Received: October 26, 2022. Revised: December 15, 2022.

International Journal of
Intelligent Engineering & Systems

http://www.inass.org/

Combine Subjective and Objective Weights into VIKOR Technique of Performance Appraisal at Higher Educational Institutions

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Abstract: A key field of research for addressing complicated decision problems is multiple criteria decision-making (MCDM), which has grown quickly. The purpose of the paper is to explore the performance appraisal model for educational institutions. In this paper, Analytic Hierarchy Process (AHP) is used to calculate the subjective weights and Shannon's method is used to calculate the objective weights, then VIKOR method is carried out using these weights which finally results in the ranking of the alternatives. To explore the feasibility of the developed model, the performance evaluation of twelve Iraqi medical colleges was considered as alternatives applied based on eight academic criteria. The results indicated that the sixth choice received the highest rating, while the fifth alternative received the lowest rating. Finally, sensitivity analysis (SA) is used to determine how the alternatives change depending on how important the criteria are. SA results the eighth criterion (Scientific output) was discovered to have the greatest influence on changing the priorities of the alternatives. The proposed method is receiving critical attention from higher authorities because it is considered a reliable scientific method of performance appraisal.

Keywords: Performance appraisal, Analytical hierarchy process, Shannon's method, VIKOR, Sensitivity analysis.

1. Introduction

The development of nations and the world depends heavily on educational institutions by supporting and supplying the highly skilled labor and research required for ongoing development [1]. Universities have recently attempted to achieve a new vision by employing contemporary methodologies to provide superior education and research services. To achieve a prestigious position among the highest-performing universities, one must effectively measure current service quality under the category of performance progress. Determining shortcomings and strengths, as well as developing and implementing effective strategic plans, must all be evaluated as part of this process. Furthermore, university administrators use rankings to help them develop plans for promoting the growth and development of their institutions [2, 3]. Competition between colleges and universities has a long history. The evaluation of the competition has long been based on implicit reputation, without any supporting facts. However, surveys have evolved in many nations as a method of evaluating and ranking education institutes due to the increased competition between universities and the rapid growth of the international higher education market [4]. Performance evaluation, performance assessment, performance measurement, and performance review have all been used as synonymous with performance appraisal [5]. University ratings have been around for more than 35 years and continuously updating [6] and are considered a worldwide phenomenon. Rankings originated in 1983 with the publication of the annual America's Best Colleges Review by US News and World Report [7]. Media organizations use university rankings to inform the public about the status of academic institutions both domestically and internationally. As a result, universities need to know their relative positions to other institutions on a national and international level regularly to make better assessments of their progress. In practically the used conventional technique methods, educational institutions are evaluated by assigning a percentage to each of the evaluation axes without using a scientific or mathematical approach to calculate the weights of those axes, but instead relying solely on expert opinions. In this study, Subjective (AHP) and objective (Shannon) weighting methods are used to calculate the importance of criteria before evaluating alternatives using one of the multi-criteria decision-making methods (VIKOR) [8]. Thus, in comparison to the traditional method, we achieve the desired goal of this study by obtaining the most accurate weights of the criteria to reflect accurate and unbiased evaluation results. To reach the goal, an integrated AHP- Shannon's method with the (VIKOR) approach was used. This approach was chosen because it takes into account a variety of evaluation criteria and alternatives when assessing each institution's performance based on the subjective and objective weight of each evaluation criterion. AHP developed by Saaty is a potent multi-criteria decision-making tool that has been applied in a wide range of engineering, politics, and economics applications [9]. Many researchers use AHP to determine the subjective weights of criteria and sub-criteria [10]. AHP performs its calculations on Saaty’s scale to produce a matrix of pairwise comparisons [11]. The goal of Saaty’s scale is to address uncertainty and ambiguity by converting linguistic variables to quantitative values. The relevant scale with five main levels ranging from 1 to 5, as shown in Table 1. Shannon proposed the idea of entropy [12], which is based on information theory, and it is now widely utilized in fields such as engineering, finance, physics, economics, language modeling, and social sciences. The entropy method uses mathematical models to determine objective weights of criteria, but it ignores the decision maker's subjective judgment information. The criteria with very different performance ratings have higher importance for the problem because they have a greater influence on ranking outcomes [13]. In other words, criteria are less important if the performance ratings for that criteria are similar across all alternatives [14]. The VIKOR technique was created by Opricovic and Tzeng (2004). This method is based on compromise programming, a technique that is often employed in (MCDM) [15-17]. This strategy focuses on evaluating and selecting from a set of alternatives, as well as devising compromise solutions for problems with opposing criteria. The VIKOR method is useful in multi-criteria decision analysis, particularly when the decision maker is unsure how to express his or her preference at the outset [18]. In this study, [19] ranks 12 private universities using AHP for weighting criteria and VIKOR for ranking the alternatives. S. Nisel and R. Nisel [20] initially, used VIKOR with two steps of weights firstly equal weights and afterward the modified weights based on normalized variations are used to rank the investigated institutions. While [21] rate the academic divisions of Islamic University by using the DEA technique based on the Shannon method to weight the criteria. Fuzzy AHP and MOOSRA methodologies were used by [22] to define and show an application of a structured methodology to assess the relative efficiency and ranking of a group of private engineering colleges. [23] were combined VIKOR and DEMATEL techniques in an attempt to construct a multi-criteria framework for the performance evaluation and ranking of (16) engineering departments in an Indian university based on Entropy method for weighting the criteria. The authors [24] assessed the performance of five secondary schools and two high schools by supposing equal weight for all criteria. By presenting some studies related to evaluating the performance of educational institutions, it was discovered that they use one method to calculate the weights of standards or the hypothesis of equal weights, demonstrating the efficacy of this study and its difference from previous studies through the use Analytic Hierarchy Process (AHP) is used to calculate the subjective weights and Shannon’s method is used to calculate the objective weights, then VIKOR method is carried out using these weights which finally results in the ranking of the alternatives. This study is structured as follows; the methodology is presented in the following section. Section 3 presents the results of an empirical study of a medical colleges ranking. Sensitivity analysis is presented in section 4. Finally, the conclusion is provided in the article's final section.

