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Fuzzy logic computational model for performance evaluation of Sudanese Universities and academic staff

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Consistency checking

Abstract The excellence of a Sudanese universities and academic staff member can be effectively classified by systematic and objective design criteria, which participates in developing the learning outcomes in Sudan. In the first phase of this study, we reviewed the literatures, determined and defined the suitable quantitative and qualitative criteria and then designed & exploited pairwise comparison and evaluation forms through a survey to get experts opinions/preference on the evaluation criteria that are used to measure the universities and academic staff performance. This paper presents a fuzzy logic computational model based on this survey to measure and classify the performance of Sudanese universities and academic staff, which includes computation of criteria weights and overall evaluation of Sudanese universities and academic staff using AHP and TOPSIS techniques.

1. Introduction

Throughout the last three decades, there has been significant growth in the total number of universities and high educational institutes in Sudan. The total number was raised from 11 institutes in 1980s to more than 127 higher education institutes in 1990s & 2000s (Ministry of Higher Education, 2016). Fig. 1 represents the total numbers of different types of institutes and the growth rate of public & private universities with Bar chart and Combo chart respectively.

This considerable increase requires contiguous scientific research in performance assessment to assist the following entities:

- High Education institutes to match up their current qualifications versus the standard requirements and plan for future improvement.
- Applicants & Students' Parents to make out the differences between institutes and figure out the best higher education institutes.

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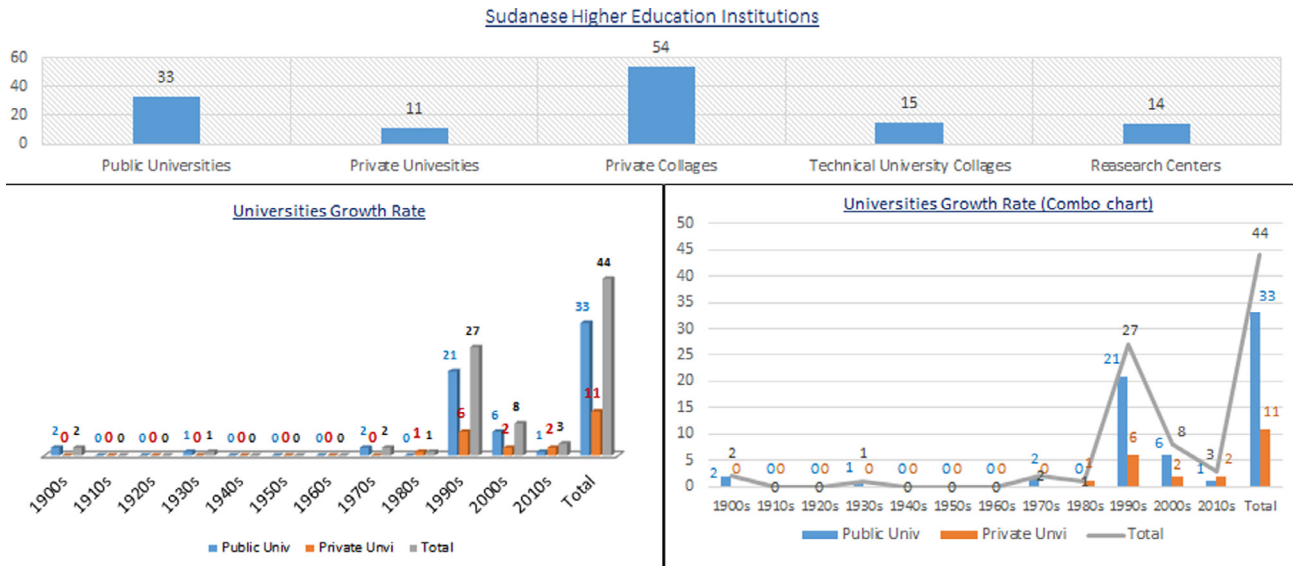


Figure 1 Statistical Info about Sudanese higher education institutions (Institution types and universities growth rate).

- Ministry of higher education in Sudan to observe and keep track of the required standards and maintain future plans.

Currently, organization and funding systems at universities, in general, have considerably changed. The social necessity dominates the classical activities of teaching and research (Etzkowitz, 2003). Getting universities and academic staff evaluation in line with the changes in the university system has become a main concern especially in Sudan and in many other countries around the world.

Decision of quality classification in performance evaluation of Sudanese universities and academic staff is based on quantitative and qualitative criteria which involve not only data but also human judgment. Therefore, performance evaluation and academic staff classification could be considered as a MCDM (Multiple Criteria Decision Making) problem.

There are many fuzzy related appraisal techniques in the literature such as Analytic hierarchy process (AHP). AHP is a quantitative technique for ranking decision alternatives using various criteria (Russell et al., 2003; Shaout and Yousif, 2014). Structuring the alternatives into a hierarchical framework is the AHP technique to resolve complex decisions. However, due to uncertainty in the decision-maker's judgment, pair-wise comparison, a crisp with a traditional AHP may be incompetent to completely get the decision-maker's judgment. Hence, fuzzy logic is introduced into the pair-wise comparison in the AHP to overcome this weakness in the traditional AHP. It is referred to as fuzzy AHP (FAHP) (Ayağ, 2005; Shaout and Yousif, 2014).

Fuzzy Technique for Order Preference by Similarity to Ideal Solution (FTOPSIS) is another technique of the multi-criteria decision making (MCDM) technique that is widely employed to solve MCDM problems (Shaout and Yousif, 2014). TOPSIS technique is based on the concept that the selected alternative is the shortest geometric distance to the positive ideal solution and the longest geometric distance to the negative ideal solution (Akkoç and Vatansever, 2013; Chen, 2000).

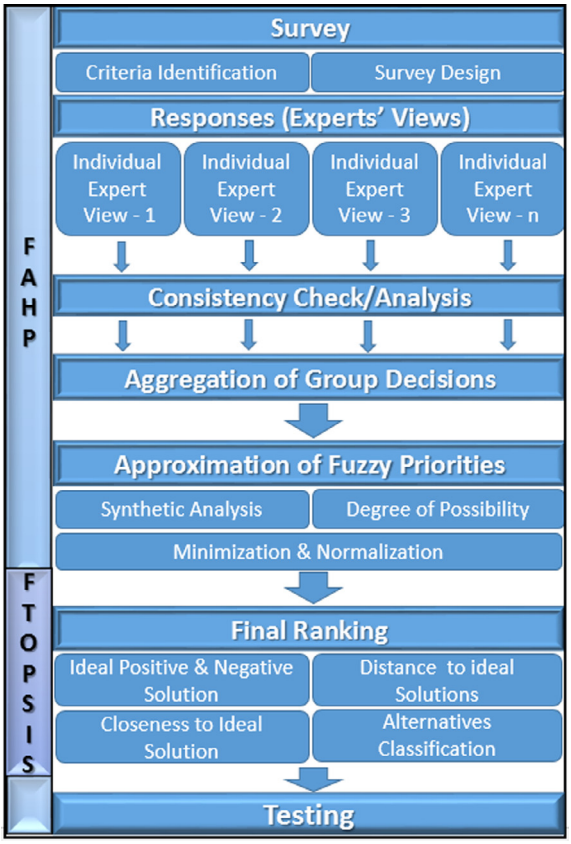


Figure 2 Quality classification model for performance evaluation of Sudanese universities and academic staff.

The multistage fuzzy logic inference has been proposed in order to decrease the number of fuzzy rules for compound systems (Shaout and Trivedi, 2013). Besides input and output variables, intermediate variables are adopted in fuzzy rules to mirror human knowledge. The major benefit of using a multistage structure is that the number of fuzzy rules will only

grow quadratically with the number of input variables and membership functions. The Fuzzy based Multifactorial evaluation technique is presented to deliver a synthetic assessment of an object relative to an objective in a fuzzy decision environment that has many factors (GMeenakshi, 2012). More techniques descriptions, concepts and key benefits are shown in the Appendix A Table 32.

Fuzzy Analytic Hierarchy Process (FAHP) (Saaty, 1980; Yu and Bai, 2010) is an effective instrument to deal with MCDM because of its clarity in concept. The problem is rearranged into a hierarchy of simple and understandable subproblems. The hierarchy comprises of goal layer, criteria layer, and alternative layer. A survey to get experts opinions/preference on the evaluation criteria that are used to measure the universities and academic staff performance has been designed and conducted. Then, the pairwise comparisons were used to compute the relative weights of the notes in each group. Finally, the importance of alternatives to the final goal was acquired.

In a majority of problems in real-life, only part of the decision data can be precisely measured. The fuzziness and uncertainty existing in many of these problems may participate in vague judgments of decision makers in traditional AHP techniques (Bouyssou et al., 2000). Hence, several researchers (Boender et al., 1989; Buckley, 1985; Chang, 1996; Laarhoven and Pedrycz, 1983; Lootsma, 1997; Ribeiro, 1996) have examined the fuzzy AHP and presented evidence that fuzzy AHP technique shows reasonably enough description of these kind of decision making processes compared to the classical AHP techniques.

Membership functions (MFs) are the fundamental blocks of fuzzy set theory. The choice of MF depends on the nature of problem at hand. MFs can take values between 0 & 1. The selection of MFs influences how well fuzzy systems approximate functions. The most common fuzzy sets (MFs) are triangles, trapezoids, and Gaussian bell curves (Mitaim, 1996). A comparison has been made among the predicted data using different membership functions. The MF has been selected based on minimum error in prediction of data. It has been observed that triangulated MF has been given minimum error (Manal et al., 2012). Barua et al. (2014) provide a theoretical explanation of the practical success of triangular membership functions. We used triangular MF in this paper since it is simpler to implement and fast in computation (Pedrycz, 1994; Barua et al., 2014).

Taking into consideration the huge number of universities and academic staff (alternatives) to be evaluated and classified in this study, we integrated FAHP with Fuzzy TOPISIS in order to improve, simplify the evaluation process and get the final result. This integration has been introduced and applied in a verity of areas (Torfi et al., 2010; Yang et al., 2009; Dağdeviren et al., 2009; Shaout and Yousif, 2014).

In this paper, nine main criteria and forty-one sub criteria will be identified, considered and weighted as performance evaluation criteria for Sudanese high academic institutes. Furthermore, three levels of academic staff evaluation criteria will be identified, considered and weighted. The first level consists of six criteria, the second level consist of twenty-seven criteria and the last level consists of fifty criteria.

Classification model for performance evaluation of Sudanese university and academic staff will be developed and proposed. It consists of all steps required such as consistency check, aggregation, approximation and ranking.

The consistency of judgment that is carried out by experts/participants during a series of pairwise comparison methods represents a key evaluation issue to the reliability of the ultimate output (performance evaluation). This study presents a solution based on a Fuzzy Consistency Algorithm (FCA) (Shaout and Yousif, 2014) to check and evaluate the consistency level of expert's judgment. The new algorithm proposes a consistent preference linguistic value(s) as an option to the experts in case of inconsistency judgment in evaluation performance. Based on the proposed algorithm, the research introduces a new tool that allows experts to trace and understand the roots of inconsistency and select the relevant consistent option(s). The algorithm allows the degree of consistency to be configured by the user. The study also applies the proposed algorithm to the performance evaluation of Sudanese universities as an empirical study. Finally, fifteen higher education institutes (10 public universities & 5 private universities) were ranked using the proposed hybrid computational model. Then, the model result was compared with the previous admission results for 2014/2015 & 2015/2016, which were prepared by the General Administration for Admissions, Degree Evaluations & Verification in Sudan.

This paper is organized as follows: Section 1 introduces statistical info about Sudanese higher education institutions growth. Preliminary arithmetical operation on interval is introduced in Section 2. Section 3, presents the classification model for performance evaluation of Sudanese universities and academic staff. The proposed evaluation criteria is presented in Section 4. Section 5 presents the application of fuzzy analytic hierarchy process & FTOPSIS on universities & academic staff performance evaluation. The data collection and consistency analysis for individual expert views (both offline & online algorithm) is explained in Section 6. Sections 7 and 8 present the aggregation of group decisions and fuzzy preferences approximation. Section 9 presents the final ranking technique. Model testing is presented in Section 10. Analysis & observations and Conclusion are presented in Sections 11 and 12.

2. Preliminary

The preliminary arithmetical operations on intervals, normalization approach, and definition of TFN (Triangular Fuzzy Number) and its relevant calculations for TOPSIS are explained in these definitions:

Definition 1 Kaufmann and Gupta, 1991. For any $x_1, x_2, y_1, y_2 \in R$, *where* $x_1 < x_2, y_1 < y_2$ Let $x = [x_1, x_2]$ and $y = [y_1, y_2]$ be two + ve interval numbers. The athematic interval can be presented as follows:

$$x + y = [x_1 + x_2, y_1 + y_2], x - y = [x_1 - x_2, y_1 - y_2],$$
$$xy = [x_1 x_2, y_1 y_2], x/y = [x_1/x_2, y_1/y_2].$$

Definition 2 Kaufmann and Gupta, 1991. Let $\tilde{a} = (a_1, a_2, a_3)$ and $\tilde{b} = (b_1, b_2, b_3)$ be two triangular number fuzzy numbers, then the vertex method is defined to calculate the distance between them as follows:

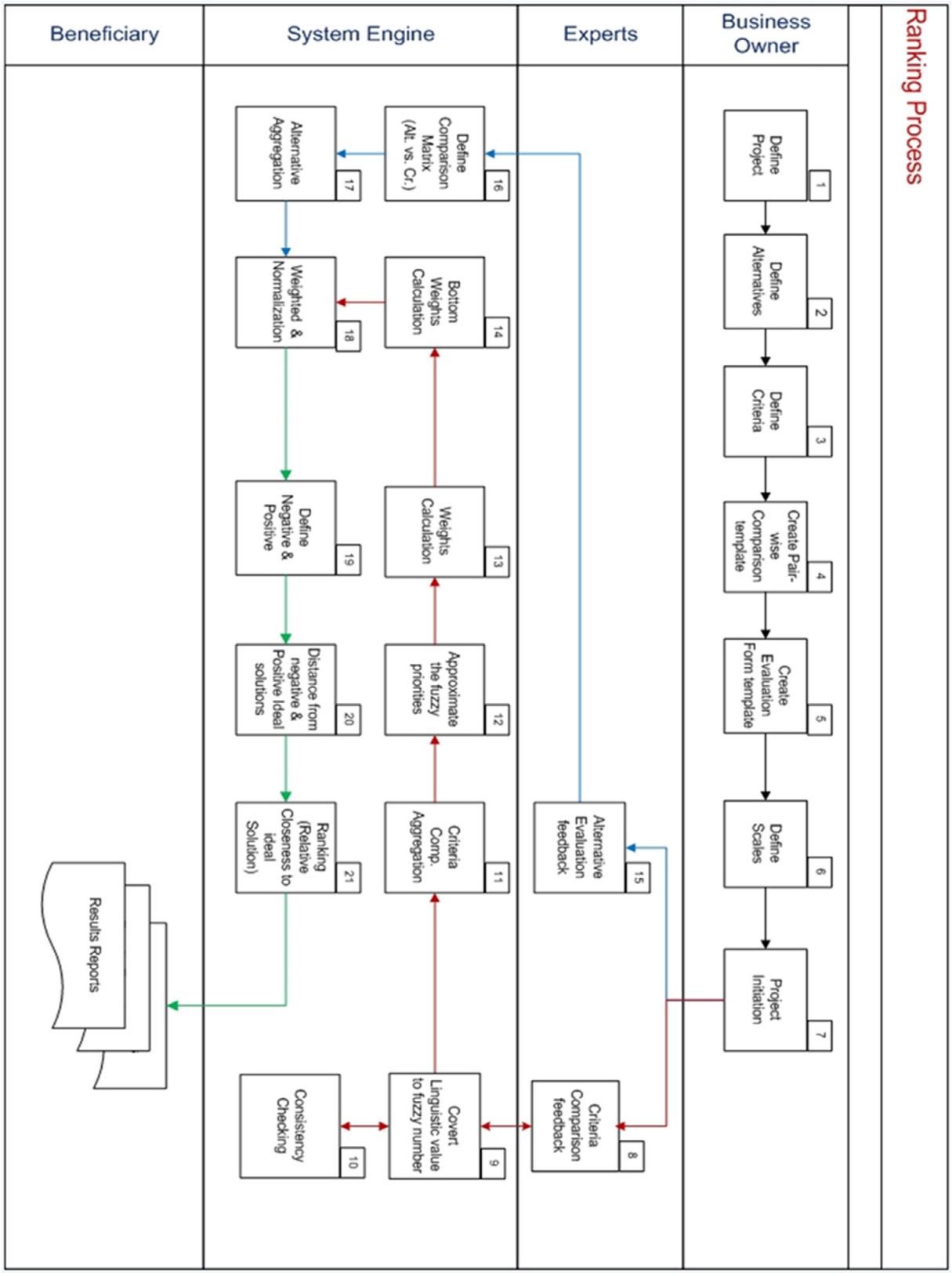


Figure 3 Process workflow of the classification model.

$$d(\tilde{a},\tilde{b}) = \sqrt{\frac{1}{3}[(a_1-b_1)^2+(a_2-b_2)^2+(a_3-b_3)^2}.$$

Definition 3 (*Chakraborty and Yeh, 2007; Chakraborty and Yeh, 2009; Çelen, 2014*). Vector normalization: In this procedure, each rating of the decision matrix is divided by its norm. The normalized value r_{ij} is obtained by

$$r_{ij} = (x_{ij}) \Big/ \sqrt{\sum_{i=1}^{m} x_{ij}^2}$$

where x_{ij} is the performance rating of the ith alternative for the attribute C_j. This procedure has the advantage of converting all attributes into dimensionless measurement unit, thus making inter-attribute comparison easier.

3. Classification model for performance evaluation of Sudanese universities & academic staff

In this model, we use two methods, the Fuzzy AHP and fuzzy TOPISIS methods. In each method, several techniques are

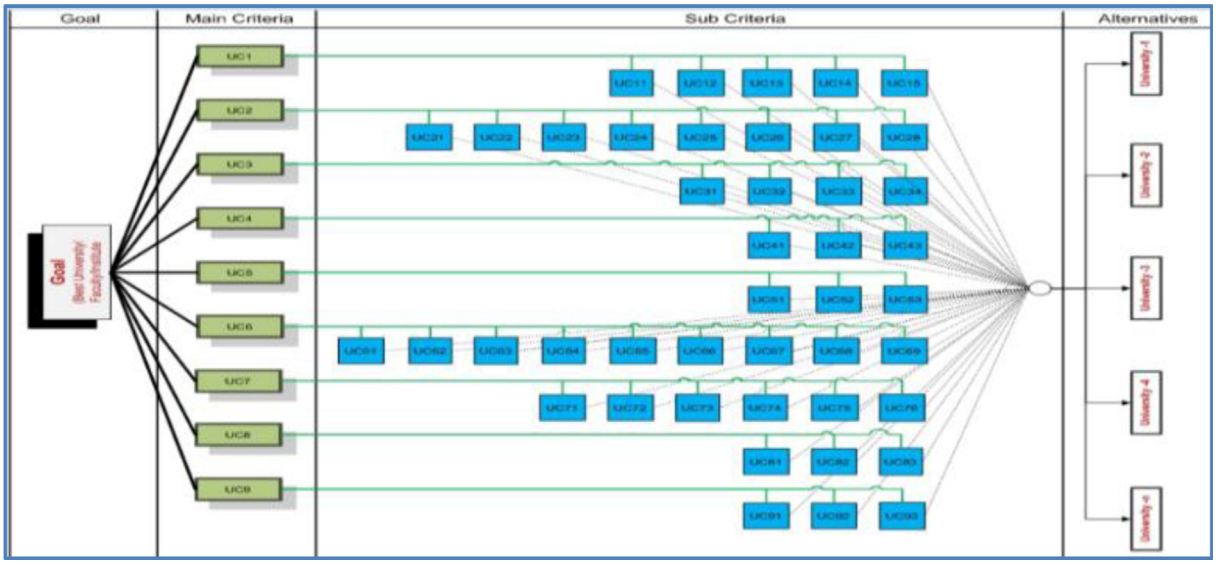


Figure 4 Hierarchical framework of performance evaluation criteria for Sudanese universities.

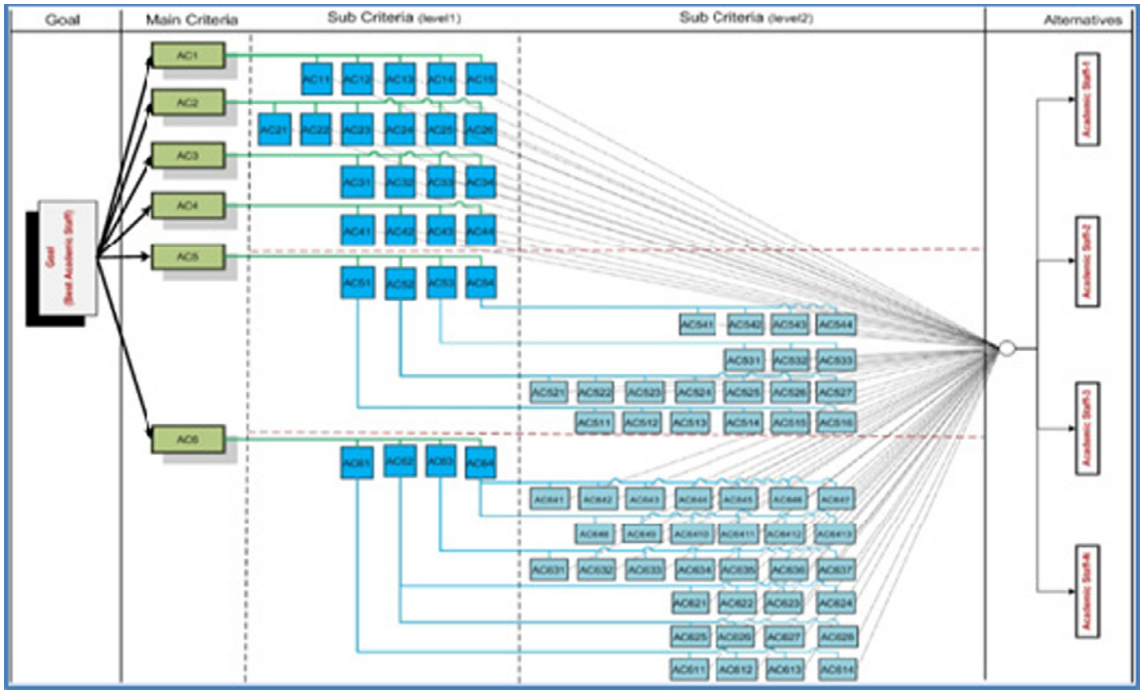


Figure 5 Hierarchical framework of performance evaluation criteria for academic Staff.

adapted and represented as shown in the general Model in Fig. 2. The techniques are used as follows:

- FAHP is used to construct the Sudanese universities and academic staff performance evaluation system and to determine the relative weights of the system criteria.
- Fuzzy TOPSIS is used to obtain the final rank of Universities & Academic staff.

In general, evaluating the universities performance and academic staff involves the following steps:

(i) Construct the performance evaluation system for universities & academic staff by identifying the overall goal (top level) and evaluation criteria/elements (lower level) that impact the overall goal. Then select the scale method and structure the decision hierarchy from the decision goal.
(ii) Construct a set of pairwise comparison matrices and design a survey to get experts opinions/preference on the evaluation criteria that are used to measure the universities and academic staff performance.
(iii) Check and analyze the consistency of the individual experts' responses.
(iv) Aggregate the consistent views.
(v) Approximate the fuzzy priorities and obtain the criteria weights.
(vi) Sort the relative distance of the alternative solutions to the ideal solution as a ranking process.
(vii) Finally, perform model testing.

The importance of a fuzzy method is to set the relative precedence of measures with fuzzy numbers rather than crisp numbers so that the experts' subjective views could be reflected. Details of the fuzzy method will be explained in the following sections.

Figure 6 Pairwise comparison for strategic planning criterion with other criteria in the same level with respect to Institutional frame work criterion.

Table 1 Triangular Fuzzy scale (TFN values).

SR	Statement	TFN
1	Absolute – more important	(2/9, 1 /4, 2/7)
2	Very strong – more important	(2/7, 1/3, 2/5)
3	Fairly strong – more Important	(2/5, 1/2, 2/3)
4	Weak – more important	(2/3, 1, 3/2)
5	Equal	(1, 1, 1)
6	Weak – less important	(2/3, 1, 3/2)
7	Fairly strong – less important	(3/2, 2, 5/2)
8	Very strong – less Important	(5/2, 3, 7/2)
9	Absolute – less important	(7/2, 4, 9/2)

3.1. Process workflow

This section presents the process workflow of the proposed classification model in swim lane diagram (i.e. functional band) where all related tasks are visually explained. The responsibilities were defined and shared between universities, ministry of higher education (business owner) and experts as shown in Fig. 3.

3.2. Process description

The following is the process description for each process in the process workflow shown in Fig. 3:

1. Define Project: In this stage, the administrator needs to define a project name, year, etc. Several types of projects or several projects with the same type could be defined.
2. Define Alternatives: It allows the administrator to specify the alternatives for a specific related project.
3. Define Criteria: It allows you to define criteria and sub criteria for a related specific project.
4. Pairwise Comparisons Template: It allows you to define the pairwise comparison template for each level of criteria.
5. Create Evaluation Forms Template: This stage lets you define the evaluation forms of the template according to the concerned bottom criteria and alternatives for a related specific project.
6. Define Scales: This process allows you to define a suitable fuzzy scale for each template. It contains the linguistic values and related fuzzy triangular numbers.
7. Project Initiation: Project initiation process allows the business owner to initiate the project by defining the experts/participants in order to start the process, send and get the evaluation feedback.
8. Criteria Comparison Feedback: This stage gets the individual evaluation preference feedback for criteria using the related linguistic values.
9. Conversion to TFN: The system engine converts linguistic value to Fuzzy triangular number as specified in the scale.
10. Consistency Checking: System engine utilizes the proposed algorithm in sections (7.1 to 7.4) to validate the consistency of the expert's preference and provides consistent options.

11. Criteria Comparison Aggregation: It aggregates all consistent expert feedback with the option of using different types of aggregation methods.
12. Fuzzy Preferences Approximation: This process consists of several steps which are explained in Section 8.2.
13. Weight Calculation: All criteria weight are calculated and saved per each level.
14. Bottom Weight Calculation: Only the bottom criteria are recalculated and saved.
15. Alternative Evaluation Feedback: This stage gets the individual evaluation preference feedback for alternatives using the related linguistic values. This process could be started immediately after the initiation process (i.e. that means after the initiation process both processes 8 & 15 could be stared simultaneously).
16. Define Alternative Comparison Matrix: The system engine construct a matrix between alternatives and related bottom criteria.
17. Alternatives Feedback Aggregation: It aggregates expert feedback with the option of using different types of aggregation methods
18. Weights & Normalization: In this stage, the alternative matrix will be normalized and weighted with weight obtained in the process (in step 14).
19. Define FNIS & FPIS: It calculates the fuzzy negative ideal solutions and fuzzy positive ideal solution for each bottom criteria.
20. Distance from Ideal Solutions: In this stage, the alternatives' distances from both negative and positive ideal solutions will be calculated.
21. Closeness to Ideal Solution (Ranking): In this process, the engine system calculates the closeness to ideal solution for each alternative and accordingly ranks the alternatives.

4. The proposed evaluation criteria

As outcomes from the literature review, two sets of criteria were defined. The first one is for university performance evaluation and the other one is for academic staff performance evaluation.

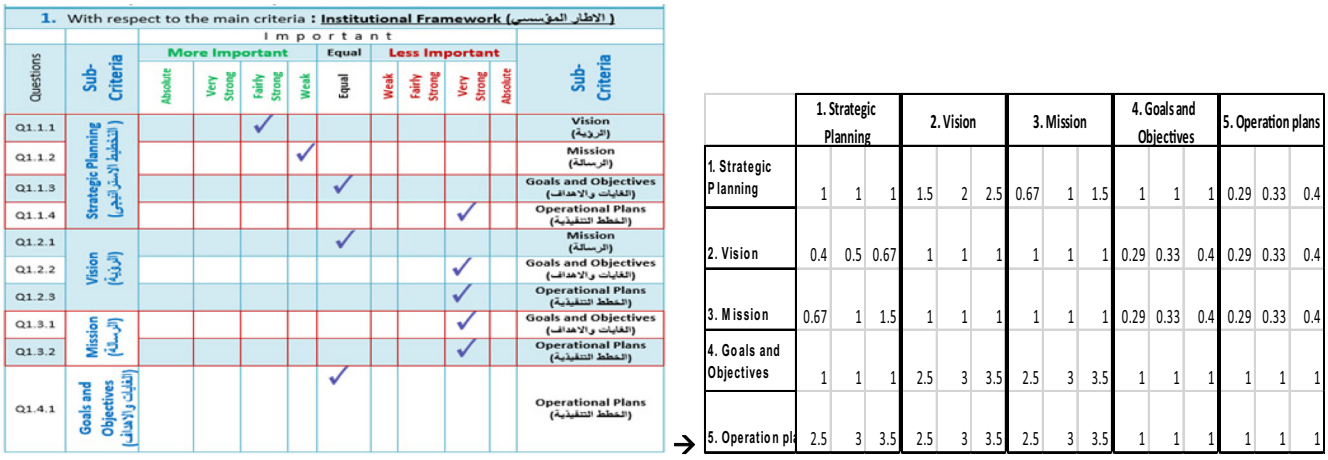


Figure 7 Shows the part of feedback for responder #25.

