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Ranking Knowledge Level Using Generalized TOPSIS in Single-Valued Neutrosophic Environment

Roliza Md Yasin[1*], Nurul Ain Syamimi Shamsudin[2], Nurul Khairunnisa Ramli [3], Suriana Alias[4], Norzieha Mustapha[5]

[1, 4, 5]Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA Kelantan, Bukit Ilmu, Machang, Kelantan, Malaysia
[2]Hong Leong Bank Berhad, Petaling Jaya, Selangor
[3]Blossom Lab International Sdn. Bhd., Sungai Petani, Kedah, Malaysia

[*] Corresponding author : roliza927@uitm.edu.my

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ABSTRACT

The attempt on using multi-criteria decision making (MCDM) techniques in analyzing questionnaire had started a few years back. As the issue of uncertainty is found to be common in capturing the accurate human response, the use of a single-valued neutrosophic set was proposed to handle it. This study adopts the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) on a set of secondary data and proposed generalized TOPSIS technique with single-valued neutrosophic data in obtaining the ranking of the respondent knowledge level on two aspects. The knowledge level of diagnosing dental emergency problem and giving appropriate emergency treatment are analyzed using these two techniques. Based on the value of relative closeness coefficient, it gives consistent conclusion with the previous work.

Keywords: MCDM, Questionnaire, Single-Valued Neutrosophic Set (SVNS), TOPSIS.

1 INTRODUCTION

The need on conducting a survey in capturing the response on a certain issue is certainly obvious. One of the most common techniques in realizing the survey's objectives would involve the questionnaire distribution to the targeted respondent. To date, there are few studies focused on analyzing questionnaires in a more elegant environment. The environment is defined by the mathematical set theory which is generalized from the fuzzy set [1], intuitionistic fuzzy set [2], and neutrosophic set [3]. The concept of a fuzzy set has been developed to deal with the problem of uncertainty, imprecision, and vagueness. However, a fuzzy set can only express the falsity by taking the complement of the truth membership. Meanwhile, intuitionistic fuzzy set (IFS) cannot represent the indeterminacy of information due to the restriction of the sum of memberships functions i.e $0<T+F<1$. Due to the limitations, many sets and theories were later initiated to solve the issue of impreciseness with different forms of structures. By that, the neutrosophic theory was introduced by Smarandache [4]. The concept of neutrosophic sets is the generalization of fuzzy sets and intuitionistic fuzzy sets [5] and [6] excellently did thorough review on the development on the set. It is based on truth membership, T, indeterminate membership, I, and false membership, F. This neutrosophic triad can alternatively being defined as positive membership, neutral membership and negative membership respectively [7]. The presence of indeterminate membership gives the chance for the respondents to express their perception or feelings with higher degree of accuracy. Hence, the collected data becomes more precise, and the findings are more reliable as it better represents human judgement. This relates with the importance of having accurate data; and medical diagnosis is one of the applications of real-time results [8].

There are various questionnaire analyses had been conducted in single-valued neutrosophic environment. The attempt to incorporate the statistical tools are found in [9-11]. Alternatively, [12] introduced clustering algorithm with the triple refined indeterminate neutrosophic for Likert scale. On the other hand, [3] developed two examples from previous surveys and calculated scoring function. The work of [13] also calculated scoring function with the use of aggregation operator in dealing with twenty-four responses from twenty respondents. They further employed the clustering technique with the aim to identify a factor causing the formation of two groups of responses. To date, there are few studies adapted multi-criteria decision making (MCDM) techniques in questionnaire analysis within neutrosophic environment [14-15]. [14] extended the Integrated Simple Weighted Sum Product (WISP) method to be customized for the application of single-valued neutrosophic numbers. They presented the improvement in the evaluation rural tourist tours by adapting questionnaire and appropriate linguistic variables to enable a simpler and more precise collection of respondents' attitudes. [15] developed a questionnaire with the application of neutrosophic decision making trial and evaluation laboratory (DEMATEL) in order to access the leanness level of a manufacturing company.