2. Methodology

To successfully apply the VIKOR method tool, as with most other MCDM methods, the criteria weights must be accurately assigned. In this paper, the general outline of the model based on four phases is given in Fig. 1. Firstly, AHP is used to obtain the subjective weights of the criteria through the questionnaire results. Secondly, Shannon’s method is used to obtain the objective weight of the criteria. Thirdly, combine both objective and subjective weights to reach the final one. Finally, using VIKOR method evaluates and classifies the alternatives based on the obtained weights.

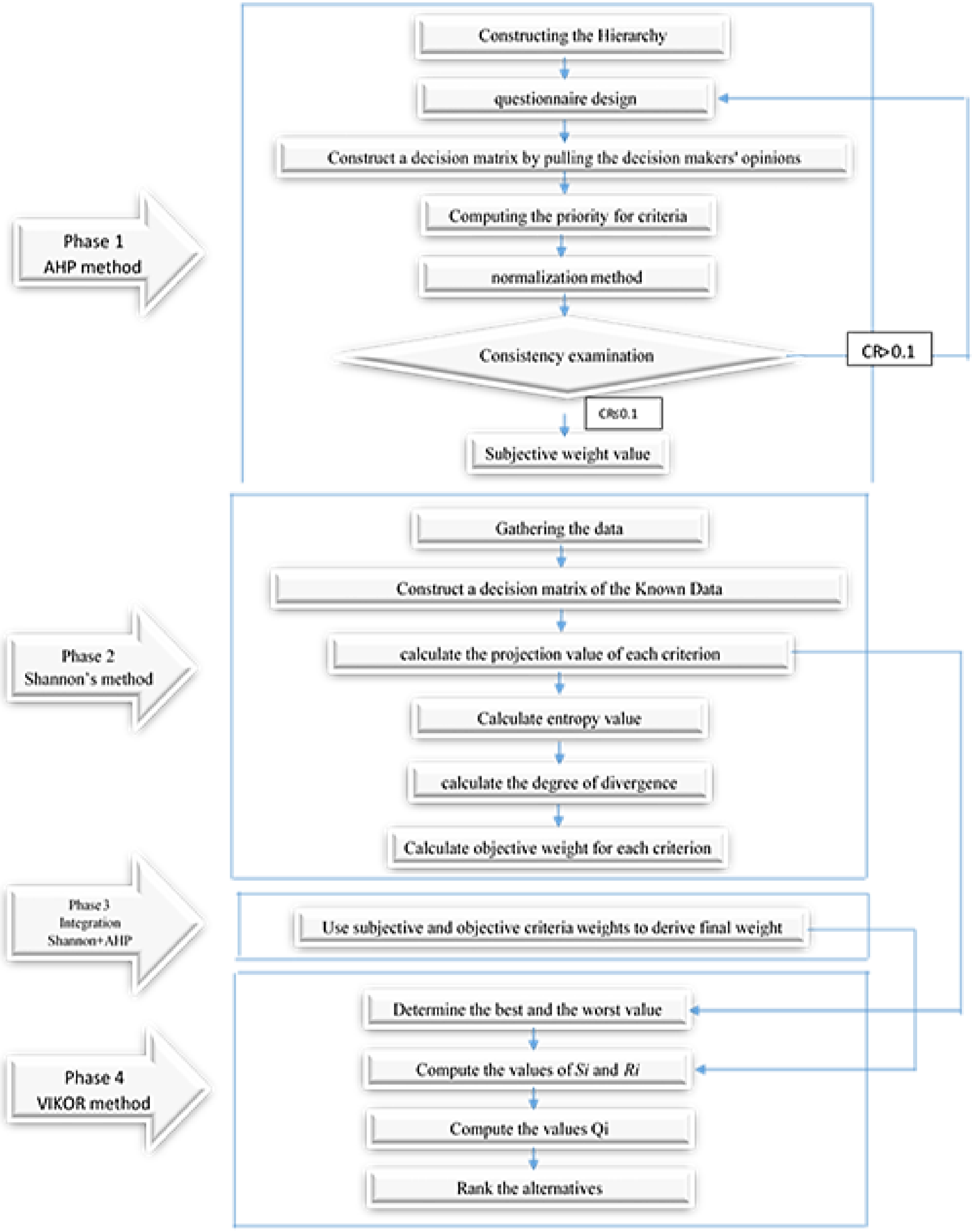

Figure. 1 The Framework of methodology

2.1 AHP phase

This phase is used to calculate the subjective weight for each criterion based on this procedure:

Step 1: Constructing the Hierarchy

The purpose of this step is to determine a set of criteria relevant to performance evaluation for alternatives. A set of criteria as explored in Fig. 1 involve two aspects: Academic Aspect (A) and Managerial Aspect (M). Each consists of main criteria; Academic Aspect (A) consists of Teaching (AT), Research (AR), and Faculty (AF) criteria while Managerial Aspect (M) consists of Administrative Support (MA), Extension Education Service (ME), Internationalization (MI), and

