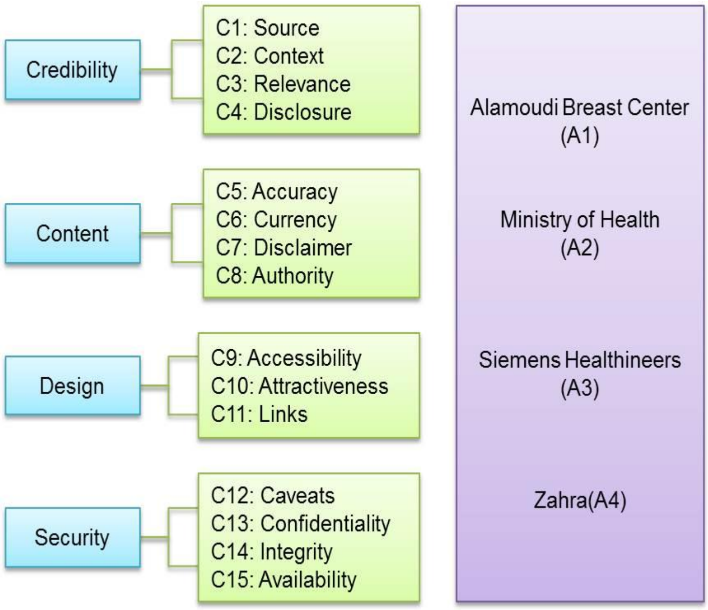

Figure 1. Fuzzy TOPSIS Framework

Table I. Evaluation of Weight by Decision Makers

	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**	**C13**	**C14**	**C15**
DM1	SI	I	SI	SI	SI	I	I	M	SI	I	M	M	I	I	I
DM2	M	NI	M	NI	M	M	M	NI	I	M	M	SNI	NI	M	NI
DM3	I	SI	SI	NI	SI	M	NI	NI	SI	I	I	NI	NI	SI	SI
DM4	M	I	I	M	M	M	I	M	I	M	M	M	NI	I	M

Table II. Fuzzy Weights of Criteria

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15
Fuzzy Weights	(.45, .65, .83)	(.45, .65, .83)	(.55, .75, .90)	(.30, .50, .68)	(.50, .70, .85)	(.35, .55, .75)	(.35, .55, .75)	(.20, .40, .60)	(.60, .80, .95)	(.40, .60, .80)	(.35, .55, .75)	(.18, .35, .55)	(.20, .40, .60)	(.50, .70, .88)	(.40, .60, .78)

Table III. Fuzzy Decision Matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15
A1	(.15, .35, .55)	(.30, .50, .65)	(.25, .45, .60)	(.20, .40, .60)	(.20, .40, .60)	(.15, .30, .50)	(.00, .20, .40)	(.25, .45, .65)	(.05, .20, .40)	(.25, .40, .60)	(.25, .40, .55)	(.15, .35, .55)	(.15, .35, .55)	(.15, .35, .55)	(.15, .35, .55)
A2	(.35, .55, .75)	(.50, .70, .90)	(.50, .70, .85)	(.25, .45, .65)	(.40, .60, .80)	(.25, .45, .65)	(.15, .35, .55)	(.25, .45, .65)	(.25, .45, .65)	(.35, .55, .75)	(.35, .55, .70)	(.20, .40, .60)	(.35, .55, .75)	(.35, .55, .75)	(.20, .30, .50)
A3	(.35, .55, .70)	(.55, .75, .90)	(.50, .70, .80)	(.15, .35, .55)	(.30, .50, .70)	(.20, .40, .60)	(.20, .40, .60)	(.25, .45, .65)	(.20, .40, .60)	(.25, .45, .65)	(.30, .45, .60)	(.20, .40, .60)	(.20, .40, .60)	(.30, .50, .70)	(.10, .25, .45)
A4	(.25, .45, .65)	(.25, .45, .65	(.30, .50, .70)	(.25, .45, .65)	(.30, .50, .70)	(.35, .55, .75)	(.10, .30, .50)	(.20, .40, .60)	(.25, .45, .65)	(.45, .65, .85)	(.25, .40, .60)	(.15, .35, .55)	(.15, .35, .55)	(.30, .50, .70)	(.30, .45, .65)