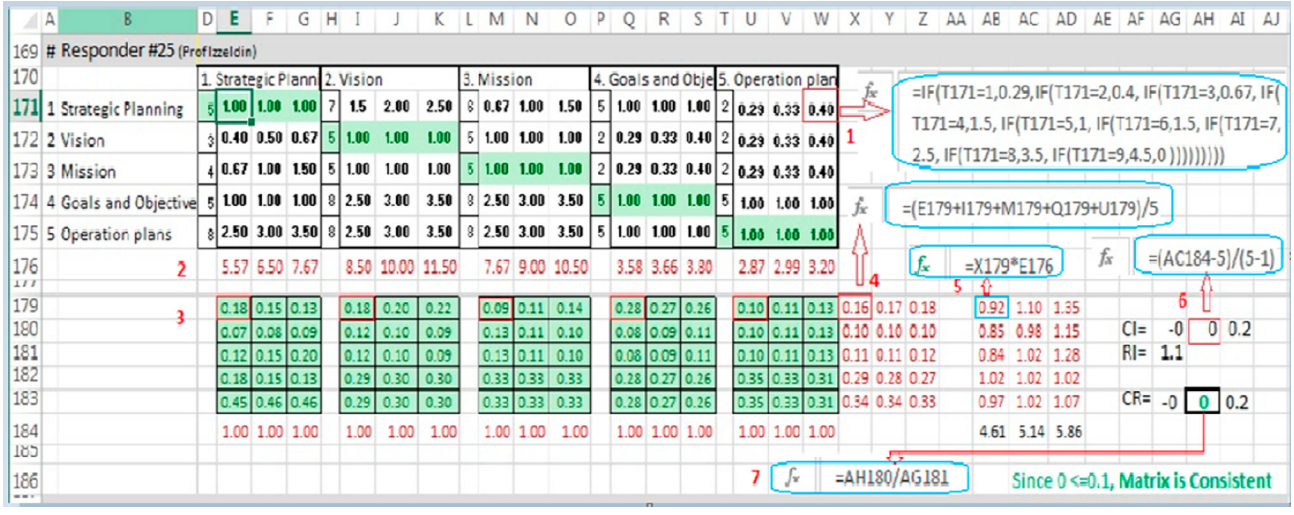


Figure 8 Shows comparison matrix of sub criteria of institutional framework criteria and consistency checking calculation process and result (for responder #25).

		1	Strategic Planning			Vision			Mission			Goals and Objectives			Operation plans		
1	Strategic Planning		1.00	1.00	1.00	1	1.00	1.00	1	1.00	1.00	1	1.00	1.00	1	1.00	1.00
2	Vision		1.00	1.00	1.00	1.00	1.00	1.00	1	1.00	1.00	1	1.00	1.00	1	1.00	1.00
3	Mission		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1	1.00	1.00	1	1.00	1.00
4	Goals and Objectives		1.00	1.00	1.00	1.00	1.00	1.00	1	1.00	1.00	1.00	1.00	1.00	1	1.00	1.00
5	Operation plans		1.00	1.00	1.00	1.00	1.00	1.00	1	1.00	1.00	1	1.00	1.00	1.00	1.00	1.00

		2	Strategic Planning			Vision			Mission			Goals and Objectives			Operation plans		
1	Strategic Planning		1.00	1.00	1.00	2.5	3.00	3.50	1.5	2.00	2.50	1.5	2.00	2.50	0.67	1.00	1.50
2	Vision		0.29	0.33	0.40	1.00	1.00	1.00	1.5	2.00	2.50	1.5	2.00	2.50	0.67	1.00	1.50
3	Mission		0.40	0.50	0.67	0.40	0.50	0.67	1.00	1.00	1.00	1.5	2.00	2.50	0.67	1.00	1.50
4	Goals and Objectives		0.40	0.50	0.67	0.40	0.50	0.67	0.4	0.50	0.67	1.00	1.00	1.00	0.67	1.00	1.50
5	Operation plans		0.67	1.00	1.50	0.67	1.00	1.50	0.67	1.00	1.50	0.67	1.00	1.50	1.00	1.00	1.00

		3	Strategic Planning			Vision			Mission			Goals and Objectives			Operation plans		
1	Strategic Planning		1.00	1.00	1.00	1	1.00	1.00	1	1.00	1.00	1	1.00	1.00	1	1.00	1.00
2	Vision		1.00	1.00	1.00	1.00	1.00	1.00	3.5	4.00	4.50	1	1.00	1.00	1	1.00	1.00
3	Mission		1.00	1.00	1.00	0.20	0.25	0.29	1.00	1.00	1.00	0.67	1.00	1.50	0.67	1.00	1.50
4	Goals and Objectives		1.00	1.00	1.00	1.00	1.00	1.00	0.67	1.00	1.50	1.00	1.00	1.00	1	1.00	1.00
5	Operation plans		1.00	1.00	1.00	1.00	1.00	1.00	0.67	1.00	1.50	1	1.00	1.00	1.00	1.00	1.00

		4	Strategic Planning			Vision			Mission			Goals and Objectives			Operation plans		
1	Strategic Planning		1.00	1.00	1.00	1.5	2.00	2.50	1.5	2.00	2.50	1.5	2.00	2.50	1	1.00	1.00
2	Vision		0.40	0.50	0.67	1.00	1.00	1.00	1	1.00	1.00	1	1.00	1.00	0.4	0.50	0.67
3	Mission		0.40	0.50	0.67	1.00	1.00	1.00	1.00	1.00	1.00	1	1.00	1.00	0.4	0.50	0.67
4	Goals and Objectives		0.40	0.50	0.67	1.00	1.00	1.00	1	1.00	1.00	1.00	1.00	1.00	0.4	0.50	0.67
5	Operation plans		1.00	1.00	1.00	1.50	2.00	2.50	1.5	2.00	2.50	1.5	2.00	2.50	1.00	1.00	1.00

		6	1. Strategic Planning			2. Vision			3. Mission			4. Goals and Objectiv			5. Operation plans		
1	Strategic Planning		1.00	1.00	1.00	1.5	2.00	2.50	0.67	1.00	1.50	1.00	1.00	1.00	0.29	0.33	0.40
2	Vision		0.40	0.50	0.67	1.00	1.00	1.00	1.00	1.00	1.00	0.29	0.33	0.40	0.29	0.33	0.40
3	Mission		0.67	1.00	1.50	1.00	1.00	1.00	1.00	1.00	1.00	0.29	0.33	0.40	0.29	0.33	0.40
4	Goals and Objectives		1.00	1.00	1.00	2.50	3.00	3.50	2.50	3.00	3.50	1.00	1.00	1.00	1.00	1.00	1.00
5	Operation plans		2.50	3.00	3.50	2.50	3.00	3.50	2.50	3.00	3.50	1.00	1.00	1.00	1.00	1.00	1.00

Aggregation:

			Strategic Planning			Vision			Mission			Goals and Objectiv			Operation plans		
1	Strategic Planning		1.00	1.00	1.00	1.41	1.64	1.85	1.09	1.32	1.56	1.18	1.32	1.44	0.72	0.80	0.90
2	Vision		0.54	0.61	0.71	1.00	1.00	1.00	1.39	1.52	1.62	0.85	0.92	1.00	0.60	0.70	0.83
3	Mission		0.64	0.76	0.92	0.60	0.66	0.72	1.00	1.00	1.00	0.78	0.92	1.08	0.55	0.70	0.90
4	Goals and Objectives		0.69	0.76	0.85	1.00	1.08	1.19	0.92	1.08	1.29	1.00	1.00	1.00	0.77	0.87	1.00
5	Operation plans		1.11	1.25	1.39	1.20	1.43	1.67	1.11	1.43	1.81	1.00	1.15	1.30	1.00	1.00	1.00

Figure 9 Aggregation of experts' Judgments (AIJ Method).

4.1. University performance evaluation criteria

These criteria are part of the national standards directory of quality assurance for higher Education in Sudan which was established by the Evaluation and Accreditation Corporation (EVAC) in the Ministry of Higher Education and Scientific Research (Ministry of Higher Education, 2016; Yousif and Shaout, 2016a). The nine factors/criteria and related sub-factors/criteria are listed in table format in Appendix B (Table 33) and structured as AHP in Fig. 4. The following is a brief description of each criteria:

- *Institutional Frame Work (UC1):* This factor is used as an indicator for institute identification, programs, activities and roles in the society. Any development for the education institute should consider and start from the institutional frame work. Institutional frame work includes the following sub criteria: strategic planning, vision, mission, goals & objectives and operational plans.
- *Governance & Administration (UC2):* This factor defines and controls the institution. It includes the following sub criteria: rules and regulations, organizational and functional structures, boards, committees, leadership, external relation and financial resources & management.
- *Infrastructure & Services (UC3):* It is one of the most importance tools that help the institution to perform several functions and achieve the organization mission. This factor consists of the following sub criteria/factors: sites & spaces, Facilities and equipment, university services, structure of information and communication technology.

- *Human Resources (UC4):* Human resource plays the main role in preparing and executing the policy and plan of institution. It comprises the human resources management, academic staff and helping frames.
- *Students & Graduates (UC5):* Students and graduate factors are some of the most important inputs and outputs of the educational process. It includes the following sub criteria: Admission and Registration, Student Affairs Administration and graduates.
- *Teaching and Learning Resources (UC6):* This factor includes academic programs, curriculums, academic advising/counseling, academic evaluation for students, libraries, electronic libraries, laboratories, workshops and centers of educational technologies.
- *Scientific Research and Graduate Studies (UC7):* It includes administration of scientific, research, funding of scientific research, marketing of scientific research, administration of graduates studies, admission supervision & evaluation of postgraduate's students and postgraduate programs.
- *Community Service (UC8):* One of the important roles of the education institution is relationship and services that are provided to the community. It includes the following sub-criteria: management of community service and community service programs.
- *Quality Management (UC9):* This factor concerns the availability of procedures that can ensure the compliance of the requirements and standards. This factor includes the following sub criteria: quality management and quality management programs.

4.2. Academic staff performance evaluation criteria

As outcomes from the literature review, six main criteria were defined for academic staff evaluation (Yousif and Shaout, 2016a; عماد ابو الرب). The following are the summary of these criteria and related sub criteria as listed in the table format in Appendix B (Table 34) and structured as AHP in Fig. 5.

- *Excellence in Research and Scientific Activities (AC1):* This criterion includes sub criteria such as publications, qualities of research, invitation to lecturer in important conferences, participation in postgraduate thesis examination & discussion and membership in editorial boards of the journal.
- *Teaching Quality (AC2):* Teaching quality evaluates the teaching aspects such as ability to cover different materials efficiently, commitment to academic work, academic counseling and office hours, teaching attitude, teaching advance courses and designing teaching programs and syllabi.
- *Service & Administration (AC3):* This criterion evaluates all related administration services such as participation in faculty technical committees, taking part on managerial roles and participation in the scientific community in Sudan.
- *Knowledge Transfer/Exchange and Engaging Communities Performance (AC4):* This criterion assesses the activities & collaboration with public groups, application of knowledge to improve business/industry/commerce, enhancing the quality of life for community and involvement of projects supported by faculty/university.
- *Student Feedback (AC5):* Students evaluate academic staff in the following area: teaching capabilities and preparation for lecture, material contribution in the scientific achievement of students, content of material and relationship with students.
- *Peers Feedback (AC6):* Peers evaluate the academic staff in the course content, delivery and teaching methods, learning environment, collaboration and professionalism.

5. Application of FAHP & FTOPSIS to universities & academic staff performance evaluation

The proposed classification model in the prior section (Fig. 2) is exploited to build a structured technique for organizing and analyzing complex decisions as shown in Figures ures2 and 3. In our case study, the various elements/criteria are evaluated by comparing them to each other two at a time, with respect to their impact on a criterion above them in the hierarchy. For example, we compare the (UC11: Strategic Planning) criterion with the following criteria (UC12: Vision), (UC13: Mission), (UC14: Goals and Objectives) and (UC15: Operational Plans) with respect to (UC1: Institutional Frame- work) criterion as shown in Fig. 6. Similar comparisons were designed and executed for all criteria at several levels using the related linguistic values, which will be converted into triangular fuzzy numbers as indicated in the scale in Table 1 (Tolga et al., 2005).

6. Data collection

Appropriate set of criteria of universities and academic staff evaluation were incorporated in pairwise comparisons and evaluation survey. Fig. 6 shows a sample of one level of comparison equations and related answer sheet. Forty-four questionnaires survey out of seventy were returned. Removing inconsistent questionnaire, we were left with thirty-five consistent questionnaires after consistency checking as shown in the table below.

Distributed Questionnaires	70
Returned	46
Returned Percentage	66%
Consistent Returned	35
Consistent Returned Percentage	76%

6.1. Consistency analysis for individual expert views

The consistency of judgment that is performed by responders/experts during a chain of pairwise comparison methods considers a key evaluation issue to the reliability of the final performance evaluation output. Sometimes the experts/participants are not able to express consistent preferences in case of several criteria. In our case, most of the layers have several criteria. Within this study, out of 46 responses, there were 11 responses which were excluded from the study.

In addition of checking and analyzing the experts' judgments after receiving the responses, we have proposed an

algorithm to detect the inconsistency in the experts' judgments. The proposed algorithm also provide consistency options.

6.1.1. Off-line consistency checking

In order to verify a reliable excellence level of each judgment, the responses were analyzed and a consistency ratio (CR) (Saaty, 1995) was calculated and checked for each individual expert's responses. The consistency ratio (CR) is described as the ratio between the consistency of a given evaluation matrix (CI: consistency index) and the consistency of a random matrix. Hence, we included only responses that meet the condition (CR < = 0.1). As (Saaty, 1980), we can approximate CR via λ max as follows:

$$CI = (\lambda \max - - n)/(n-1) \quad \text{and} \quad CR = CI/RC \leqslant 01.0$$

All the pairwise comparison judgments of respondents that exceed the tolerable level of (0.1) are excluded from further analysis.

In this study, Excel was selected to be our smart auto consistency checking tool, where a group of functions are developed to check the comparison consistency and aggregate the consistent judgments.