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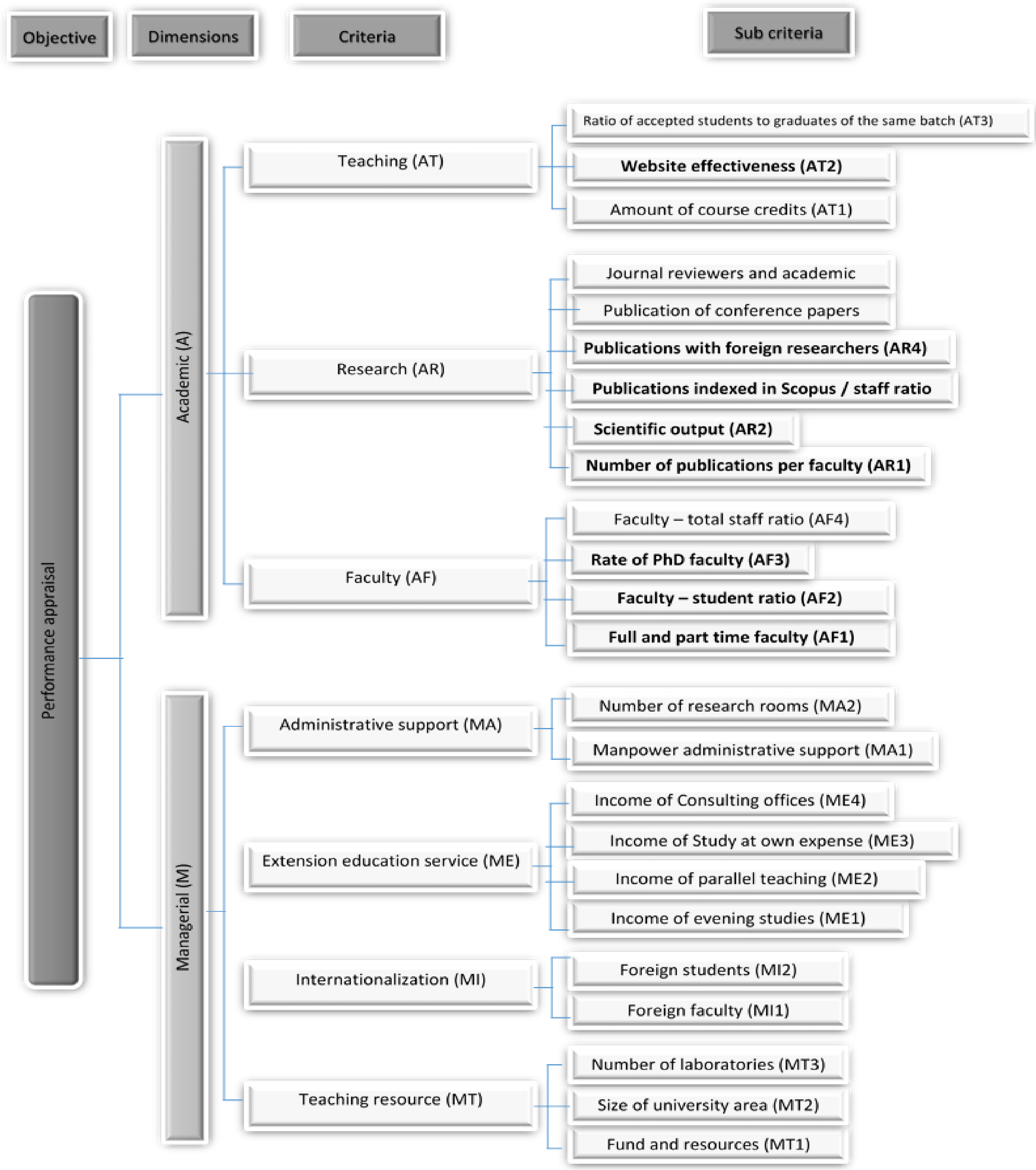


Figure. 2 Hierarchical appraisal structure of higher education institutions

Teaching Resource (MT). each main criterion of both aspects (Academic and Managerial) consist of many sub-criteria as shown in Fig. 2. These criteria were developed through discussions with specialists, ministry of higher education decision-makers, senior staff experts at various universities, and information published in publications and refereed journals. To implement the proposed method of the study, we focused on the sub-criteria described as follows:

1- Faculty/student ratio AF2 (C1): Total number of students divided by the total number of faculty.
2- Rate of Ph.D. faculty AF3 (C2): Total number of Ph.D. faculty divided by the total number of faculty.
3- Number of publications per faculty AR1 (C3): Total number of publications published divided by the number of faculty.
4- Publications indexed in Scopus / total publications ratio AR3 (C4): Number of

publications indexed in Scopus divided by the total number of publications.
5- Full and part-time faculty AF1 (C5): Number of full-time faculty divided by the total number of faculty.
6- Publications with foreign researchers AR4 (C6): Percentage of research published in cooperation with foreign researchers divided by the total number of publications.
7- Website effectiveness AT2 (C7): The percentage of comprehensiveness of the website on the activities of the college, such as lectures, scientific research, student projects, and so on.
8- Scientific output (C8) AR2: The outputs such as the results of the thesis, scientific research, patents, student projects, and so on.
Step 2: Questionnaire Design

The questionnaire is designed by collecting customer opinions on the relative importance of different criteria and alternatives and making pairwise comparisons between each criterion. The procedure creates an (n*n) pairwise comparison matrix, which reflects the decision-maker's assessment of the relative importance of the various criteria using Saaty's scale that shown in Table 1.

The criteria in the row are ranked according to each of the criteria the columns represent during pairwise comparison. The number of comparisons (NO.) varies with the number of criteria, as in Eq. (1).

$$NO. = \ [n\ (n-1)\ /\ 2] \tag{1}$$

Where n=8 (The number of criteria).
Step 3: Construction of a Decision Matrix by Pulling the Decision Makers' Opinions

Building a decision matrix for the criteria (as shown in Eq. (2)) after taking the average of the opinions of the decision makers using Eq. (3) to obtain a single decision matrix that represents the levels of preference among the criteria.