Inspired by [16] work on questionnaire-TOPSIS innovative algorithm in evaluating college students' emergency response capability, this present study uses the secondary data in neutrosophic environment collected by [13]. Among the early study on TOPSIS in single-valued neutrosophic environment is the work by Biswas et al. [17]. Their several years of hard works resulted to the development of nonlinear programming based on TOPSIS method in determining the relative closeness intervals of alternatives [18]. Further, they extended the TOPSIS strategy to be solved for multi-attribute group decision making problems in SVNS and interval neutrosophic set environments as well [19]. A similarity measure based on Hamming distance was used to determine the weights of decision makers.

In [13], a set of questionnaires consisted of twenty-four open-ended questions was designed and distributed with the aim to identify the dental students' knowledge level on diagnosis and treatment for dental emergencies cases. The researchers sought for qualitative evaluation from three experts on each student responses and proposed the use of single-valued neutrosophic sets (SVNS) which allow the use of linguistic variable of SVNS. In TOPSIS, the value of relative closeness coefficient is used in ranking the student knowledge level and it is calculated by considering the distance measures on both similarity and dissimilarity of ideal solution. Hence, it is expected that the finding becomes more acceptable in representing the relation between the criteria of knowledge and student perspective in emergency cases as compared to scoring function measure.

2 PRELIMINARIES

This section introduces some definitions which guides the explanation in subsequent section.

Definition 2.1: Neutrosophic Set [5].

Let X be a space of objects with generic elements in X denoted by x; then a neutrosophic set A is an object having the form $A = \{\langle x, T_A(x), I_A(x), F_A(x)\rangle, x \in X\}$ where the functions $T, I, F: X \to]^{-}0, 1^{+}[$ define respectively the truth-membership function, an indeterminacy membership function, and a falsity-membership function of the element $x \in X$ to the set A with the condition: $-0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3^{+}$.

The function $T_A(x), I_A(x)$ and $F_A(x)$ are real standard or nonstandard subsets of $]^{-}0, 1^{+}[$. Since it is difficult to apply a neutrosophic set setting to practical problems Wang et al. [20] introduced the concept of a single-valued neutrosophic set, which is an instance of a neutrosophic set and can be used in real scientific and engineering applications.

Definition 2.2: Single-valued neutrosophic set [20].

Let X be a universal space of points (objects), with a generic element of X denoted by x. A single-valued neutrosophic set A in X is characterized by a truth membership function, $T_A(x)$, an indeterminacy-membership function, $I_A(x)$ and falsity-membership function, $F_A(x)$. Here $T_A(x), I_A(x), F_A(x) \in [0, 1]$ and $A = \{\langle x, T_A(x), I_A(x), F_A(x)\rangle, x \in X\}$

Definition 2.3: Euclidean distance [21]

Let $A = \{\langle x, T_A(x), I_A(x), F_A(x)\rangle, x \in X\}$ and $B = \{\langle x, T_B(x), I_A(x), F_B(x)\rangle, x \in X\}$ be any two SVNS in X; then the Euclidean distance between SVNSs A and B are defined in Equation (1).

$$d(A,B) = \sqrt{\frac{1}{3n}\sum_{i=1}^{n}(T_A(x_i) - T_B(x_i))^2 + (I_A(x_i) - I_B(x_i))^2 + (F_A(x_i) - F_B(x_i))^2} \tag{1}$$

3 METHODOLOGY

This section discusses the procedure following [17] and applied to a set of secondary data [13]. The data was collected from the questionnaire feedback of twenty dental students regarding their medical emergency knowledge. The questionnaire consisted of ten questions on diagnosis and fourteen questions on treatment. In this study, the data is analyzed in two different environments using TOPSIS approach. Section 3.1 explains on the application of conventional TOPSIS whilst Section 3.4 discusses the use of generalized TOPSIS in SVN environment.