The following steps are the arithmetic operation used to check the consistency of experts' views (Yousif and Shaout, 2016b):

1. Based on the scale, convert the experts preference from linguistic variable into numerical interval (i.e. Fuzzy Triangular Number: FTN) using Excel function such as [=IF(X = 1, 0.22), IF(X = 2, 0.29), IF(X = 3, 0.4), IF (X = 4, 0.67), IF(X = 5, 1),
2. IF(X = 6, 0.67), IF(X = 7, 1.5), IF(X = 8, 2.5), IF(X = 9, 3.5, 0)]
   Where X is cell to locate the numeric value of the linguistic value.
3. Sum up each column of the reciprocal matrix and divide each element of the matrix with the sum of its column (normalize relative weight).
4. Average across the rows to obtain Principal Eigen vector (priority vector).
5. Obtain principle Eigen value (λ) by adding of products between each element of Eigen vector and the sum of columns of the reciprocal matrix (from step2).
6. Calculate consistency Index (CI): $CI = (\lambda \max - n)/(n-1)$ *where n is Judgment matrix order/dimension*.
7. Calculate consistency ratio (CR): $CR = \frac{CI}{RI}$ *where RI is Random Index*.
8. Defuzzify the TFN and compare the output crisp value with 0.1 (if result < =0.10 then acceptable level of inconsistency).

Example. This example demonstrates consistency checking process of pairwise judgment response of comparing the subcriteria of the Institutional framework criterion. Fig. 7 is an actual response (#25) from an expert for these equations: "How important is *Strategic planning* when it is compared with *Vision, Mission, Goals and Objectives & Operational Plans*". "How important is *Vision* when it is compared with *Mission, Goals and Objectives & Operational Plans*" *and so on*. The expert indicates his preferences among those sub criteria through off-line survey using predefined linguistic values. In order to accept this response in our further evaluation processes, we have to examine the consistency degree. In Fig. 8, the comparison matrix is constructed and linguistic values are converted into fuzzy triangular numbers as a first step, then column summation and normalization, etc. As final stage, the consistency ratio is calculated and found that the expert's preference is consistent. (i.e. CR < =0.1). Excel functions and predefined formula are used in the calculations to simplify the process.

The same checking is done for all responders judgments. 24% of the total responses are excluded from further evaluation process due to inconsistency in comparison evaluation.

6.1.2. On-line consistency checking fuzzy consistency algorithm (FCA)

One of the challenges that we faced in analyzing the surveyed data is the inconsistency of pairwise comparison in experts' responses for both university and academic staff criteria evaluation. The cause of the inconsistency is that the experts/participants are frequently not able to express consistent preferences in case of several criteria. Since it is not easy to allow the expert to redo the evaluation again which will cost effort and time, the inconsistent evaluations will be removed from the evaluations.

Hence, a new Fuzzy Consistency Algorithm (FCA) will be introduced to examine the inconsistency level of expert's judgment on-line. The new algorithm proposes a consistent preference linguistic value(s) as an option to the experts in the case of inconsistency judgment. Also, it allows experts to trace and understand the roots of inconsistency in evaluation performance. Generally this algorithm works as inconsistency detection. The details of the algorithm are explained in Yousif and Shaout (2016b).

7. Aggregation of group decisions

As the second step after checking each individual pairwise comparison response of Sudanese universities and academic staff evaluation criteria and excluding/revising the inconsistent judgments, we need to aggregate the consistent fuzzy comparisons matrices. Since each individual matrix is the assessment of one expert (i.e. decision maker), aggregation is essential to achieve a group consensus of experts. There are two basic methods for aggregating the individual preferences into a group preference: aggregating of individual Judgments (AIJ) and Aggregating of individual priorities (AIP) (forman and Peniwati, 1998). In AIJ method, the aggregated/group comparison matrix is founded from the individual comparison matrices. The aggregated matrix is reflected as comparison matrix of a new expert (i.e. new individual) and the priorities of this expert are obtained as group solution.

In the AIP method, the experts act individually. Initially, the individual priorities are obtained from individual comparison matrices and then the group priorities are derived from these matrices, based on the degree of complexity of the required fuzzy arithmetic operations and whether experts share common values and working for the same organization. Forman and Peniwati (1998) stated that AIJ is the most often

Table 2 Evaluation of performance evaluation criteria with respect to main goal (UC).

	UC1	UC2	UC3	UC4	UC5	UC6	UC7	UC8	UC9
UC1	(1,1,1)	(1.42,1.64,1.91)	(0.96,1.17,1.42)	(0.93,1.1,1.3)	(1.01,1.15,1.3)	(0.73,0.85,0.99)	(0.75,1,1.33)	(1.14,1.42,1.77)	(0.79,0.89,1.01)
UC2	(0.52,0.61,0.71)	(1,1,1)	(0.73,0.85,1.01)	(1.03,1.17,1.3)	(0.82,1,1.22)	(0.57,0.66,0.78)	(0.96,1.17,1.43)	(1.29,1.64,2.06)	(0.84,0.94,1.06)
UC3	(0.71,0.85,1.04)	(0.99,1.17,1.38)	(1,1,1)	(0.59,0.69,0.82)	(0.65,0.8,1)	(0.85,1,1.15)	(1.26,1.49,1.69)	(1.29,1.51,1.77)	(1.08,1.17,1.27)
UC4	(0.77,0.9,1.08)	(0.77,0.85,0.97)	(1.23,1.45,1.71)	(1,1,1)	(1.28,1.43,1.55)	(1.36,1.57,1.77)	(1.62,1.92,2.2)	(1.45,1.74,2.04)	(1.34,1.49,1.61)
UC5	(0.77,0.87,0.99)	(0.82,1,1.22)	(1,1.24,1.54)	(0.64,0.7,0.78)	(1,1,1)	(0.94,1,1.06)	(0.83,1,1.21)	(1,1.1,1.21)	(1.02,1.29,1.62)
UC6	(1.01,1.17,1.37)	(1.29,1.51,1.77)	(0.87,1,1.17)	(0.57,0.63,0.74)	(0.94,1,1.06)	(1,1,1)	(1.45,1.74,2.04)	(1.43,1.81,2.24)	(1.01,1.22,1.47)
UC7	(0.75,1,1.33)	(0.7,0.85,1.05)	(0.59,0.67,0.8)	(0.46,0.52,0.62)	(0.83,1,1.21)	(0.49,0.57,0.69)	(1,1,1)	(1.14,1.29,1.44)	(1.09,1.37,1.7)
UC8	(0.57,0.7,0.88)	(0.48,0.61,0.78)	(0.57,0.66,0.78)	(0.49,0.57,0.69)	(0.83,0.91,1)	(0.45,0.55,0.7)	(0.69,0.77,0.88)	(1,1,1)	(0.8,1,1.25)
UC9	(0.99,1.12,1.27)	(0.94,1.06,1.2)	(0.79,0.85,0.93)	(0.62,0.67,0.75)	(0.62,0.77,0.99)	(0.68,0.82,1)	(0.59,0.73,0.92)	(0.8,1,1.25)	(1,1,1)

operated using the geometry mean operation; whereas, AIP is normally performed utilizing the athematic mean operations. How do we select the more precise method for aggregating?

In our case study, the more precise methods are the AIJ where the experts work for the same organization (HE) and share the same values. Due to inhomogeneous responses (i.e. wide range of upper and lower bandwidths), it is better to exclude the Min and Max algorithms (Chang et al., 2009) to combine evaluations of different decision makers. Instead, we used the geometric mean (l_{ij}) which is generally used in the AHP aggregation group (Davies, 1994).

$$l_{ij} = \left(\prod_{k=1}^{K} l_{ijk}\right)^{\frac{1}{k}}, \quad m_{ij} = \left(\prod_{k=1}^{K} m_{ijk}\right)^{\frac{1}{k}}, \quad u_{ij} = \left(\prod_{k=1}^{K} u_{ijk}\right)^{\frac{1}{k}}$$

where (lijk, mijk, uijk) is the fuzzy evaluation of sample member's k ($k = 1, 2 \ldots K$).

For example, we take one node in the hierarchy (UC1) and aggregate six consistent individual judgments responses by calculating the geometric mean as shown in Fig. 9. Say the $l_{ij} = 0.54$ (i.e. Cell E40) is output of aggregating Cells (E4, E11, E18, E25, E32) by calculating the geometric mean of these values (1.00, 0.29, 1.00, 0.40, 0.40). $m_{ij} = 0.61$ (i.e. Cell F40) and $u_{ij} = 0.71$ (i.e. Cell G40). Hence the aggregated judgment for six responders between strategic planning and vision is as follows (0.54, 0.61, 0.71).

8. Fuzzy preferences approximation

After aggregated consistent decisions in one combined results, we need to estimate the preferences/priorities using synthetic extent analysis by (Chang, 1996). The Fuzzy synthetic extent value S_i with respect to the ith criterion is defined as:

$$S_i = \sum_{j=1}^{m} M_{g_i}^{j} \otimes \left(\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^{j}\right)^{-1}$$

where g_i are the goals and $M_{g_i}^{j}$ represent TFNs of decision matrix with $i = 1, 2 \ldots n$ and $j = 1, 2 \ldots m$

The fuzzy preference approximation is done using the following steps:

Step 1: In the combined comparison matrix, we need to sum each row of the matrix (i.e. fuzzy addition operation) and a new Fuzzy triangular number will be produced. $\sum_{j=1}^{m} M_{g_i}^{j} = (\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j)$ where l is the lower limit value, m is the most promising value and u is the upper value.

Step 2: Compute fuzzy addition operation of $M_{g_i}^{j}$ ($j = 1, 2, 3 \ldots m$) values

$$\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^{j} = \left(\sum_{i=1}^{n} l_i, \sum_{i=1}^{n} m_i, \sum_{i=1}^{n} u_i\right)$$

Then find the inverse of the above equation

$$\left(\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^{j}\right)^{-1} = \left(1 \Big/ \sum_{i=1}^{n} u_i, 1 \Big/ \sum_{i=1}^{n} m_i, 1 \Big/ \sum_{i=1}^{n} l_i\right)$$

Step 3: Determine the intersections points by comparing each couple (i.e. membership value / degree of possibility). The minimum degree of possibility for a specific criterion is the weight of that criterion.

Table 3 Evaluation of the sub criteria of institutional framework (UC1).

	UC11	UC12	UC13	UC14	UC15
UC11	(1,1,1)	(1.41,1.64,1.85)	(1.09,1.32,1.56)	(1.18,1.32,1.44)	(0.72,0.8,0.9)
UC12	(0.54,0.61,0.71)	(1,1,1)	(1.39,1.52,1.62)	(0.85,0.92,1)	(0.6,0.7,0.83)
UC13	(0.64,0.76,0.92)	(0.6,0.66,0.72)	(1,1,1)	(0.78,0.92,1.08)	(0.55,0.7,0.9)
UC14	(0.69,0.76,0.85)	(1,1.08,1.19)	(0.92,1.08,1.29)	(1,1,1)	(0.77,0.87,1)
UC15	(1.11,1.25,1.39)	(1.2,1.43,1.67)	(1.11,1.43,1.81)	(1,1.15,1.3)	(1,1,1)

Table 4 Evaluation of the sub criteria of governance & administration (UC2).

	UC21	UC22	UC23	UC24	UC25	UC26	UC27
UC21	(1,1,1)	(1.18,1.32,1.44)	(1,1.21,1.44)	(1,1.32,1.7)	(0.73,0.87,1.02)	(1.51,2,2.54)	(0.92,1.15,1.41)
UC22	(0.69,0.76,0.85)	(1,1,1)	(0.72,0.92,1.18)	(0.78,0.92,1.08)	(0.56,0.64,0.75)	(0.93,1.21,1.59)	(0.67,0.8,0.98)
UC23	(0.69,0.82,1.01)	(0.85,1.08,1.39)	(1,1,1)	(0.79,1,1.28)	(0.65,0.8,1)	(1.54,1.89,2.26)	(0.83,1,1.2)
UC24	(0.59,0.76,1)	(0.92,1.08,1.29)	(0.79,1,1.28)	(1,1,1)	(0.59,0.76,1)	(1.19,1.52,1.91)	(0.59,0.76,1)
UC25	(0.99,1.15,1.35)	(1.33,1.55,1.79)	(1,1.25,1.54)	(1,1.32,1.7)	(1,1,1)	(1.53,2,2.58)	(0.92,1.15,1.41)
UC26	(0.39,0.5,0.67)	(0.62,0.82,1.09)	(0.43,0.53,0.65)	(0.51,0.66,0.85)	(0.37,0.5,0.66)	(1,1,1)	(0.6,0.8,1.09)
UC27	(0.71,0.87,1.09)	(1.02,1.25,1.51)	(0.83,1,1.2)	(1,1.32,1.7)	(0.71,0.87,1.09)	(0.92,1.25,1.68)	(1,1,1)

Table 5 Evaluation of the sub criteria of infrastructure & services (UC3).

	UC31	UC32	UC33	UC34
UC31	(1, 1, 1)	(1.09, 1.32, 1.56)	(0.93, 1.09, 1.28)	(0.72, 0.95, 1.27)
UC32	(0.64, 0.76, 0.92)	(1, 1, 1)	(0.9, 1.08, 1.28)	(0.91, 1.05, 1.2)
UC33	(0.79, 0.91, 1.07)	(0.78, 0.93, 1.11)	(1, 1, 1)	(0.72, 0.88, 1.09)
UC34	(0.79, 1.05, 1.39)	(0.83, 0.95, 1.09)	(0.92, 1.13, 1.39)	(1, 1, 1)

Table 6 Evaluation of the sub criteria of human resources (UC4).

	UC41	UC42	UC43
UC41	(1, 1, 1)	(0.69, 0.82, 0.99)	(0.84, 0.96, 1.1)
UC42	(1.01, 1.21, 1.46)	(1, 1, 1)	(1.45, 1.78, 2.17)
UC43	(0.91, 1.04, 1.19)	(0.46, 0.56, 0.69)	(1, 1, 1)

Table 7 Evaluation of the sub criteria of students & graduates (UC5).

	UC51	UC52	UC53
UC51	(1, 1, 1)	(1.31, 1.59, 1.84)	(2.36, 2.88, 3.4)
UC52	(0.54, 0.63, 0.77)	(1, 1, 1)	(1.84, 2.08, 2.31)
UC53	(0.29, 0.35, 0.43)	(0.44, 0.48, 0.54)	(1, 1, 1)

Say $M_1 = (l_1, m_1, u_1), M_2 = (l_2, m_2, u_2)$ are two TFNs, the degree of possibility of $M_2 = (l_2, m_2, u_2) \geqslant M_1 = (l_1, m_1, u_1)$ is defined as

$$V(M_2 \geqslant M_1) = \sup_{y \geqslant x}[\min(\mu_{M1}(x), \mu_{M2}(y))]$$

where $\mu_{M1}(x)$ and $\mu_{M2}(y)$ are membership functions of the x, y values on the axis of membership function for each criterion.

It can also be equally stated as follows:

$$V(M_2 \geqslant M_1) = hgt(M_2 \cap {}_1^M) = \mu_{M_2}(d) = \begin{cases} 1 & if\ m_2 \geqslant m_1 \\ 0 & if\ l_1 \geqslant u_2 \\ \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} & otherwise \end{cases}$$ where d is the ordinate of the highest intersection point D between μ_{M_1} *and* μ_{M_2}.