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ a_{21} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & 1 \end{bmatrix} = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ \frac{1}{a_{12}} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{1}{a_{1n}} & \frac{1}{a_{2n}} & \cdots & 1 \end{bmatrix} \tag{2}$$

Suppose, there are k decision makers (DM) (DM_k= 1, 2, 3, ..., k), who are responsible for assessing the importance of each of the *n* criteria, ($C_{i,j}$ = 1, 2, 3, ..., n).

$$a_{ij} = \frac{1}{K} \sum_{k=1}^{k} r_{ijk} \tag{3}$$

Where $\boldsymbol{r_{ijk}}$ is the criteria *i* with respect to criteria *j* from decision maker k.

$\boldsymbol{a_{ij}}$ is the criteria *i* with respect to criteria *j* after averaging.
Step 4: Computing the Priority for Criteria
This component starts with a judgment matrix that results from the previous step and normalizes the data to eliminate randomness ($\boldsymbol{C_{ij}}$) per Eq. (4).

$$C_{ij} = \frac{a_{ij}}{\sum_{j=1}^{n} a_{ij}} \tag{4}$$

Step 5: The subjective weights ($\boldsymbol{S_i}$) of criteria can be obtained from the following equation:

$$S_i = \frac{\sum_{j=1}^{n} a_{ij}}{n} \tag{5}$$

Step 6: The preferences specified in the pairwise comparison matrix must be checked for consistency, so the formulas (6, 7, 8) can be used to examine consistency [25].

$$\lambda_{max} = \sum_{j=1}^{n}[\sum_{j=1}^{n} a_{ij} * S_{ij}] \tag{6}$$

$$CI = \frac{\lambda_{max} - n}{n-1} \tag{7}$$

$$CR = \frac{CI}{RI} \tag{8}$$

Where n is the comparison matrix's dimension, λmax (eigenvalue) is the primary eigenvalue, RI is the Random Consistency Index, and CI is the consistency index. Table 2 shows the matrix's dimension (n) against the values of RI [26, 27]. If CR is equal or less than 0.1 (10%), the set of judgments is acceptable; otherwise, the judgments are unacceptable, and the pairwise comparison process that results from the expert's opinion must be repeated until a satisfactory value for CR is obtained [28].

Table 1. Preference scale for pairwise comparisons

Quantitative value	Qualitative value
1	Equal preferred
2	Moderate importance
3	Strong importance
4	Very Strong importance
5	Extreme importance

Table 2. Values of RI [26, 27]

Matrix size (n)	1	2	3	4	5	6	7	8	9	10
Random consistency index (RI)	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

2.2 Shannon (entropy weight method EWM) phase

The following procedures can be used to compute the objective weights [29]:

Step1: Create a decision matrix X that depicts the performance values of alternatives concerning evaluation criteria from the statistical data. There are *m* alternatives that can be defined as A_i(i =1, 2,.., *m*) which will be evaluated based on the criteria selected is C_j(j =1, 2, …, n)

$$X = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccc} C1 & C2 & \dots & Cn \end{array} \\ \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \end{array} \quad (9)$$

x_{ij} is the rating of alternative A_i with respect to the criterion C_j.

Step 2: Calculate the Projection Value ($\boldsymbol{P_{ij}}$) of each criterion to have comparable and dimensionless performance measures.

$$P_{ij} = \frac{a_{ij}}{\sum_{i=1}^{m} a_{ij}} \quad (10)$$

Where $(i = 1, 2, \dots, m)$ and m is the number of alternatives; $(j = 1, 2, \dots., n)$ and n is the number of criteria.

Step 3: Compute the entropy value (E_j) for each criterion j .

$$E_j = -\frac{1}{\ln m} \sum_{i=1}^{m} P_{ij} \ \ln P_{ij} \quad (11)$$

Step 4: Calculate the divergence through:

$$div_j = 1 - E_j \quad (12)$$

Step 5: Compute objective weights $\boldsymbol{O_j}$ for each criterion

$$O_j = \frac{div_j}{\sum_{j=1}^{n} div_j} \quad (13)$$

$j = 1,2, \dots., n.$
Where $0 \le O_j \le 1$ and $\sum_{j=1}^{n} O_j = 1$.

2.3 Integration of shannon-AHP phase

While objective approaches focus on a statistical examination of the available data, subjective weighing methods based on the judgment of experts. There are pros and cons to each of these strategies. While objective approaches do not benefit from designers' knowledge and expertise, the fundamental drawback of subjective methods is the potential for uncertainty in expert opinion [14, 30, 31]. To ensure that weights are determined comprehensively for increased reliability and effectiveness, it is necessary to combine the subjectivity of the AHP and the objectivity of the entropy weight method (EWM) [32]. Therefore, an overall combined weight W_j value is calculated for each criterion j.

$$W_j = \frac{S_j \, O_j}{\sum_{j=1}^{n} S_j \, O_j} \quad (14)$$

Where $j = 1,2, \dots., n$ is the number of criteria.

2.4 VIKOR phase

VIKOR method is employed for ranking the alternatives based on the following procedure [16, 19, 33]:

Step 1: Determine the Best Crisp Value $f^*{}_j$ and Worst Crisp Value $f^-{}_j$ for all Criterion Ratings are determined by using the relations:

$$f^*{}_j = \begin{cases} \max_i X_{ij}, & for\ benefit\ criteria \\ \min_i X_{ij}, & for\ cost\ criteria \end{cases} \quad (15)$$

$$f^-{}_j = \begin{cases} \min_i X_{ij}, & for\ benefit\ criteria \\ \max_i X_{ij}, & for\ cost\ criteria \end{cases} \quad (16)$$

Where $(i = 1, 2, \dots., m)$; $(j = 1, 2, \dots., n)$

$f^*{}_j$ is the best value of each criterion; $f^-{}_j$ is the worst value of each criterion.