3.1 Conventional TOPSIS

In this approach, the student responses which given as "Excellent', "Very good", "Good", "Regular", "Regular tending to bad", "Bad" and "Very bad" are assigned to a number using 7-point Likert scale. Then, conventional TOPSIS is applied here following Elhassouny and Smarandache [22] :

Step 1: All the responses are written in two matrices, $X = x_{ij}$ and $Y = y_{ik}$ where *i* = 1, … , 20 ; *j* =1, … , 10 and *k* = 1, … , 14.

Step 2: Obtain the normalized matrices for both matrix *X* and *Y* using the relationship below.

Normalized matrix for *X*, $R = r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{20} x_{ij}^2}}$;

Normalized matrix for *Y*, $P = p_{ik} = \frac{y_{ik}}{\sqrt{\sum_{i=1}^{20} y_{ik}^2}}$

Step 3: Calculate the weighted normalized matrices for matrix *X* and *Y* by the following formula with $w_d = 0.1$ and $w_t = 0.07$ [13].

Weighted normalized matrix of *X*, $V = v_{ij} = w_d * r_{ij}$;

Weighted normalized matrix of *X*, $U = u_{ik} = w_t * p_{ik}$

Step 4: Determine the positive ideal solution (PIS) and negative ideal solution (NIS) for both X and Y.

PIS of matrix *X*, $A^+ = v_i^+ = \{v_1^+, \ldots, v_{20}^+\} = \{(max_i \ \{v_{ij}|j \in J_1\}), min_i\{v_{ij}|j \in J_2\})\}$;

PIS of matrix Y, $B^+ = u_i^+ = \{u_1^+, \ldots, u_{20}^+\} = \{(max_i \ \{u_{ik}|k \in J_3\}), min_i\{u_{ik}|k \in J_4\})\}$;

NIS of matrix X, $A^- = v_i^- = \{v_1^-, \ldots, v_{20}^-\} = \{(min_i \ \{v_{ij}|j \in J_1\}), (max_i\{v_{ij}|j \in J_2\})\}$ and

NIS of matrix X, $B^- = u_i^- = \{u_1^-, \ldots, u_{20}^-\} = \{(min_i \ \{u_{ik}|k \in J_3\}), (max_i\{v_{ik}|j \in J_4\})\}$

where J_1 and J_3 are associated with the sets of students having low level of knowledge whereas J_2 and J_4 are sets of students having high level of knowledge.

Step 5: Calculate the Euclidean distances for both *X* and *Y*.

The separation values for the PIS of *X* and *Y* can be measured by using *n*-dimensional Euclidean distance.

$$D_i^+ = \sqrt{\sum_{j=1}^{10}\left(v_{ij} - v_j^+\right)^2} \quad \text{and} \quad F_i^+ = \sqrt{\sum_{k=1}^{14}(u_{ik} - u_k^+)^2}$$

The separation values for the NIS of X and Y can be measured in similar manner.

$$D_i^- = \sqrt{\sum_{j=1}^{10}\left(v_{ij} - v_j^-\right)^2} \quad \text{and} \quad F_i^+ = \sqrt{\sum_{k=1}^{14}(u_{ik} - v_k^+)^2}$$

Step 6: Calculate the relative closeness coefficient to the positive ideal solution for both X and Y.

$$C_i = \frac{D_i^+}{D_i^+ + D_i^-} \quad \text{and} \quad G_i = \frac{F_i^+}{F_i^+ + F_i^-}$$

3.2 Apply generalized TOPSIS

The TOPSIS method under single-valued neutrosophic environment is used here [17]. Therefore, this section discusses the use of generalized TOPSIS in SVN environment. Meanwhile, Figure 1 depicts the summary on the use of generalized TOPSIS in our study.