Step 4: The degree of possibility for a convex fuzzy number to be greater than k convex $M_i (i = 1 \ldots k)$ can be defined by

$V(M \geqslant M_1 \ldots M_1) = V[(M \geqslant M_1)\ and\ (M \geqslant M_2)\ and \ldots\ and\ (M \geqslant M_k)] = minV[(M \geqslant M_i)\ where\ i = 1, \ldots, k.$

Assume that, we calculate the minimum degree possibility $d(A_i)$ as $d(A_i) = \min V(S_i \geqslant S_k)\ where\ k = 1, 2, \ldots, n\ and\ k \neq i$

Then the weight vector is $W = (d(A_1), d(A_2), \ldots, d(A_n))^T$ Where $A_i (i = 1, 2, \ldots, n)$ *are n elements.*

Step 5: Normalize the weighs for all criteria which represent the final weights (i.e. importance degree/ priorities weight) for criteria or alternatives in the hierarchy level.

Empirical Example: (Part I - Criteria Weights): Let us take the same aggregated comparison matrix in as shown in Table 4 and calculate the weights of the main performance evaluation criteria for Sudanese universities.

From the comparison matrix, the summation of fuzzy triangular numbers of (UC1: Institutional framework) compared with other criteria is as follows:

$$\begin{aligned} \sum_{j=1}^{m} M_{g_i}^j &= \sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j \\ &= [(1.0000 + 1.4173 + 0.9640 + .9311 + 1.0142 \\ &\quad + 0.7300 + 0.7543 + 1.1430 + 0.7930), (1.000 \\ &\quad + 1.6406 + 1.1699 + 1.1009 + 1.1471 + 0.8535 \\ &\quad + 1.0000 + 1.4241 + 0.8880), (1.0000 + 1.9065 \\ &\quad + 1.4170 + 1.3035 + 1.3007 + 0.9921 + 1.3304 \\ &\quad + 1.7744 + 1.0110)] \\ &= (8.7469, 10.2241, 12.0365) \end{aligned}$$

Table 8 Evaluation of the sub criteria of teaching & learning resources (UC6).

	UC61	UC62	UC63	UC64	UC65	UC66	UC67	UC68	UC69
UC61	(1,1,1)	(1.08,1.15,1.2)	(1,1.15,1.3)	(1,1.15,1.3)	(1.2,1.43,1.67)	(0.92,1.15,1.41)	(0.92,1,1.08)	(0.79,1,1.28)	(1.11,1.43,1.81)
UC62	(0.83,0.87,0.92)	(1,1,1)	(1.19,1.52,1.91)	(0.92,1,1.08)	(1.33,1.55,1.79)	(0.92,1.15,1.41)	(0.92,1,1.08)	(0.92,1.15,1.41)	(1.02,1.25,1.51)
UC63	(0.77,0.87,1)	(0.52,0.66,0.85)	(1,1,1)	(0.92,1.15,1.41)	(0.92,1.08,1.29)	(1.1,1.52,2.07)	(0.71,0.87,1.09)	(0.94,1.25,1.64)	(0.83,1,1.2)
UC64	(0.77,0.87,1)	(0.92,1,1.08)	(0.71,0.87,1.09)	(1,1,1)	(1.31,1.64,2.04)	(1.02,1.43,1.97)	(1.02,1.25,1.51)	(1.13,1.55,2.11)	(0.93,1.32,1.87)
UC65	(0.6,0.7,0.83)	(0.56,0.64,0.75)	(0.78,0.92,1.08)	(0.49,0.61,0.76)	(1,1,1)	(0.61,0.8,1.06)	(0.52,0.66,0.85)	(0.73,1,1.38)	(0.85,1.06,1.32)
UC66	(0.71,0.87,1.09)	(0.71,0.87,1.09)	(0.48,0.66,0.92)	(0.51,0.7,0.98)	(0.94,1.25,1.64)	(1,1,1)	(0.99,1.15,1.35)	(1.42,1.64,1.88)	(1.29,1.52,1.76)
UC67	(0.92,1,1.08)	(0.92,1,1.08)	(0.92,1.15,1.41)	(0.67,0.8,0.98)	(1.19,1.52,1.91)	(0.74,0.87,1.02)	(1,1,1)	(1.54,1.89,2.26)	(1.29,1.52,1.76)
UC68	(0.79,1,1.28)	(0.71,0.87,1.09)	(0.61,0.8,1.06)	(0.48,0.64,0.88)	(0.73,1,1.38)	(0.53,0.61,0.7)	(0.44,0.53,0.65)	(1,1,1)	(1.19,1.32,1.47)
UC69	(0.55,0.7,0.9)	(0.67,0.8,0.98)	(0.83,1,1.2)	(0.54,0.76,1.08)	(0.76,0.94,1.18)	(0.57,0.66,0.78)	(0.57,0.66,0.78)	(0.68,0.76,0.85)	(1,1,1)

Table 9 Evaluation of the sub criteria of scientific research & graduate studies (UC7).

	UC71	UC72	UC73	UC74	UC75	UC76
UC71	(1,1,1)	(0.64,0.79,1)	(0.88,1,1.14)	(0.88,1,1.14)	(0.58,0.69,0.84)	(0.58,0.69,0.84)
UC72	(1,1.26,1.55)	(1,1,1)	(0.88,1,1.14)	(1.74,2,2.24)	(0.77,1,1.31)	(0.77,1,1.31)
UC73	(0.88,1,1.14)	(0.88,1,1.14)	(1,1,1)	(1.19,1.44,1.74)	(1.04,1.44,1.99)	(1,1.26,1.55)
UC74	(0.88,1,1.14)	(0.43,0.5,0.58)	(0.58,0.69,0.84)	(1,1,1)	(0.77,1,1.31)	(0.74,0.79,0.88)
UC75	(1.19,1.44,1.74)	(0.77,1,1.31)	(0.51,0.69,0.97)	(0.77,1,1.31)	(1,1,1)	(0.64,0.79,1)
UC76	(1.19,1.44,1.74)	(0.77,1,1.31)	(0.64,0.79,1)	(1.14,1.26,1.36)	(1,1.26,1.55)	(1,1,1)

Table 10 Evaluation of the sub criteria of community service (UC8).

	UC81	UC82
UC81	(1, 1, 1)	(1.15, 1.44, 1.77)
UC82	(0.57, 0.69, 0.87)	(1, 1, 1)

Table 11 Evaluation of the sub criteria of quality management (UC9).

	U91	U92
U91	(1, 1, 1)	(0.84, 0.96, 1.1)
U92	(0.91, 1.04, 1.19)	(1, 1, 1)

Similarly, the result of applying addition operation of TFN for comparing the (UC2: Governance & Administration) criterion with other criteria is equal to (7.7539, 9.0391, 10.5834)

Comparing (UC3: Infrastructure & Services) criterion with other criteria is equal to (8.4198, 9.6798, 11.1205)
Comparing (UC4: Human Resources) criterion with other criteria is equal to (10.8157, 12.3518, 13.9347)
Comparing (UC5: Students & Graduates) criterion with other criteria is equal to (8.0271, 9.2022, 10.6382)
Comparing (UC6: Teaching and Learning Resources) criterion with other criteria is equal to (9.5631, 11.0843, 12.8765)
Comparing (UC7: Scientific Research and Graduate Studies) criterion with other criteria is equal to (7.0598, 8.2803, 9.8448)
Comparing (UC8: Community Service) criterion with other criteria is equal to (5.8799, 6.7714, 7.9648)
Comparing (UC9: Quality Management) criterion with other criteria is equal to (7.0375, 8.0294, 9.2906)

Then we need to find $(\sum_{i=1}^{n}\sum_{j=1}^{m}M_{g_i}^{j})^{-1} = (1/\sum_{i=1}^{n}u_i, 1/\sum_{i=1}^{n}m_i, 1/\sum_{i=1}^{n}l_i) = (1/(12.0365 + 10.5834 + \cdots + 9.2906), 1/(10.2241 + 9.0391 + \cdots + 8.0294), 1/(8.7469 + 7.7539 + \cdots + 7.0375)) = (1/98.2894, 1/84.6626, 1/73.3041)$

Now, we need to calculate the fuzzy synthetic extent, which is defined as $S_i = \sum_{j=1}^{m}M_{g_i}^{j} \otimes (\sum_{i=1}^{n}\sum_{j=1}^{m}M_{g_i}^{j})^{-1}$

Hence, the Fuzzy synthetic extent value S_{UC1} with respect to the Institutional framework criterion is defined as:

$$S_{UC1} = (8.7469, 10.2241, 12.0365) \otimes (1/98.2894, 1/84.6626, 1/73.3041) = (0.089, 0.121, 0.164)$$

The Fuzzy synthetic extent value S_{UC2} with respect to the *Governance & Administration* criterion is defined as:

$$S_{UC2} = (7.7539, 9.0391, 10.5834) \otimes (1/98.2894, 1/84.6626, 1/73.3041) = (0.079, 0.107, 0.144)$$

Table 12 Evaluation of the main criteria of academic staff with respect to goal.

	AC1	AC2	AC3	AC4	AC5	AC6
AC1	(1,1,1)	(0.63,0.71,0.82)	(1.29,1.73,2.29)	(1.22,1.41,1.58)	(1.53,2,2.6)	(1,1.41,1.94)
AC2	(1.22,1.41,1.58)	(1,1,1)	(1.29,1.73,2.29)	(1.58,1.73,1.87)	(1.53,2,2.6)	(1.29,1.73,2.29)
AC3	(0.44,0.57,0.77)	(0.44,0.57,0.77)	(1,1,1)	(0.67,1,1.5)	(0.63,0.71,0.82)	(0.82,1,1.22)
AC4	(0.63,0.71,0.82)	(0.54,0.57,0.63)	(0.67,1,1.5)	(1,1,1)	(1,1.41,1.94)	(0.82,1,1.22)
AC5	(0.37,0.5,0.66)	(0.37,0.5,0.66)	(1.22,1.41,1.58)	(0.52,0.71,1)	(1,1,1)	(0.63,0.71,0.82)
AC6	(0.52,0.71,1)	(0.44,0.57,0.77)	(0.82,1,1.22)	(0.82,1,1.22)	(1.22,1.41,1.58)	(1,1,1)

Table 13 Evaluation of the sub criteria of excellence in research and scientific activities (AC1).

	AC11	AC12	AC13	AC14	AC15
AC11	(1,1,1)	(0.54,0.57,0.63)	(1.29,1.73,2.29)	(0.82,1,1.22)	(1.58,1.73,1.87)
AC12	(1.58,1.73,1.87)	(1,1,1)	(1.29,1.73,2.29)	(1.29,1.73,2.29)	(0.82,1,1.22)
AC13	(0.44,0.57,0.77)	(0.44,0.57,0.77)	(1,1,1)	(0.67,1,1.5)	(0.52,0.71,1)
AC14	(0.82,1,1.22)	(0.44,0.57,0.77)	(0.67,1,1.5)	(1,1,1)	(0.82,1,1.22)
AC15	(0.54,0.57,0.63)	(0.82,1,1.22)	(1,1.41,1.94)	(0.82,1,1.22)	(1,1,1)

Table 14 Evaluation of the sub criteria of teaching quality (AC2).

	AC21	AC22	AC23	AC25	AC26	AC27
AC21	(1,1,1)	(1,1,1)	(0.67,1,1.5)	(0.67,1,1.5)	(1.29,1.73,2.29)	(0.82,1,1.22)
AC22	(1,1,1)	(1,1,1)	(1,1.41,1.94)	(0.67,1,1.5)	(1.29,1.73,2.29)	(0.82,1,1.22)
AC23	(0.67,1,1.5)	(0.52,0.71,1)	(1,1,1)	(0.67,1,1.5)	(1.58,1.73,1.87)	(0.82,1,1.22)
AC24	(0.67,1,1.5)	(0.67,1,1.5)	(0.67,1,1.5)	(1,1,1)	(1.87,2,2.12)	(0.82,1,1.22)
AC25	(0.44,0.57,0.77)	(0.44,0.57,0.77)	(0.54,0.57,0.63)	(0.45,0.5,0.54)	(1,1,1)	(0.37,0.5,0.66)
AC26	(0.82,1,1.22)	(0.82,1,1.22)	(0.82,1,1.22)	(0.82,1,1.22)	(1.53,2,2.6)	(1,1,1)

Table 15 Evaluation of the sub criteria of service & administration (AC3).

	AC31	AC32	AC33	AC34
AC31	(1,1,1)	(1,1,1)	(0.63,0.71,0.82)	(0.54,0.57,0.63)
AC32	(1,1,1)	(1,1,1)	(0.63,0.71,0.82)	(1,1,1)
AC33	(1.22,1.41,1.58)	(0.82,1,1.22)	(1,1,1)	(1.58,1.73,1.87)
AC34	(1.58,1.73,1.87)	(0.54,0.57,0.63)	(0.54,0.57,0.63)	(1,1,1)

Table 16 Evaluation of the sub criteria of knowledge transfer (AC4).

	AC41	AC42	AC43	AC44
AC41	(1,1,1)	(0.63,0.71,0.82)	(0.54,0.57,0.63)	(0.44,0.57,0.77)
AC42	(1.22,1.41,1.58)	(1,1,1)	(1,1,1)	(0.52,0.71,1)
AC43	(1.58,1.73,1.87)	(1,1,1)	(1,1,1)	(0.52,0.71,1)
AC44	(1.29,1.73,2.29)	(1,1.41,1.94)	(1,1.41,1.94)	(1,1,1)

Table 17 Evaluation of the sub criteria of students feedback (AC5).

	AC51	AC52	AC53	AC54
AC51	(1,1,1)	(1.22,1.41,1.58)	(1.58,1.73,1.87)	(1,1.41,1.94)
AC52	(0.63,0.71,0.82)	(1,1,1)	(1.87,2,2.12)	(1,1.41,1.94)
AC53	(0.54,0.57,0.63)	(0.45,0.5,0.54)	(1,1,1)	(0.67,1,1.5)
AC54	(0.52,0.71,1)	(0.52,0.71,1)	(0.67,1,1.5)	(1,1,1)

Table 18 Evaluation of the sub criteria of peers feedback (AC6).

	AC61	AC62	AC63	AC64
AC61	(1,1,1)	(1,1,1)	(0.82,1,1.22)	(0.82,1,1.22)
AC62	(1,1,1)	(1,1,1)	(0.82,1,1.22)	(0.82,1,1.22)
AC63	(0.82,1,1.22)	(0.82,1,1.22)	(1,1,1)	(1,1,1)
AC64	(0.82,1,1.22)	(0.82,1,1.22)	(1,1,1)	(1,1,1)

Table 19 Evaluation of the sub criteria of teaching capability (AC51).