Step 2: Compute the values of maximum group utility (S_i) and the minimum individual regret of the opponent (R_i)

$$S_{i=} \sum_{j=1}^{n} W_j \left[\frac{f_j^* - x_{ij}}{f_j^* - f_j^-}\right] \quad (17)$$

$$R_i = \underset{j}{Max} \left[W_j \left[\frac{f_j^* - x_{ij}}{f_j^* - f_j^-} \right] \right] \quad (18)$$

Step 3: Compute (Q_i) for each alternative by the relation:

$$\tilde{Q}_{i=} v \left[\frac{S_j^* - S_{ij}^-}{S_j^* - S_j^-} \right] + (1 - v) \left[\frac{R_j^* - R_{ij}^-}{R_j^* - R_j^-} \right] \quad (19)$$

Where $\boldsymbol{Q_i}$ is the values of distance between each alternative and the best alternative;

$S_j^* = \min_i S_i$ (minimum value of S_i);

$S_j^- = \max_i S_i$ (maximum value of S_i);

$R_j^* = \min_i R_i$ (minimum value of R_i);

$R_j^- = \max_i R_i$ (maximum value of R_i);

The weight for the maximum group utility strategy is known as v [34] (VIKOR index value), and its value ranges between [0, 1]. According to the literature, the VIKOR index value is commonly assumed to be $v = 0.5$.

Step 4: Rank the Alternatives

The alternatives are sorted in ascending order by sorting the values of S_i , R_i , and Q_i . As a consequence, three ranking lists are generated based on the crisp values of *S*, *R*, and *Q*, which are then used to propose alternative compromise solutions. The smaller value of *S*, *R*, and *Q*, the better the alternative [35].

3. Illustrated case

To explore the feasibility of the developed model, performance evaluation of twelve Iraqi medical colleges (Al-Kindi (A1), Baghdad (A2), Al-Mustansiriya (A3), Al-Nahrain (A4), Al-Iraqiya (A5), Kufa (A6), Babylon (A7), Tikrit (A8), Diyala (A9), Karbala (A10), Wasit (A11), Kirkuk (A12)) will be considered as a case study in this model. Also, to explore the feasibility of the developed model, only the eight sub-criteria aforementioned from (24) sub-criteria will be adopted in the experimental case based on Fig. 2.

The developed model combines the two techniques of AHP and Shannon's method to calculate the subjective and objective weights respectively, then used VIKOR method to perform an appraisal and ranking of the adopted colleges. We sent a questionnaire to a group comprising 85 experts in July 2022 and received the feedback after (21 days). Of the 85 questionnaires, 39 (45.88%) expert responses (30 (35.29%) were used in this study because (CR) for these responses were equal or less than 0.1 and 9 answers (10.59%) were rejected due to data inconsistency, according to what appeared in the value of (CR)) and 46 (54.12%) unanswered questionnaires. The questionnaire information is summarized in Table 3.

3.1 Computations of subjective weight using AHP method

By using Eq. (3), the decision maker's matrix results from the average of the (30) acceptable responses to the questionnaire are shown in Table 4.

Normalization of each criterion and weight based on Eqs. (4) and (5) respectively are shown in Table 5.

Based on Eqs. (6) to (8), the consistency ratio (CR) of data is (0.006), this result of (CR) demonstrates the validity of this study.

3.2 Computations for objective weights using (EWM)

After determining the subjective weights, we determined the objective weights based on the known data of the problem of 12 medical colleges (alternatives) which obtained from the database in the Iraqi Ministry of Higher Education and Scientific Research as shown in Table 6.

Table 3. Questionnaire information

Variables	Items	No. of responses	No. of accepted	Ratio
Experience Years	< 15 year	4	1	3.33%
	15-20 year	11	8	26.67%
	20-25 year	6	5	16.67%
	25-30 year	8	7	23.33%
	> 30 year	10	9	30%
Sum		39	30	100%
Job Title	Professor	14	12	40%
	Ass. professor	18	15	50%
	Lecturer	7	3	10%
Sum		39	30	100%

Table 4. Pair-wise comparison and calculation

	C1	C2	C3	C4	C5	C6	C7	C8
C1	1	0.9622	1.3778	2.0833	1.87	1.7889	2.169	1.147
C2	1.039	1	1.3111	1.322	1.4444	1.4278	1.9527	1.4316
C3	0.725	0.762	1	1.5555	1.6361	1.7444	1.8666	1.1772
C4	0.48	0.756	0.642	1	1.3555	1.1122	1.8111	0.8622
C5	0.534	0.692	0.611	0.737	1	1.0638	1.3205	0.8955
C6	0.558	0.7	0.573	0.899	0.939	1	1.2972	1.0583
C7	0.461	0.512	0.552	0.552	0.757	0.771	1	0.7555
C8	0.871	0.698	0.849	1.116	1.116	0.945	1.322	1

Table 5. Normalized comparison matrix and subjective weights of criteria

	C1	C2	C3	C4	C5	C6	C7	C8	Weight
C1	0.1764	0.158	0.1992	0.2249	0.185	0.1816	0.1703	0.1377	0.1792
C2	0.1833	0.164	0.1896	0.1427	0.1427	0.1449	0.1533	0.1719	0.1616
C3	0.1279	0.125	0.1446	0.1679	0.1617	0.177	0.1465	0.1414	0.149
C4	0.0847	0.124	0.0928	0.1079	0.1339	0.1129	0.1422	0.1035	0.1128
C5	0.0942	0.114	0.0883	0.0795	0.0988	0.108	0.1037	0.1075	0.0992
C6	0.0984	0.115	0.0829	0.097	0.0928	0.1015	0.1018	0.1271	0.1021
C7	0.0813	0.084	0.0798	0.0596	0.0748	0.0782	0.0785	0.0907	0.0784
C8	0.1537	0.115	0.1228	0.1205	0.1103	0.0959	0.1038	0.1201	0.1177