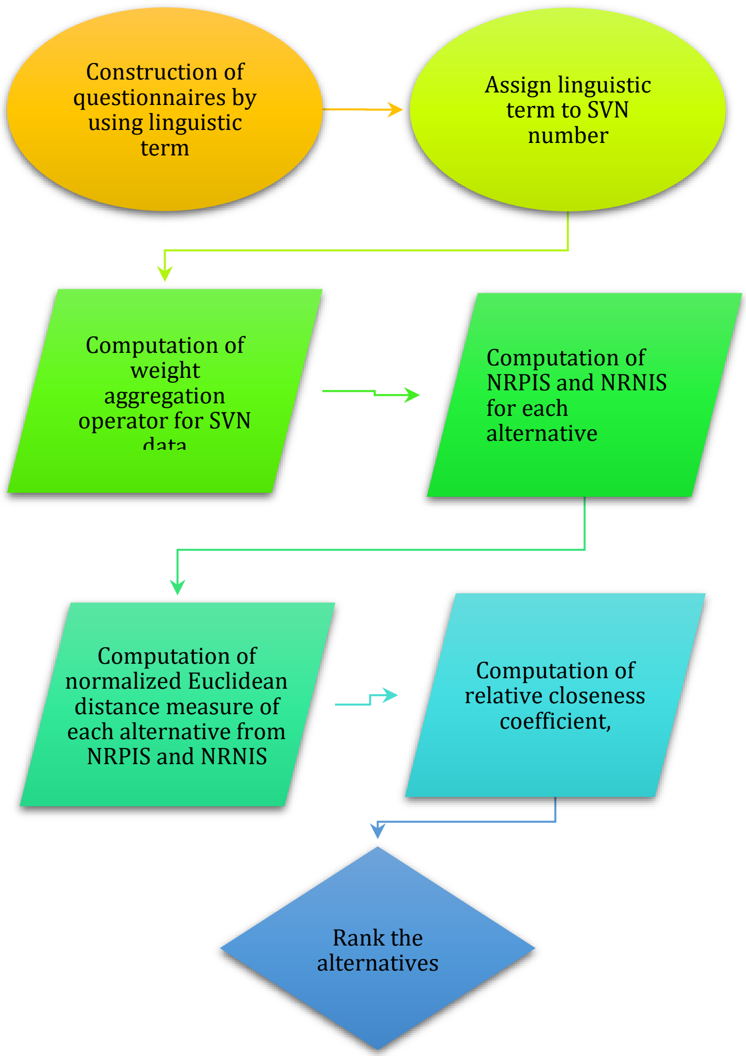

Figure 1: The process of generalized TOPSIS

According to Figure 1, all the steps for generalized TOPSIS are discussed below :

Step 1: Assign linguistic term to SVN number

All the students responses are assigned to single-valued neutrosophic numbers that correspond to the seven linguistic terms as shown in Table 1.

Table 1 : Linguistic terms used (Fernandez et al. [13])

Linguistic Term	**SVN Numbers**
Excellent (E)	(1;0;0)
Very Good (VG)	(0.80;0.15;0.20)
Good (G)	(0.60;0.35;0.40)
Regular (R)	(0.50;0.50;0.50)
Regular tending to Bad (RB)	(0.40;0.65;0.60)
Bad (B)	(0.20;0.85;0.80)
Very Bad (VB)	(0;1;1)

Step 2: Aggregate the SVN data

The SVN data is aggregated using the single-valued neutrosophic weighted average operator [13] in Equation (2) and assign into aggregated decision matrices, .

$$F_w(A_1, A_2, \dots, A_n) = \left\langle 1 - \prod_{j=1}^{n} \left(1 - T_{A_j}(x)\right)^{w_j}, \prod_{j=1}^{n} I_{A_j}(x)^{w_j}, \prod_{j=1}^{n} F_{A_j}(x)^{w_j} \right\rangle \tag{2}$$

where

$W = (w_1, w_2, \dots, w_n)$ is the weight vector of $A_j (j = 1,2, \dots, n)$ such that $w_n \in [0,1]$ with $\sum w_j = 1$ and n = 20.

Step 3: Determine the neutrosophic relative positive ideal solution (NRPIS) and neutrosophic relative negative ideal solution (NRNIS).