	AC511	AC512	AC513	AC514	AC515	AC516
AC511	(1,1,1)	(0.84,1,1.19)	(0.54,0.63,0.77)	(0.43,0.55,0.74)	(0.64,0.79,1)	(0.49,0.55,0.64)
Ac512	(0.84,1,1.19)	(1,1,1)	(1,1.26,1.55)	(0.74,0.79,0.88)	(0.88,1,1.14)	(0.88,1,1.14)
AC513	(1.31,1.59,1.84)	(0.64,0.79,1)	(1,1,1)	(0.77,1,1.31)	(1,1,1)	(1,1,1)
AC514	(1.36,1.82,2.36)	(1.14,1.26,1.36)	(0.77,1,1.31)	(1,1,1)	(1.15,1.59,2.11)	(1.15,1.59,2.11)
AC515	(1,1.26,1.55)	(0.88,1,1.14)	(1,1,1)	(0.48,0.63,0.88)	(1,1,1)	(0.88,1,1.14)
AC516	(1.55,1.82,2.06)	(0.88,1,1.14)	(1,1,1)	(0.48,0.63,0.88)	(0.88,1,1.14)	(1,1,1)

Table 20 Evaluation of the sub criteria of material contribution (AC52).

	AC521	AC522	AC523	AC524	AC525	AC526	AC527
AC521	(1,1,1)	(1,1.26,1.55)	(0.74,0.79,0.88)	(0.48,0.63,0.88)	(0.54,0.63,0.77)	(0.54,0.63,0.77)	(0.49,0.55,0.64)
AC522	(0.64,0.79,1)	(1,1,1)	(1,1.26,1.55)	(1,1.26,1.55)	(0.58,0.69,0.84)	(0.66,0.69,0.74)	(0.66,0.69,0.74)
AC523	(1.14,1.26,1.36)	(0.64,0.79,1)	(1,1,1)	(0.88,1,1.14)	(0.88,1,1.14)	(0.74,0.79,0.88)	(0.74,0.79,0.88)
AC524	(1.15,1.59,2.11)	(0.64,0.79,1)	(0.88,1,1.14)	(1,1,1)	(0.88,1,1.14)	(0.77,1,1.31)	(1,1,1)
AC525	(1.31,1.59,1.84)	(1.19,1.44,1.74)	(0.88,1,1.14)	(0.88,1,1.14)	(1,1,1)	(0.66,0.69,0.74)	(0.66,0.69,0.74)
AC526	(1.31,1.59,1.84)	(1.36,1.44,1.52)	(1.14,1.26,1.36)	(0.77,1,1.31)	(1.36,1.44,1.52)	(1,1,1)	(0.88,1,1.14)
AC527	(1.55,1.82,2.06)	(1.36,1.44,1.52)	(1.14,1.26,1.36)	(1,1,1)	(1.36,1.44,1.52)	(0.88,1,1.14)	(1,1,1)

Table 21 Evaluation of the sub criteria of material content (AC53).

	AC531	AC532	AC533
AC531	(1,1,1)	(0.77,1,1.31)	(1,1,1)
AC532	(0.77,1,1.31)	(1,1,1)	(0.77,1,1.31)
AC533	(1,1,1)	(0.77,1,1.31)	(1,1,1)

Similarly,

$S_{UC3} = (0.086, 0.114, 0.152),\ S_{UC4} = (0.110, 0.146, 0.190),$
$S_{UC5} = (0.082, 0.109, 0.145),\ S_{UC6} = (0.097, 0.131, 0.176)$
$S_{UC7} = (0.072, 0.098, 0.134),\ S_{UC8} = (0.060, 0.080,\ and\ 0.109),$
$S_{UC9} = (0.072, 0.095, 0.127)$

Using these vectors and the equation below, we can get the degree of possibility

$$V(M_2 \geqslant M_1) = hgt(M_2 \cap M_1) = \mu_{M_2} = \begin{cases} 1 & if\, m_2 \geqslant m_1 \\ 0 & if\, l_1 \geqslant u_2 \\ \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} & otherwise \end{cases}$$

For UC1: Institutional frame work, let

$l_2 = 0.089, l_1 = 0.079, m_2 = 0.121, m_1 = 0.144, u_2 = 0.164, u_1 = 0.144$ Then: $V(S_{UC1} \geqslant S_{UC2})$: V ((0.089, 0.121, 0.164) $\geqslant$ (0.079, 0.107, 0.144)) = 1.000

Similarly

$V(S_{UC1} \geqslant S_{UC3})$: V ((0.089, 0.121, 0.164) $\geqslant$ (0.086, 0.114, 0.152)) = 1.000

Table 22 Evaluation of the sub criteria of relationship of faculty member and students (AC54).

	AC541	AC542	AC543	AC544
AC541	(1,1,1)	(0.88,1,1.14)	(0.74,0.79,0.88)	(0.77,1,1.31)
AC542	(0.88,1,1.14)	(1,1,1)	(0.77,1,1.31)	(0.77,1,1.31)
AC543	(1.14,1.26,1.36)	(0.77,1,1.31)	(1,1,1)	(1,1.26,1.55)
AC544	(0.77,1,1.31)	(0.77,1,1.31)	(0.64,0.79,1)	(1,1,1)

Table 23 Evaluation of the sub criteria of course content (AC61).

	AC611	AC612	AC613	AC614
AC611	(1,1,1)	(0.91,1.19,1.54)	(0.58,0.64,0.72)	(0.6,0.76,0.97)
AC612	(0.65,0.84,1.11)	(1,1,1)	(0.74,1,1.36)	(0.66,0.76,0.88)
AC613	(1.39,1.57,1.72)	(0.74,1,1.36)	(1,1,1)	(0.72,0.84,1)
AC614	(1.03,1.32,1.68)	(1.14,1.32,1.51)	(1,1.19,1.39)	(1,1,1)

Table 24 Evaluation of the sub criteria of Delivery & Teaching Methods (AC62).

	AC621	AC622	AC623	AC624	AC625	AC626	AC627	AC628
AC621	(1,1,1)	(0.66,0.69,0.74)	(0.88,1,1.14)	(1,1,1)	(0.74,0.79,0.88)	(0.49,0.55,0.64)	(0.58,0.69,0.84)	(0.88,1,1.14)
AC622	(1.36,1.44,1.52)	(1,1,1)	(1,1,1)	(0.88,1,1.14)	(0.88,1,1.14)	(0.88,1,1.14)	(1,1,1)	(0.88,1,1.14)
AC623	(0.88,1,1.14)	(1,1,1)	(1,1,1)	(1.14,1.26,1.36)	(0.88,1,1.14)	(1,1,1)	(0.88,1,1.14)	(0.88,1,1.14)
AC624	(1,1,1)	(0.88,1,1.14)	(0.74,0.79,0.88)	(1,1,1)	(0.77,1,1.31)	(0.77,1,1.31)	(0.77,1,1.31)	(0.64,0.79,1)
AC625	(1.14,1.26,1.36)	(0.88,1,1.14)	(0.88,1,1.14)	(0.77,1,1.31)	(1,1,1)	(1,1,1)	(0.88,1,1.14)	(0.58,0.69,0.84)
AC626	(1.55,1.82,2.06)	(0.88,1,1.14)	(1,1,1)	(0.77,1,1.31)	(1,1,1)	(1,1,1)	(1.14,1.26,1.36)	(0.77,1,1.31)
AC627	(1.19,1.44,1.74)	(1,1,1)	(0.88,1,1.14)	(0.77,1,1.31)	(0.88,1,1.14)	(0.74,0.79,0.88)	(1,1,1)	(1,1,1)
AC628	(0.88,1,1.14)	(0.88,1,1.14)	(0.88,1,1.14)	(1,1.26,1.55)	(1.19,1.44,1.74)	(0.77,1,1.31)	(1,1,1)	(1,1,1)

Table 25 Evaluation of the sub criteria of learning environment (AC63).

	AC631	AC632	AC633	AC634	AC635	AC636	AC637
AC631	(1,1,1)	(1,1,1)	(0.88,1,1.14)	(0.58,0.69,0.84)	(0.49,0.55,0.64)	(0.49,0.55,0.64)	(0.88,1,1.14)
AC632	(1,1,1)	(1,1,1)	(0.77,1,1.31)	(1,1,1)	(0.74,0.79,0.88)	(0.74,0.79,0.88)	(0.77,1,1.31)
AC633	(0.88,1,1.14)	(0.77,1,1.31)	(1,1,1)	(1,1,1)	(0.74,0.79,0.88)	(0.74,0.79,0.88)	(0.66,0.69,0.74)
AC634	(1.19,1.44,1.74)	(1,1,1)	(1,1,1)	(1,1,1)	(0.43,0.55,0.74)	(0.43,0.55,0.74)	(0.77,1,1.31)
AC635	(1.55,1.82,2.06)	(1.14,1.26,1.36)	(1.14,1.26,1.36)	(1.36,1.82,2.36)	(1,1,1)	(1,1,1)	(0.77,1,1.31)
AC636	(1.55,1.82,2.06)	(1.14,1.26,1.36)	(1.14,1.26,1.36)	(1.36,1.82,2.36)	(1,1,1)	(1,1,1)	(0.88,1,1.14)
AC637	(0.88,1,1.14)	(0.77,1,1.31)	(1.36,1.44,1.52)	(0.77,1,1.31)	(0.77,1,1.31)	(0.88,1,1.14)	(1,1,1)

Table 26 Evaluation of the sub criteria of Communication, collaboration & Professionalism (AC64).

	AC641	AC642	AC643	AC644	AC645	AC646	AC647	AC648	AC649	AC6410	AC6411
AC641	(1,1,1)	(1,1,1)	(0.88,1,1.14)	(0.88,1,1.14)	(0.88,1,1.14)	(1,1,1)	(1,1,1)	(1,1,1)	(0.88,1,1.14)	(0.88,1,1.14)	(0.88,1,1.14)
AC642	(1,1,1)	(1,1,1)	(0.77,1,1.31)	(0.88,1,1.14)	(0.88,1,1.14)	(0.77,1,1.31)	(0.88,1,1.14)	(0.66,0.69,0.74)	(0.66,0.69,0.74)	(0.66,0.69,0.74)	(0.58,0.69,0.84)
AC643	(0.88,1,1.14)	(0.77,1,1.31)	(1,1,1)	(0.77,1,1.31)	(1,1,1)	(1,1,1)	(0.77,1,1.31)	(0.58,0.69,0.84)	(0.58,0.69,0.84)	(0.58,0.69,0.84)	(0.66,0.69,0.74)
AC644	(0.88,1,1.14)	(0.88,1,1.14)	(0.77,1,1.31)	(1,1,1)	(0.88,1,1.14)	(0.88,1,1.14)	(0.88,1,1.14)	(0.88,1,1.14)	(0.88,1,1.14)	(0.88,1,1.14)	(1.14,1.26,1.36)
AC645	(0.88,1,1.14)	(0.88,1,1.14)	(1,1,1)	(0.88,1,1.14)	(1,1,1)	(0.66,0.69,0.74)	(0.58,0.69,0.84)	(0.66,0.69,0.74)	(0.58,0.69,0.84)	(0.58,0.69,0.84)	(0.58,0.69,0.84)
AC646	(1,1,1)	(0.77,1,1.31)	(1,1,1)	(0.88,1,1.14)	(1.36,1.44,1.52)	(1,1,1)	(0.77,1,1.31)	(0.77,1,1.31)	(0.88,1,1.14)	(0.88,1,1.14)	(0.88,1,1.14)
AC647	(1,1,1)	(0.88,1,1.14)	(0.77,1,1.31)	(0.88,1,1.14)	(1.19,1.44,1.74)	(0.77,1,1.31)	(1,1,1)	(0.58,0.69,0.84)	(0.58,0.69,0.84)	(0.66,0.69,0.74)	(0.76,0.87,1)
AC648	(1,1,1)	(1.36,1.44,1.52)	(1.19,1.44,1.74)	(0.88,1,1.14)	(1.36,1.44,1.52)	(0.77,1,1.31)	(1.19,1.44,1.74)	(1,1,1)	(1,1,1)	(1,1,1)	(1.14,1.26,1.36)
AC649	(0.88,1,1.14)	(1.36,1.44,1.52)	(1.19,1.44,1.74)	(0.88,1,1.14)	(1.19,1.44,1.74)	(0.88,1,1.14)	(1.19,1.44,1.74)	(1,1,1)	(1,1,1)	(0.88,1,1.14)	(1.36,1.44,1.52)
AC6410	(0.88,1,1.14)	(1.36,1.44,1.52)	(1.19,1.44,1.74)	(0.88,1,1.14)	(1.19,1.44,1.74)	(0.88,1,1.14)	(1.36,1.44,1.52)	(1,1,1)	(0.88,1,1.14)	(1,1,1)	(1.14,1.26,1.36)
AC6411	(0.88,1,1.14)	(1.19,1.44,1.74)	(1.36,1.44,1.52)	(0.74,0.79,0.88)	(1.19,1.44,1.74)	(0.88,1,1.14)	(1,1.14,1.33)	(0.74,0.79,0.88)	(0.66,0.69,0.74)	(0.74,0.79,0.88)	(1,1,1)

$V(S_{UC1} \geqslant S_{UC4})$: V ((0.089, 0.121, 0.164) $\geqslant$ (0.110, 0.146, 0.190)) = 0.683
$V(S_{UC1} \geqslant S_{UC5})$: V ((0.089, 0.121, 0.164) $\geqslant$ (0.082, 0.109, 0.145)) = 1.000
$V(S_{UC1} \geqslant S_{UC6})$: V ((0.089, 0.121, 0.164) $\geqslant$ (0.097, 0.131, 0.176)) = 0.868
$V(S_{UC1} \geqslant S_{UC7})$: V ((0.089, 0.121, 0.164) $\geqslant$ (0.072, 0.098, 0.134)) = 1.000
$V(S_{UC1} \geqslant S_{UC8})$: V ((0.089, 0.121, 0.164) $\geqslant$ (0.060, 0.080, 0.109)) = 1.000
$V(S_{UC1} \geqslant S_{UC9})$: V ((0.089, 0.121, 0.164) $\geqslant$ (0.072, 0.095, 0.127)) = 1.000

Membership function plots for the above are presented in Appendix C.