Table 6. Computations of known data

	C1	C2	C3	C4	C5	C6	C7	C8
A1	12.4	0.829	0.995	10	2.6	0.339	0.108	0.005
A2	10.63	0.858	1	10	2.51	0.666	0.086	0.02
A3	10.22	0.896	1	6	3.86	0.588	0.056	0.469
A4	8.233	0.872	1	10	4.497	0.486	0.07	0.006
A5	9.268	0.72	0.935	2	0.139	0.001	0.001	0.01
A6	5.397	0.921	0.991	10	1.995	0.516	0.101	0..004
A7	9.748	0.843	1	8	5.027	0.38	0.005	2.195
A8	5.052	0.73	1	6	2.092	0.656	0.001	0.039
A9	10.149	0.716	1	10	3.597	0.46	0.128	0.22
A10	6.76	0.809	0.975	10	1.288	0.61	0.11	0.09
A11	7.925	0.7	0.9	10	2.387	0.617	0.115	0.013
A12	7.359	0.798	0.587	10	0.716	0.6	0.001	0.009

Table 7. Projection value (P_{ij})

	C1	C2	C3	C4	C5	C6	C7	C8
A1	0.1367	0.0935	0.0958	0.1087	0.0925	0.0608	0.1602	0.0065
A2	0.1171	0.0968	0.0963	0.1087	0.0893	0.1194	0.1276	0.0016
A3	0.1126	0.1011	0.0963	0.0652	0.1373	0.1054	0.0831	0.1527
A4	0.0907	0.0984	0.0963	0.1087	0.16	0.0871	0.1039	0.002
A5	0.1021	0.0812	0.09	0.0217	0.0049	0.0002	0.0015	0.0033
A6	0.0595	0.1039	0.0954	0.1087	0.071	0.0925	0.1499	0.7148
A7	0.1074	0.0951	0.0963	0.087	0.1788	0.0681	0.0074	0.7148
A8	0.0557	0.0824	0.0963	0.0652	0.0744	0.1176	0.0015	0.0127
A9	0.1118	0.0808	0.0963	0.1087	0.128	0.0824	0.1899	0.0716
A10	0.0745	0.0913	0.0939	0.1087	0.0458	0.1093	0.1632	0.0293
A11	0.0873	0.079	0.0866	0.1087	0.0849	0.1106	0.1706	0.0042
A12	0.0811	0.09	0.0565	0.1087	0.0255	0.1075	0.0015	0.0029

Table 8. The values for (E_j), (div_j), and (O_j)

	C1	C2	C3	C4	C5	C6	C7	C8
E_j	0.1095	0.0892	0.0904	0.0971	0.0886	0.0685	0.1181	0.0132
div_j	0.8905	0.9108	0.9096	0.9029	0.9114	0.9315	0.8819	0.9868
O_j	0.1216	0.1243	0.1242	0.1233	0.1244	0.1272	0.1204	0.1347

Table 9. Final weight for each criterion (W_j)

	C1	C2	C3	C4	C5	C6	C7	C8
W_j	0.1743	0.1608	0.1482	0.1114	0.0988	0.104	0.0756	0.1269

Table 10. the values of ($f^*{}_j$) and the ($f^-{}_j$)

	C1	C2	C3	C4	C5	C6	C7	C8
$f^*{}_j$	0.05567	0.1039	0.0963	0.1087	0.1788	0.1194	0.1899	0.7148
$f^-{}_j$	0.13665	0.079	0.0565	0.0217	0.0049	0.0002	0.0015	0.0016

Table 11. The values for (S_i), (R_i), and (Q_i)

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12
S_i	0.477	0.3768	0.4226	0.3052	0.7832	0.1129	0.3196	0.4514	0.4094	0.3413	0.4541	0.5887
R_i	0.1792	0.136	0.126	0.1176	0.147	0.0615	0.1145	0.1397	0.1499	0.1131	0.1616	0.149
Q_i	0.7716	0.5134	0.5051	0.3819	0.8631	0	0.3794	0.5845	0.5967	0.3896	0.6798	0.7266

Table 12. The ranking of the medical colleges by S, R, and Q in ascending order

	1	2	3	4	5	6	7	8	9	10	11	12
S	A6	A4	A7	A10	A2	A9	A3	A8	A11	A1	A12	A5
R	A6	A10	A7	A4	A3	A2	A8	A5	A12	A9	A11	A1
Q	A6	A7	A4	A10	A3	A2	A8	A9	A11	A1	A12	A5

Table 13. (a) sensitivity analysis by the increase (25%) for each criterion and (b) sensitivity analysis by a decrease (25%) for each criterion