The NRPIS and NRNIS are defined in Equation (3) and (4) respectively.

$$Q_N^+ = [d_1^{w+}, d_2^{w+}, \dots, d_n^{w+}] \tag{3}$$

$$Q_N^- = [d_1^{w-}, d_2^{w-}, \dots, d_n^{w-}] \tag{4}$$

where

$d_j^{w+} = \langle T_j^{w+}, I_j^{w+}, F_j^{w+} \rangle$ for $j = 1,2,\ldots,n$

$T_j^{w+} = \left\{ \left(\max_i \left\{ T_{ij}^{w_i} \right\} \middle| j \in J_1 \right), \left(\min_i \left\{ T_{ij}^{w_i} \right\} \middle| j \in J_2 \right) \right\}$; $T_j^{w-} = \left\{ \left(\min_i \left\{ T_{ij}^{w_i} \right\} \middle| j \in J_1 \right), \left(\max_i \left\{ T_{ij}^{w_i} \right\} \middle| j \in J_2 \right) \right\}$

$I_j^{w+} = \left\{ \left(\min_i \left\{ I_{ij}^{w_i} \right\} \middle| j \in J_1 \right), \left(\max_i \left\{ T_{ij}^{w_i} \right\} \middle| j \in J_2 \right) \right\}$; $I_j^{w-} = \left\{ \left(\max_i \left\{ I_{ij}^{w_i} \right\} \middle| j \in J_1 \right), \left(\min_i \left\{ I_{ij}^{w_i} \right\} \middle| j \in J_2 \right) \right\}$

$F_j^{w+} = \left\{ \left(\min_i \left\{ F_{ij}^{w_i} \right\} \middle| j \in J_1 \right), \left(\max_i \left\{ F_{ij}^{w_i} \right\} \middle| j \in J_2 \right) \right\}$; $F_j^{w-} = \left\{ \left(\max_i \left\{ F_{ij}^{w_i} \right\} \middle| j \in J_1 \right), \left(\min_i \left\{ F_{ij}^{w_i} \right\} \middle| j \in J_2 \right) \right\}$

Step 4: Calculate the normalized Euclidean distance measure of each alternative from NRPIS and NRNIS.

The normalized Euclidean distances are calculated using Equation (5) and (6).

$$D_{Eu}^{i+} = \left[\frac{1}{3n} \sum_{j=1}^{n} \left\{ \left(T_{ij}^{w_j}(x_j) - T_j^{w+} \right)^2 + \left(I_{ij}^{w_j}(x_j) - I_j^{w+} \right)^2 + \left(F_{ij}^{w_j}(x_j) - F_j^{w+} \right)^2 \right\} \right] \tag{5}$$

$$D_{Eu}^{i-} = \left[\frac{1}{3n} \sum_{j=1}^{n} \left\{ \left(T_{ij}^{w_j}(x_j) - T_j^{w-} \right)^2 + \left(I_{ij}^{w_j}(x_j) - I_j^{w-} \right)^2 + \left(F_{ij}^{w_j}(x_j) - F_j^{w-} \right)^2 \right\} \right] \tag{6}$$

Step 5: Evaluate the relative closeness coefficient, $C_i^{\,*}$.

The relative closeness coefficient is calculated using Equation (7).

$$C_i^* = \frac{D_{Eu}^{i-}\left(d_{ij}^{w_j}, d_j^{w-} \right)}{D_{Eu}^{i+}\left(d_{ij}^{w_j}, d_j^{w-} \right) + D_{Eu}^{i-}\left(d_{ij}^{w_j}, d_j^{w-} \right)} \quad ; \quad i = 1,\ldots,n \tag{7}$$

where $0 \leq C_i^* \leq 1$.

Step 6: Rank the alternatives according to the relative closeness coefficient values. The biggest value indicates the best alternative.

The values and ranking are shown in detail in Section 4.

4 RESULTS AND DISCUSSION

The calculated relative closeness coefficient in single-valued neutrosophic environment is shown in Table 2 and compared with a scoring function value obtained by [13].