Similarly:

For UC2: Governance & Administration

$$V(S_{UC2} \geqslant S_{UC1}) := 0.798, V(S_{UC2} \geqslant S_{UC3}) = 0.886,$$
$$V(S_{UC2} \geqslant S_{UC4}) := 0.467,\ V(S_{UC2} \geqslant S_{UC5}) = 0.970,$$

$$V(S_{UC2} \geqslant S_{UC6}) := 0.661,\ V(S_{UC2} \geqslant S_{UC7}) = 1.000,$$
$$V(S_{UC2} \geqslant S_{UC8}) := 1.000,\ V(S_{UC2} \geqslant S_{UC9}) = 1.000.$$

For UC3: Infrastructure & Services

$$V(S_{UC3} \geqslant S_{UC1}) = 0.907,\ V(S_{UC3} \geqslant S_{UC2}) = 1.000,$$
$$V(S_{UC3} \geqslant S_{UC4}) = 0.569,\ V(S_{UC3} \geqslant S_{UC5}) = 1.000,$$

$$V(S_{UC3} \geqslant S_{UC6}) = 0.766,\ V(S_{UC3} \geqslant S_{UC7}) = 1.000,$$
$$V(S_{UC3} \geqslant S_{UC8}) = 1.000,\ V(S_{UC3} \geqslant S_{UC9}) = 1.000.$$

For UC4: Human Resources

$$V(S_{UC4} \geqslant S_{UC1}) = 1.000,\ V(S_{UC4} \geqslant S_{UC2}) = 1.000,$$
$$V(S_{UC4} \geqslant S_{UC3}) = 1.000,\ V(S_{UC4} \geqslant S_{UC5}) = 1.000,$$

$$V(S_{UC4} \geqslant S_{UC6}) = 1.000,\ V(S_{UC4} \geqslant S_{UC7}) = 1.000,$$
$$V(S_{UC4} \geqslant S_{UC8}) = 1.000,\ V(S_{UC4} \geqslant S_{UC9}) = 1.000.$$

For UC5: Students & Graduates

$$V(S_{UC5} \geqslant S_{UC1}) = 0.823,\ V(S_{UC5} \geqslant S_{UC2}) = 1.000,$$
$$V(S_{UC5} \geqslant S_{UC3}) = 0.913,\ V(S_{UC5} \geqslant S_{UC4}) = 0.485,$$

$$V(S_{UC5} \geqslant S_{UC6}) = 0.683,\ V(S_{UC5} \geqslant S_{UC7}) = 1.000,$$
$$V(S_{UC5} \geqslant S_{UC8}) = 1.000,\ V(S_{UC5} \geqslant S_{UC9}) = 1.000.$$

For UC6: Teaching and Learning Resources

$$V(S_{UC6} \geqslant S_{UC1}) = 1.000,\ V(S_{UC6} \geqslant S_{UC2}) = 1.000,$$
$$V(S_{UC6} \geqslant S_{UC3}) = 1.000,\ V(S_{UC6} \geqslant S_{UC4}) = 0.814,$$

$$V(S_{UC6} \geqslant S_{UC5}) = 1.000,\ V(S_{UC6} \geqslant S_{UC7}) = 1.000,$$
$$V(S_{UC6} \geqslant S_{UC8}) = 1.000,\ V(S_{UC6} \geqslant S_{UC9}) = 1.000.$$

For UC7: Scientific Research and Graduate Studies

$$V(S_{UC7} \geqslant S_{UC1}) = 0.664,\ V(S_{UC7} \geqslant S_{UC2}) = 0.861,$$
$$V(S_{UC7} \geqslant S_{UC3}) = 0.746,\ V(S_{UC7} \geqslant S_{UC4}) = 0.335,$$

$$V(S_{UC7} \geqslant S_{UC5}) = 0.829,\ V(S_{UC7} \geqslant S_{UC6}) = 0.528,$$
$$V(S_{UC7} \geqslant S_{UC8}) = 1.000,\ V(S_{UC7} \geqslant S_{UC9}) = 1.000.$$

Table 27 Contains the normalized & weighted decision matrix using the bottom criteria weight for universities.

	University/ Criteria	Weights	1 University of Gadarif	2 University of al-Jazirah	3 Sudan University of Sc. & Tech	4 Omdurman Islamic University	5 Blue Nile University	6 University of Dongola	7 Kordofan University	8 Al Fashir University	9 Red Sea University	10 University of Khartoum	11 University of Sc. and Tech.	12 Ahfad University for Women	13 University of Medical Sc. & Tech.	14 Omdurman Ahlia University	15 National Ribat University
1	UC11	0.0481	(0.0102, 0.0111, 0.0117)	(0.0102, 0.0111, 0.0117)	(0.0238, 0.0222, 0.021)	(0.0102, 0.0111, 0.0117)	(0.0102, 0.0111, 0.0117)	(0.0102, 0.0111, 0.0117)	(0.0102, 0.0111, 0.0117)	(0.0068, 0.0056, 0.0047)	(0.0102, 0.0111, 0.0117)	(0.0238, 0.0222, 0.021)	(0.0068, 0.0056, 0.0047)	(0.0102, 0.0111, 0.0117)	(0.0102, 0.0111, 0.0117)	(0.0068, 0.0056, 0.0047)	(0.0102, 0.0111, 0.0117)
2	UC12	0.019684	(0.0034, 0.0028, 0.0024)	(0.0051, 0.0057, 0.0061)	(0.0051, 0.0057, 0.0061)	(0.0051, 0.0057, 0.0061)	(0.0034, 0.0028, 0.0024)	(0.0034, 0.0028, 0.0024)	(0.0034, 0.0028, 0.0024)	(0.0034, 0.0028, 0.0024)	(0.0034, 0.0028, 0.0024)	(0.0119, 0.0114, 0.0109)	(0.0034, 0.0028, 0.0024)	(0.0051, 0.0057, 0.0061)	(0.0051, 0.0057, 0.0061)	(0.0034, 0.0028, 0.0024)	(0.0051, 0.0057, 0.0061)
3	UC13	0.006956	(0.0011, 0.001, 0.001)	(0.0011, 0.001, 0.001)	(0.004, 0.0041, 0.0043)	(0.0011, 0.001, 0.001)	(0.0011, 0.001, 0.001)	(0.0011, 0.001, 0.001)	(0.0011, 0.001, 0.001)	(0.0011, 0.001, 0.001)	(0.0011, 0.001, 0.001)	(0.004, 0.0041, 0.0043)	(0.0011, 0.001, 0.001)	(0.0011, 0.001, 0.001)	(0.0011, 0.001, 0.001)	(0.0011, 0.001, 0.001)	(0.0011, 0.001, 0.001)
4	UC14	0.0222	(0.0036, 0.0033, 0.003)	(0.0036, 0.0033, 0.003)	(0.0127, 0.0132, 0.0137)	(0.0036, 0.0033, 0.003)	(0.0036, 0.0033, 0.003)	(0.0036, 0.0033, 0.003)	(0.0036, 0.0033, 0.003)	(0.0036, 0.0033, 0.003)	(0.0036, 0.0033, 0.003)	(0.0127, 0.0132, 0.0137)	(0.0036, 0.0033, 0.003)	(0.0036, 0.0033, 0.003)	(0.0036, 0.0033, 0.003)	(0.0036, 0.0033, 0.003)	(0.0036, 0.0033, 0.003)
5	UC15	0.05106	(0.0157, 0.017, 0.0177)	(0.0157, 0.017, 0.0177)	(0.0157, 0.017, 0.0177)	(0.0157, 0.017, 0.0177)	(0.0105, 0.0085, 0.0071)	(0.0105, 0.0085, 0.0071)	(0.0105, 0.0085, 0.0071)	(0.0105, 0.0085, 0.0071)	(0.0105, 0.0085, 0.0071)	(0.0157, 0.017, 0.0177)	(0.0105, 0.0085, 0.0071)	(0.0157, 0.017, 0.0177)	(0.0157, 0.017, 0.0177)	(0.0105, 0.0085, 0.0071)	(0.0105, 0.0085, 0.0071)
6	UC21	0.0206304	(0.0042, 0.0045, 0.0047)	(0.0042, 0.0045, 0.0047)	(0.0098, 0.009, 0.0084)	(0.0042, 0.0045, 0.0047)	(0.0042, 0.0045, 0.0047)	(0.0042, 0.0045, 0.0047)	(0.0042, 0.0045, 0.0047)	(0.0042, 0.0045, 0.0047)	(0.0042, 0.0045, 0.0047)	(0.0098, 0.009, 0.0084)	(0.0042, 0.0045, 0.0047)	(0.0042, 0.0045, 0.0047)	(0.0042, 0.0045, 0.0047)	(0.0042, 0.0045, 0.0047)	(0.0042, 0.0045, 0.0047)
7	UC22	0.0099975	(0.0024, 0.0022, 0.002)	(0.0024, 0.0022, 0.002)	(0.0036, 0.0044, 0.0049)	(0.0024, 0.0022, 0.002)	(0.0024, 0.0022, 0.002)	(0.0024, 0.0022, 0.002)	(0.0024, 0.0022, 0.002)	(0.0024, 0.0022, 0.002)	(0.0024, 0.0022, 0.002)	(0.0036, 0.0044, 0.0049)	(0.0024, 0.0022, 0.002)	(0.0024, 0.0022, 0.002)	(0.0024, 0.0022, 0.002)	(0.0024, 0.0022, 0.002)	(0.0024, 0.0022, 0.002)
8	UC23	0.0160653	(0.0033, 0.0035, 0.0036)	(0.0033, 0.0035, 0.0036)	(0.0077, 0.007, 0.0066)	(0.0033, 0.0035, 0.0036)	(0.0033, 0.0035, 0.0036)	(0.0033, 0.0035, 0.0036)	(0.0033, 0.0035, 0.0036)	(0.0033, 0.0035, 0.0036)	(0.0033, 0.0035, 0.0036)	(0.0077, 0.007, 0.0066)	(0.0033, 0.0035, 0.0036)	(0.0033, 0.0035, 0.0036)	(0.0033, 0.0035, 0.0036)	(0.0033, 0.0035, 0.0036)	(0.0033, 0.0035, 0.0036)
9	UC24	0.0134319	(0.0029, 0.0025, 0.0021)	(0.0044, 0.0049, 0.0052)	(0.0044, 0.0049, 0.0052)	(0.0029, 0.0025, 0.0021)	(0.0029, 0.0025, 0.0021)	(0.0029, 0.0025, 0.0021)	(0.0029, 0.0025, 0.0021)	(0.0029, 0.0025, 0.0021)	(0.0029, 0.0025, 0.0021)	(0.0044, 0.0049, 0.0052)	(0.0029, 0.0025, 0.0021)	(0.0044, 0.0049, 0.0052)	(0.0044, 0.0049, 0.0052)	(0.0029, 0.0025, 0.0021)	(0.0029, 0.0025, 0.0021)
10	UC25	0.0224036	(0.005, 0.0056, 0.0061)	(0.005, 0.0056, 0.0061)	(0.0117, 0.0113, 0.0109)	(0.0033, 0.0028, 0.0024)	(0.0033, 0.0028, 0.0024)	(0.0033, 0.0028, 0.0024)	(0.0033, 0.0028, 0.0024)	(0.0033, 0.0028, 0.0024)	(0.005, 0.0056, 0.0061)	(0.0117, 0.0113, 0.0109)	(0.0033, 0.0028, 0.0024)	(0.005, 0.0056, 0.0061)	(0.005, 0.0056, 0.0061)	(0.0033, 0.0028, 0.0024)	(0.005, 0.0056, 0.0061)
11	UC26	0.0033828	(0.0007, 0.0006, 0.0005)	(0.0011, 0.0012, 0.0013)	(0.0011, 0.0012, 0.0013)	(0.0007, 0.0006, 0.0005)	(0.0007, 0.0006, 0.0005)	(0.0007, 0.0006, 0.0005)	(0.0007, 0.0006, 0.0005)	(0.0007, 0.0006, 0.0005)	(0.0007, 0.0006, 0.0005)	(0.0011, 0.0012, 0.0013)	(0.0007, 0.0006, 0.0005)	(0.0011, 0.0012, 0.0013)	(0.0011, 0.0012, 0.0013)	(0.0007, 0.0006, 0.0005)	(0.0007, 0.0006, 0.0005)
12	UC27	0.0160885	(0.0022, 0.0023, 0.0024)	(0.0022, 0.0023, 0.0024)	(0.0056, 0.0045, 0.0036)	(0.0022, 0.0023, 0.0024)	(0.0022, 0.0023, 0.0024)	(0.0022, 0.0023, 0.0024)	(0.0022, 0.0023, 0.0024)	(0.0022, 0.0023, 0.0024)	(0.0022, 0.0023, 0.0024)	(0.0084, 0.009, 0.0091)	(0.0022, 0.0023, 0.0024)	(0.0022, 0.0023, 0.0024)	(0.0084, 0.009, 0.0091)	(0.0022, 0.0023, 0.0024)	(0.0056, 0.0045, 0.0036)
13	UC31	0.036208	(0.0097, 0.0099, 0.0099)	(0.0097, 0.0099, 0.0099)	(0.0097, 0.0099, 0.0099)	(0.0097, 0.0099, 0.0099)	(0.0097, 0.0099, 0.0099)	(0.0097, 0.0099, 0.0099)	(0.0097, 0.0099, 0.0099)	(0.0097, 0.0099, 0.0099)	(0.0097, 0.0099, 0.0099)	(0.0097, 0.0099, 0.0099)	(0.0065, 0.0049, 0.004)	(0.0065, 0.0049, 0.004)	(0.0097, 0.0099, 0.0099)	(0.0097, 0.0099, 0.0099)	(0.0097, 0.0099, 0.0099)
14	UC32	0.028644	(0.0057, 0.0046,	(0.0086, 0.0092,	(0.0086, 0.0092,	(0.0086, 0.0092,	(0.0057, 0.0046,	(0.0057, 0.0046,	(0.0057, 0.0046,	(0.0057, 0.0046,	(0.0057, 0.0046,	(0.0086, 0.0092,	(0.0086, 0.0092,	(0.0086, 0.0092,	(0.0086, 0.0092, 0.0095)	(0.0057, 0.0046,	(0.0086, 0.0092,

(*continued on next page*)

Table 27 (*continued*)