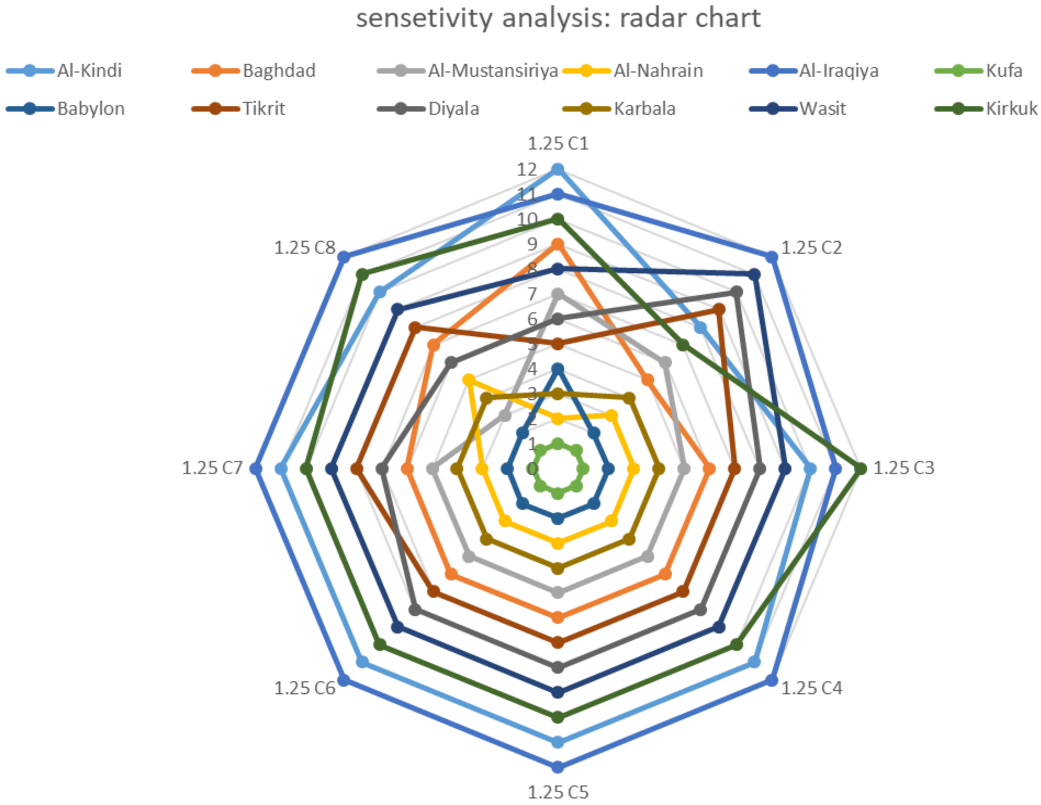
Scenario no.	**The new weight of criteria**	**ranking**
1	1.25 ($W_{c1\ old}$)	A6>A4>A10>A7>A8>A9>A3>A11>A2>A12>A5>A1
2	1.25 ($W_{c2\ old}$)	A6>A7>A4>A10>A2>A3>A12>A1>A8>A9>A11>A5
3	1.25 ($W_{c3\ old}$)	A6>A7>A4>A10>A3>A2>A8>A9>A11>A1>A5>A12
4	1.25 ($W_{c4\ old}$)	A6>A7>A4>A10>A3>A2>A8>A9>A11>A12>A1>A5
5	1.25 ($W_{c5\ old}$)	A6>A7>A4>A10>A3>A2>A8>A9>A11>A12>A1>A5
6	1.25 ($W_{c6\ old}$)	A6>A7>A4>A10>A3>A2>A8>A9>A11>A12>A1>A5
7	1.25 ($W_{c7\ old}$)	A6>A7>A4>A10>A3>A2>A9>A8>A11>A12>A1>A5
8	1.25 ($W_{c8\ old}$)	A6>A4>A3>A10>A4>A9>A2>A8>A11>A1>A12>A5

(a)

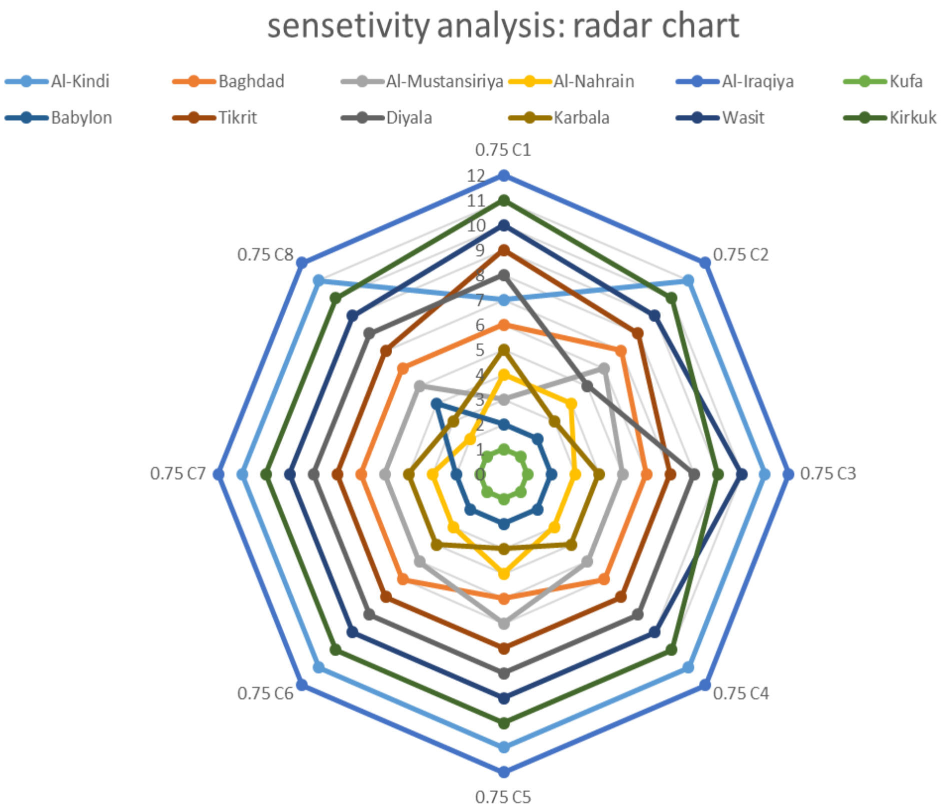
Scenario no.	**The new weight of criteria**	**ranking**
1	0.25 ($W_{c1\ old}$)	A6>A7>A3>A4>A10>A2>A1>A9>A8>A11>A12>A5
2	0.25 ($W_{c2\ old}$)	A6>A7>A10>A4>A9>A3>A2>A8>A11>A12>A1>A5
3	0.25 ($W_{c3\ old}$)	A6>A7>A4>A10>A3>A2>A8>A9>A12>A11>A1>A5
4	0.25 ($W_{c4\ old}$)	A6>A7>A4>A10>A3>A2>A8>A9>A11>A12>A1>A5
5	0.25 ($W_{c5\ old}$)	A6>A7>A10>A4>A2>A3>A8>A9>A11>A12>A1>A5
6	0.25 ($W_{c6\ old}$)	A6>A7>A4>A10>A3>A2>A8>A9>A11>A12>A1>A5
7	0.25 ($W_{c7\ old}$)	A6>A7>A4>A10>A3>A2>A8>A9>A11>A12>A1>A5
8	0.25 ($W_{c8\ old}$)	A6>A4>A10>A7>A3>A2>A8>A9>A11>A12>A1>A5