Table 2: Relative closeness coefficient and scoring function

	Diagnosis		**Treatment**	
Student, S_i	C_i^* **(present)**	**Scoring function [13]**	C_i^* **(present)**	**Scoring function [13]**
1	0.0589	1.015	0.1453	1.1043
2	**0.7947**	2.144	1.0000	2.3213
3	0.2003	1.557	0.3983	1.4838
4	**0.7300**	2.205	**0.9163**	2.2052
5	0.1470	1.388	**0.5651**	1.7034
6	0.1470	1.388	**0.5110**	1.6217
7	0.1470	1.388	0.3320	1.4209
8	0.1891	1.309	0.4748	1.5682
9	**0.7300**	2.205	**0.8529**	2.1168
10	0.0712	1.431	0.4122	1.5027
11	0.0468	1.001	0.2180	1.2311
12	0.0922	1.056	0.0001	0.9235
13	**0.5865**	2.144	**0.9736**	2.2846
14	0.0000	0.944	0.1599	1.1497
15	**0.8345**	2.262	**0.9163**	2.2052
16	0.4113	2.079	**0.8854**	2.1622
17	0.0358	1.722	0.3914	1.4738
18	0.1036	1.463	0.3914	1.4738
19	**0.8345**	2.262	**0.8854**	2.1622
20	0.0142	1.603	0.3914	1.4738

There are 6 students (student 2, 4, 9, 13, 15, and 19) obtain more than 0.5 value of C_i^* indicating all of them have good knowledge in diagnosing dental emergency problem. This is consistent to [13] where they categorized the same 6 students as very good according to the calculated scoring functions. Further, there are 9 students (student 2, 4, 5, 6, 9, 13, 15, 16 and 19) obtained more than 0.5 value of C_i^* indicating all of them have good knowledge in giving appropriate emergency treatment. This is also consistent to [13] where they categorized the 9 students as regular according to the calculated scoring functions.

Table 3 compares the students ranking according to relative closeness coefficient values C_i^* obtained from two different types of data for diagnostic questions. The first data set is in the form of SVN numbers, whilst the second is in the form of 7-point Likert scale.

Table 3: Ranking of students according to TOPSIS and generalized TOPSIS for diagnostic questions

Ranking	C_i^* **for TOPSIS**	**Student,** S_i	C_i^* **for TOPSIS with SVN data**	**Student,** S_i
1	0.53933	19	**0.8345**	19
2	0.53687	15	**0.8345**	15
3	0.51219	4	**0.7947**	2
4	0.48562	9	**0.7300**	4
5	0.44111	2	**0.7300**	9
6	0.42982	13	**0.5865**	13
7	0.38064	16	0.4113	16
8	0.33437	3	0.2003	3
9	0.29158	5	0.1891	8
10	0.28486	12	0.1470	5
11	0.28327	17	0.1470	6
12	0.28255	8	0.1470	7
13	0.28074	7	0.1036	18
14	0.27704	18	0.0922	12
15	0.25478	1	0.0712	10
16	0.25476	10	0.0589	1
17	0.25216	6	0.0468	11
18	0.24679	11	0.0358	17
19	0.24490	20	0.0142	20
20	0.23628	14	4.0202×10^{-5}	14

From Table 3, the top six ranking order of the student's diagnosis knowledge are $S_{19} \succ S_{15} \succ S_4 \succ S_9 \succ S_2 \succ S_{13}$ and $S_{19} \succ S_{15} \succ S_2 \succ S_4 \succ S_9 \succ S_{13}$ for both techniques of TOPSIS respectively. With similar manner, Table 4 compares the students ranking according to relative closeness coefficient values for treatment questions.