Table IV. Weighted Fuzzy Decision Matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15
A1	(.07, .23, .45)	(.14, .33, .54)	(.14, .34, .54)	(.06, .20, .41)	(.10, .28, .51)	(.05, .17, .38)	(.00, .11, .30)	(.05, .18, .39)	(.03, .16, .38)	(.10, .24, .48)	(.09, .22, .41)	(.03, .12, .30)	(.03, .14, .33)	(.08, .25, .48)	(.06, .21, .43)
A2	(.16, .36, .62)	(.23, .46, .74)	(.28, .53, .77)	(.08, .23, .44)	(.20, .42, .68)	(.09, .25, .49)	(.05, .19, .41)	(.05, .18, .39)	(.15, .32, .57)	(.14, .33, .60)	(.12, .30, .53)	(.04, .14, .33)	(.07, .22, .45)	(.18, .39, .66)	(.08, .18, .39)
A3	(.16, .36, .58)	(.25, .49, .74)	(.28, .53, .72)	(.05, .18, .37)	(.15, .35, .60)	(.07, .22, .45)	(.07, .22, .45)	(.05, .18, .39)	(.12, .32, .57)	(.10, .27, .52)	(.11, .25, .45)	(.04, .14, .33)	(.04, .16, .36)	(.15, .35, .61)	(.04, .15, .35)
A4	(.11, .29, .54)	(.11, .29, .54)	(.17, .38, .63)	(.08, .23, .44)	(.15, .35, .60)	(.12, .30, .56)	(.04, .17, .38)	(.04, .16, .36)	(.15, .36, .62)	(.18, .39, .68)	(.09, .22, .45)	(.03, .12, .30)	(.03, .14, .33)	(.15, .35, .61)	(.12, .27, .50)

Table V. Distance

		C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15
$d_i^-(A_i, A^-)$	**A1**	.30	.37	.38	.26	.34	.24	.18	.25	.24	.32	.27	.19	.21	.31	.28
	A2	.42	.52	.56	.29	.48	.32	.26	.25	.39	.40	.36	.21	.29	.45	.25
	A3	.40	.53	.54	.24	.41	.29	.29	.25	.38	.34	.30	.21	.23	.42	.22
	A4	.36	.36	.43	.29	.41	.38	.24	.23	.42	.46	.29	.19	.21	.42	.34
$d_i^+(A_i, A^+)$	**A1**	.77	.69	.68	.79	.72	.81	.87	.81	.82	.74	.77	.86	.84	.75	.78
	A2	.65	.57	.52	.77	.60	.74	.79	.81	.68	.67	.70	.84	.77	.63	.79
	A3	.66	.55	.53	.81	.66	.77	.77	.81	.69	.72	.75	.84	.82	.66	.83
	A4	.71	.71	.64	.77	.66	.69	.82	.82	.65	.62	.76	.86	.84	.66	.72

Table VI. Closeness Coefficients

	A1	A2	A3	A4
A^-	4.14	5.45	5.06	5.02
A^+	11.71	10.53	10.86	10.93
CC_i	0.26	0.34	0.32	0.31
Ranking	(4)	(1)	(2)	(3)

COMPARISON WITH FUZZY VIKOR

This phase compared the fuzzy TOPSIS results obtained in this study to another popular MCDM method known as VIKOR [19]. Both fuzzy TOPSIS and VIKOR are broadly applied as solutions for different selections and rankings. Fuzzy VIKOR was introduced by Opricovic [20], which addresses conflicting and non-commensurable criteria issues pertaining to MCDM.

In view of this, fuzzy VIKOR and fuzzy TOPSIS were compared, which revealed that both approaches were ideal and their ranking of the most recommended and the least recommended calculated fuzzy values achieved scalar (crisp) values [21, 22]. In addition, the robustness of both approaches was theoretically reaffirmed [21]. Table VII presents how the alternatives for each approach were ranked. Both approaches yielded similar ranking in order of alternatives using similar data. Unlike fuzzy TOPSIS, alternatives with a low Q index value for fuzzy VIKOR are favored.

Table VII. Comparison between Fuzzy TOPSIS and Fuzzy VIKOR

	Fuzzy TOPSIS		Fuzzy VIKOR	
	Results (CC_i)	Rank	Results (Q)	Rank
A1	.26	4	1.00	4
A2	.34	1	.01	1
A3	.32	2	.43	2
A4	.31	3	.53	3

CONCLUSION

The challenges to deliver health services and lack of medical professionals in certain countries, particularly in Saudi Arabia, may cause the public to heavily depend on online health-related information. These information providers must be regularly evaluated to provide quality information for health improvement.

This study specifically adopted fuzzy TOPSIS with the application of linguistic variables to evaluate the quality of online information on breast cancer in Saudi Arabia, which assists expert decision making in terms of uncertainty and subjectivity.

Using the method tested and evaluated in this study, the public, including breast cancer patients, can identify reliable online information sources on breast cancer issues. Furthermore, this study also provides guidance about the credibility of online information providers in generating quality information on other health issues. The results of this study matched favorably with the results of fuzzy VIKOR, which justified its reliability.

In our future work, the application of other MCDM approaches will be studied, followed by a comparative analysis of these approaches, including fuzzy TOPSIS, to identify the best approach for dealing with the aspects of uncertainty and subjectivity in expert decision making.

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