(b)

Received: October 26, 2022. Revised: December 15, 2022.



(a)



(b)

Figure. 3 Radar chart: (a) sensitivity analysis by the increase (25%) for each criterion and (b) sensitivity analysis by a decrease (25%) for each criterion

Calculate (P_{ij}) value for each criterion of the decision matrix that is shown in Table 6 using Eq. (10) to be criteria comparable as shown in Table 7.

Based on Eqs. (11) to (13), Table 8 represented the results of values (E_j), (div_j), and (O_j), where (O_j) is the objective weight.

After obtaining the subjective weight from Table 5 and objective weights from Table 7, the final weight Table 9 was obtained using Eq. (14).

3.3 Ranking colleges using VIKOR method

After identifying the final weights of the performance appraisal criteria in Table 9, then VIKOR method is used to appraise and rank twelve medical colleges based on the data mentioned in Table 7 after normalized).

Table 10 described the values of Best Crisp Value (${f^*}_j$) and Worst Crisp Value (${f^-}_j$) for each criterion based on Eqs. (15) and (16).

Based on Eqs. (17) to (19), Table 11 shows the values of maximum group utility (S_i), minimum individual regret of the opponent (R_i), and the values of distance between each alternative and the best alternative (Q_i).

The alternatives are ordered by sorting the values of S_i , R_i , and Q_i in ascending order. As a result, we have three ranking lists according to the values of S, R, and Q as shown in Table 12.

In this study, the ranking is determined based on the value of (Q), which is a measure of separating each alternative from the best alternative and the lower value is the better.

The sixth alternative (A6) was given the greatest score out of all of the alternatives because it scored well in the majority of the criteria and particularly those that carried the most weight. On the contrary, the fifth alternative (A5) was ranked last. As a result, the ratings for the other alternatives were ordered accordingly.

4. Sensitivity analysis

Sensitivity analysis (SA) measures the effect on a model's output when the value of one input is changed while all other inputs are preserved. SA can be repeated for any number of single-form inputs [36]. This method generates a variety of possible outcomes by changing model input values, which may affect the order in which the alternatives are prioritized. The results are described as sensitive if it becomes a big change in the order of the alternatives by raising or lowering the importance of the criteria. Otherwise, the results are described as robust [37].

The basic objective of sensitivity analysis is to identify the factors that have the biggest impact on how decisions are made. It was assumed that the weight of each criterion increased by 25% in one case and decreased by 25% in another, and since there are 8 criteria, there are 16 tests. The results are shown in Table 13(a) and Fig. 3 (a) when increasing the weight of each criterion by (25%), while Table 13 (b) and Fig. 3 (b) shows the results of a decrease in the weight of each criterion by (25%) with maintaining balance for the rest of the weights of the criteria in each experiment so that the sum of the weights in each case is equal to 1.

5. Conclusions

Using scientific methods to determine weights is a critical step in obtaining the best evaluation. We used the integration of AHP-Shannon technique to obtain the most accurate weights possible then used in VIKOR method to appraise and rank the education institutions. In this study, sensitivity analysis is used to determine how the alternatives change depending on how important the criteria are. The results will be analyzed, and the change in alternative classification is determined based on the value of (Q). In the classification, variant (A6) received first place in 16 trials, while variant (A7) received second place in 16 trials according to the value of (Q). As a result, one can conclude that the decision-making process is rarely affected by the weight of criteria. The eighth criterion (Scientific output) was discovered to have the greatest influence on changing the priorities of the alternatives. As a result, colleges can focus on this criterion to improve their ranking within the classification (this study and the results are considered as a model through which colleges can know their strengths and weaknesses (For example, Medical College / Al-kufa (A6) has a high value relative to the eighth standard C8, which has the highest weight in terms of importance and the highest sensitivity when analyzing, and therefore this criterion is considered a strength and alternative Medical College / Baghdad (A2) has a low value compared to the same criterion, so it is considered a weakness For this alternative, and the Medical College / Baghdad must develop and take care of it). In this study, eight sub-criteria were used out of a total of twenty-four sub-criteria. In future studies, the remaining criteria can be used, as well as the possibility of using a different set of criteria and running different scenarios during the analysis process to identify areas of weakness that need to be addressed and developed.

Conflicts of interest

The authors declare no conflict of interest.

Author contributions

Conceptualization, Saja A. Nahoo (SANAHOO) and AllaEldin H. Kassam (AHK); methodology, SANAHOO and AHK; software, SANAHOO; validation, SANAHOO and AHK; formal analysis, SANAHOO; investigation, SANAHOO and AHK; resources, SANAHOO and AHK; data curation, SANAHOO; writing—original draft preparation, SANAHOO; writing—review and editing, SANAHOO and AHK ; visualization, SANAHOO; supervision, AHK.

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