Table 4: Ranking of students according to TOPSIS and generalized TOPSIS for treatment questions

Ranking	C_i^* **for TOPSIS**	**Student,** S_i	C_i^* **for TOPSIS with SVN data**	**Student,** S_i
1	0.8306	13	**0.99996**	2
2	0.8268	2	**0.97355**	13
3	0.8053	4	**0.91635**	4
4	0.7925	19	**0.91635**	15
5	0.7856	16	**0.88544**	16
6	0.7808	15	**0.88544**	19
7	0.7542	9	**0.85290**	9
8	0.5794	5	**0.56509**	5
9	0.5405	6	**0.51104**	6
10	0.4997	18	0.47478	8
11	0.4964	8	0.41223	10
12	0.4729	20	0.39832	3
13	0.4719	3	0.39136	17
14	0.4531	7	0.39136	18
15	0.4531	17	0.39136	20
16	0.4506	10	0.33201	7
17	0.3315	11	0.21801	11
18	0.2689	1	0.15990	14
19	0.2666	14	0.14531	1
20	0.2047	12	$7.2591\text{x}10^{-5}$	12

As for the treatment knowledge ranking shown in Table 4, the top nine ranking order is $S_{13} \succ S_2 \succ S_4 \succ S_{19} \succ S_{16} \succ S_{15} \succ S_9 \succ S_5 \succ S_6$ for TOPSIS and $S_2 \succ S_{13} \succ S_4 \succ S_{15} \succ S_{16} \succ S_{19} \succ S_9 \succ S_5 \succ S_6$ for generalized TOPSIS in SVN environment.

Table 5: Summary result for knowledge level of students in emergency cases

Summary result by MCDM techniques	Ranking order	Top students
Scoring function for diagnosis [13]	$S_{15} \succ S_{19} \succ S_4 \succ S_9 \succ S_2 \succ S_{13}$	2, 4, 9, 13, 15, and 19
TOPSIS for diagnosis	$S_{19} \succ S_{15} \succ S_4 \succ S_9 \succ S_2 \succ S_{13}$	2, 4, 9, 13, 15, and 19
Generalized TOPSIS for diagnosis	$S_{19} \succ S_{15} \succ S_2 \succ S_4 \succ S_9 \succ S_{13}$	2, 4, 9, 13, 15, and 19
Scoring Function for treatment [13]	$S_2 \succ S_{13} \succ S_4 \succ S_{15} \succ S_9 \succ S_{16} \succ S_{19} \succ S_5 \succ S_6$	2, 4, 5, 6, 9, 13, 15, 16, and 19
TOPSIS for treatment	$S_{13} \succ S_2 \succ S_4 \succ S_{19} \succ S_{16} \succ S_{15} \succ S_9 \succ S_5 \succ S_6$	2, 4, 5, 6, 9, 13, 15, 16, and 19
Generalized TOPSIS for treatment	$S_2 \succ S_{13} \succ S_4 \succ S_{15} \succ S_{16} \succ S_{19} \succ S_9 \succ S_5 \succ S_6$	2, 4, 5, 6, 9, 13, 15, 16, and 19

According to Table 5, there are top six students indicating all of them have good knowledge in diagnosing dental emergency problem and there are top nine students indicating all of them have good knowledge in giving appropriate emergency treatment. The ranking order is slightly different compared to each different MCDM techniques but the same top students in representing the relations between the criteria of knowledge level and student perspective in emergency cases indicate the good result of research.

5 CONCLUSION

In analysing the questionnaire responses in SVN environment, this study chooses TOPSIS approach as an alternative to the scoring function method. It is found that the technique gives consistent findings with [13], demonstrating that the TOPSIS approach has equal performance for determining the dentistry students level of knowledge in diagnosing and providing dental emergency treatment. The use of SVN number relates with the linguistic variable in more detail and precise way for representing the human judgements. The indicator is shown by the membership values of truth, indeterminate, and falsity membership. Therefore, from this research, it is hoped that many more analysis on the questionnaire responses in SVN environment shall be explored and able to solve the MCDM problem. The SVN data have the capability in capturing the complexity of human thinking which always result to uncertainty conditions. Besides, other uncertainty MCDM technique for ranking result are DEMATEL, fuzzy-analytic hierarchy process (AHP), neutrosophic-AHP, and fuzzy-analytic network process (ANP) technique can be applied in future.

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