University/ Criteria	Weights	1 University of Gadarif	2 University of al-Jazirah	3 Sudan University of Sc. & Tech	4 Omdurman Islamic University	5 Blue Nile University	6 University of Dongola	7 Kordofan University	8 Al Fashir University	9 Red Sea University	10 University of Khartoum	11 University of Sc. and Tech.	12 Ahfad University for Women	13 University of Medical Sc. & Tech.	14 Omdurman Ahlia University	15 National Ribat University
		0.0038)	0.0095)	0.0095)	0.0095)	0.0038)	0.0038)	0.0038)	0.0038)	0.0038)	0.0095)	0.0095)	0.0095)		0.0038)	0.0095)
15 UC33	0.026164	(0.0052, 0.0042, 0.0035)	(0.0078, 0.0084, 0.0087)	(0.0078, 0.0084, 0.0087)	(0.0078, 0.0084, 0.0087)	(0.0052, 0.0042, 0.0035)	(0.0052, 0.0042, 0.0035)	(0.0052, 0.0042, 0.0035)	(0.0052, 0.0042, 0.0035)	(0.0052, 0.0042, 0.0035)	(0.0078, 0.0084, 0.0087)	(0.0078, 0.0084, 0.0087)	(0.0078, 0.0084, 0.0087)	(0.0078, 0.0084, 0.0087)	(0.0052, 0.0042, 0.0035)	(0.0078, 0.0084, 0.0087)
16 UC34	0.032984	(0.007, 0.0057, 0.0048)	(0.0104, 0.0115, 0.0121)	(0.0104, 0.0115, 0.0121)	(0.007, 0.0057, 0.0048)	(0.007, 0.0057, 0.0048)	(0.007, 0.0057, 0.0048)	(0.007, 0.0057, 0.0048)	(0.007, 0.0057, 0.0048)	(0.007, 0.0057, 0.0048)	(0.0104, 0.0115, 0.0121)	(0.0104, 0.0115, 0.0121)	(0.007, 0.0057, 0.0048)	(0.0104, 0.0115, 0.0121)	(0.007, 0.0057, 0.0048)	(0.0104, 0.0115, 0.0121)
17 UC41	0.039494	(0.0074, 0.0081, 0.0085)	(0.0074, 0.0081, 0.0085)	(0.0173, 0.0161, 0.0153)	(0.0074, 0.0081, 0.0085)	(0.0074, 0.0081, 0.0085)	(0.0074, 0.0081, 0.0085)	(0.0074, 0.0081, 0.0085)	(0.0074, 0.0081, 0.0085)	(0.0074, 0.0081, 0.0085)	(0.0173, 0.0161, 0.0153)	(0.0074, 0.0081, 0.0085)	(0.0074, 0.0081, 0.0085)	(0.0173, 0.0161, 0.0153)	(0.0074, 0.0081, 0.0085)	(0.0074, 0.0081, 0.0085)
18 UC42	0.159929	(0.0267, 0.0308, 0.0358)	(0.0666, 0.0616, 0.0535)	(0.0666, 0.0616, 0.0535)	(0.0267, 0.0308, 0.0358)	(0.0267, 0.0308, 0.0358)	(0.0267, 0.0308, 0.0358)	(0.0267, 0.0308, 0.0358)	(0.0267, 0.0308, 0.0358)	(0.0267, 0.0308, 0.0358)	(0.0666, 0.0616, 0.0535)	(0.0267, 0.0308, 0.0358)	(0.0267, 0.0308, 0.0358)	(0.0666, 0.0616, 0.0535)	(0.0267, 0.0308, 0.0358)	(0.0267, 0.0308, 0.0358)
19 UC43	0.017577	(0.0039, 0.0034, 0.0029)	(0.0059, 0.0068, 0.0073)	(0.0059, 0.0068, 0.0073)	(0.0039, 0.0034, 0.0029)	(0.0039, 0.0034, 0.0029)	(0.0039, 0.0034, 0.0029)	(0.0039, 0.0034, 0.0029)	(0.0039, 0.0034, 0.0029)	(0.0039, 0.0034, 0.0029)	(0.0059, 0.0068, 0.0073)	(0.0039, 0.0034, 0.0029)	(0.0039, 0.0034, 0.0029)	(0.0059, 0.0068, 0.0073)	(0.0039, 0.0034, 0.0029)	(0.0039, 0.0034, 0.0029)
20 UC51	0.08862	(0.0233, 0.0235, 0.0236)	(0.0233, 0.0235, 0.0236)	(0.0233, 0.0235, 0.0236)	(0.0233, 0.0235, 0.0236)	(0.0233, 0.0235, 0.0236)	(0.0233, 0.0235, 0.0236)	(0.0233, 0.0235, 0.0236)	(0.0233, 0.0235, 0.0236)	(0.0233, 0.0235, 0.0236)	(0.0233, 0.0235, 0.0236)	(0.0233, 0.0235, 0.0236)	(0.0233, 0.0235, 0.0236)	(0.0233, 0.0235, 0.0236)	(0.0155, 0.0117, 0.0094)	(0.0233, 0.0235, 0.0236)
21 UC52	0.01638	(0.0043, 0.0043, 0.0044)	(0.0043, 0.0043, 0.0044)	(0.0043, 0.0043, 0.0044)	(0.0043, 0.0043, 0.0044)	(0.0043, 0.0043, 0.0044)	(0.0043, 0.0043, 0.0044)	(0.0043, 0.0043, 0.0044)	(0.0043, 0.0043, 0.0044)	(0.0043, 0.0043, 0.0044)	(0.0043, 0.0043, 0.0044)	(0.0043, 0.0043, 0.0044)	(0.0043, 0.0043, 0.0044)	(0.0043, 0.0043, 0.0044)	(0.0029, 0.0022, 0.0017)	(0.0043, 0.0043, 0.0044)
22 UC53	0	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)
23 UC61	0.023718	(0.0053, 0.0046, 0.004)	(0.008, 0.0091, 0.0099)	(0.008, 0.0091, 0.0099)	(0.0053, 0.0046, 0.004)	(0.0053, 0.0046, 0.004)	(0.0053, 0.0046, 0.004)	(0.0053, 0.0046, 0.004)	(0.0053, 0.0046, 0.004)	(0.0053, 0.0046, 0.004)	(0.008, 0.0091, 0.0099)	(0.0053, 0.0046, 0.004)	(0.0053, 0.0046, 0.004)	(0.008, 0.0091, 0.0099)	(0.0053, 0.0046, 0.004)	(0.0053, 0.0046, 0.004)
24 UC62	0.023895	(0.005, 0.0042, 0.0035)	(0.0076, 0.0083, 0.0088)	(0.0076, 0.0083, 0.0088)	(0.0076, 0.0083, 0.0088)	(0.005, 0.0042, 0.0035)	(0.005, 0.0042, 0.0035)	(0.005, 0.0042, 0.0035)	(0.005, 0.0042, 0.0035)	(0.005, 0.0042, 0.0035)	(0.0076, 0.0083, 0.0088)	(0.0076, 0.0083, 0.0088)	(0.005, 0.0042, 0.0035)	(0.0076, 0.0083, 0.0088)	(0.005, 0.0042, 0.0035)	(0.005, 0.0042, 0.0035)
25 UC63	0.020532	(0.0034, 0.004, 0.0046)	(0.0086, 0.0079, 0.0069)	(0.0086, 0.0079, 0.0069)	(0.0034, 0.004, 0.0046)	(0.0034, 0.004, 0.0046)	(0.0034, 0.004, 0.0046)	(0.0034, 0.004, 0.0046)	(0.0034, 0.004, 0.0046)	(0.0034, 0.004, 0.0046)	(0.0086, 0.0079, 0.0069)	(0.0034, 0.004, 0.0046)	(0.0034, 0.004, 0.0046)	(0.0086, 0.0079, 0.0069)	(0.0034, 0.004, 0.0046)	(0.0034, 0.004, 0.0046)
26 UC64	0.025311	(0.0067, 0.0067, 0.0067)	(0.0067, 0.0067, 0.0067)	(0.0067, 0.0067, 0.0067)	(0.0067, 0.0067, 0.0067)	(0.0067, 0.0067, 0.0067)	(0.0067, 0.0067, 0.0067)	(0.0067, 0.0067, 0.0067)	(0.0067, 0.0067, 0.0067)	(0.0067, 0.0067, 0.0067)	(0.0067, 0.0067, 0.0067)	(0.0067, 0.0067, 0.0067)	(0.0067, 0.0067, 0.0067)	(0.0067, 0.0067, 0.0067)	(0.0044, 0.0034, 0.0027)	(0.0067, 0.0067, 0.0067)
27 UC65	0.012213	(0.0035, 0.0036, 0.0037)	(0.0035, 0.0036, 0.0037)	(0.0035, 0.0036, 0.0037)	(0.0035, 0.0036, 0.0037)	(0.0023, 0.0018, 0.0015)	(0.0023, 0.0018, 0.0015)	(0.0035, 0.0036, 0.0037)	(0.0023, 0.0018, 0.0015)	(0.0023, 0.0018, 0.0015)	(0.0035, 0.0036, 0.0037)	(0.0035, 0.0036, 0.0037)	(0.0035, 0.0036, 0.0037)	(0.0035, 0.0036, 0.0037)	(0.0023, 0.0018, 0.0015)	(0.0035, 0.0036, 0.0037)
28 UC66	0.02124	(0.0035, 0.0041,	(0.0088, 0.0082,	(0.0088, 0.0082,	(0.0035, 0.0041,	(0.0035, 0.0041,	(0.0035, 0.0041,	(0.0035, 0.0041,	(0.0035, 0.0041,	(0.0035, 0.0041,	(0.0088, 0.0082,	(0.0035, 0.0041,	(0.0035, 0.0041,	(0.0088, 0.0082, 0.0071)	(0.0035, 0.0041,	(0.0035, 0.0041,

		0.0048)	0.0071)	0.0071)	0.0048)	0.0048)	0.0048)	0.0048)	0.0048)	0.0048)	0.0071)	0.0048)	0.0048)		0.0048)	0.0048)
29 UC67	0.02478	(0.0063,	(0.0063,	(0.0095,	(0.0063,	(0.0025,	(0.0025,	(0.0025,	(0.0025,	(0.0063,	(0.0095,	(0.0063,	(0.0063,	(0.0095, 0.0108,	(0.0063,	(0.0063,
		0.0054,	0.0054,	0.0108,	0.0054,	0.0027,	0.0027,	0.0027,	0.0027,	0.0054,	0.0108,	0.0054,	0.0054,	0.0116)	0.0054,	0.0054,
		0.0046)	0.0046)	0.0116)	0.0046)	0.0031)	0.0031)	0.0031)	0.0031)	0.0046)	0.0116)	0.0046)	0.0046)		0.0046)	0.0046)
30 UC68	0.013983	(0.0017,	(0.0043,	(0.0065,	(0.0017,	(0.0017,	(0.0017,	(0.0017,	(0.0017,	(0.0017,	(0.0065,	(0.0043,	(0.0017,	(0.0065, 0.0069,	(0.0017,	(0.0017,
		0.0017,	0.0034,	0.0069, 0.007)	0.0017,	0.0017,	0.0017,	0.0017,	0.0017,	0.0017,	0.0069,	0.0034,	0.0017,	0.007)	0.0017,	0.0017,
		0.0019)	0.0028)		0.0019)	0.0019)	0.0019)	0.0019)	0.0019)	0.0019)	0.007)	0.0028)	0.0019)		0.0019)	0.0019)
31 UC69	0.011328	(0.0025,	(0.0038,	(0.0038,	(0.0025,	(0.0025,	(0.0025,	(0.0025,	(0.0025,	(0.0025,	(0.0038,	(0.0025,	(0.0025,	(0.0038, 0.0044,	(0.0025,	(0.0025,
		0.0022,	0.0044,	0.0044,	0.0022,	0.0022,	0.0022,	0.0022,	0.0022,	0.0022,	0.0044,	0.0022,	0.0022,	0.0047)	0.0022,	0.0022,
		0.0019)	0.0047)	0.0047)	0.0019)	0.0019)	0.0019)	0.0019)	0.0019)	0.0019)	0.0047)	0.0019)	0.0019)		0.0019)	0.0019)
32 UC71	0.007665	(0.0017,	(0.0026,	(0.0026, 0.003,	(0.0017,	(0.0017,	(0.0017,	(0.0017,	(0.0017,	(0.0017,	(0.0026,	(0.0017,	(0.0017,	(0.0026, 0.003,	(0.0017,	(0.0017,
		0.0015,	0.003,	0.0032)	0.0015,	0.0015,	0.0015,	0.0015,	0.0015,	0.0015,	0.003,	0.0015,	0.0015,	0.0032)	0.0015,	0.0015,
		0.0013)	0.0032)		0.0013)	0.0013)	0.0013)	0.0013)	0.0013)	0.0013)	0.0032)	0.0013)	0.0013)		0.0013)	0.0013)
33 UC72	0.016352	(0.0029,	(0.0072,	(0.0072,	(0.0029,	(0.0016,	(0.0016,	(0.0016,	(0.0016,	(0.0029,	(0.0072,	(0.0029,	(0.0029,	(0.0072, 0.0068,	(0.0016,	(0.0029,
		0.0034,	0.0068,	0.0068,	0.0034,	0.0017,	0.0017,	0.0017,	0.0017,	0.0034,	0.0068,	0.0034,	0.0034,	0.0061)	0.0017,	0.0034,
		0.0041)	0.0061)	0.0061)	0.0041)	0.0018)	0.0018)	0.0018)	0.0018)	0.0041)	0.0061)	0.0041)	0.0041)		0.0018)	0.0041)
34 UC73	0.015987	(0.0027,	(0.0067,	(0.0067,	(0.0027,	(0.0027,	(0.0027,	(0.0027,	(0.0027,	(0.0027,	(0.0067,	(0.0027,	(0.0027,	(0.0067, 0.0062,	(0.0027,	(0.0027,
		0.0031,	0.0062,	0.0062,	0.0031,	0.0031,	0.0031,	0.0031,	0.0031,	0.0031,	0.0062,	0.0031,	0.0031,	0.0053)	0.0031,	0.0031,
		0.0036)	0.0053)	0.0053)	0.0036)	0.0036)	0.0036)	0.0036)	0.0036)	0.0036)	0.0053)	0.0036)	0.0036)		0.0036)	0.0036)
35 UC74	0.006716	(0.0015,	(0.0023,	(0.0023,	(0.0015,	(0.0015,	(0.0015,	(0.0015,	(0.0015,	(0.0015,	(0.0023,	(0.0015,	(0.0015,	(0.0023, 0.0026,	(0.0006,	(0.0015,
		0.0013,	0.0026,	0.0026,	0.0013,	0.0013,	0.0013,	0.0013,	0.0013,	0.0013,	0.0026,	0.0013,	0.0013,	0.0028)	0.0007,	0.0013,
		0.0011)	0.0028)	0.0028)	0.0011)	0.0011)	0.0011)	0.0011)	0.0011)	0.0011)	0.0028)	0.0011)	0.0011)		0.0008)	0.0011)
36 UC75	0.011753	(0.0027,	(0.0041,	(0.0041,	(0.0011,	(0.0027,	(0.0027,	(0.0027,	(0.0027,	(0.0027,	(0.0041,	(0.0027,	(0.0027,	(0.0041, 0.0047,	(0.0011,	(0.0027,
		0.0023,	0.0047,	0.0047, 0.005)	0.0012,	0.0023,	0.0023,	0.0023,	0.0023,	0.0023,	0.0047,	0.0023,	0.0023,	0.005)	0.0012,	0.0023,
		0.002)	0.005)		0.0013)	0.002)	0.002)	0.002)	0.002)	0.002)	0.005)	0.002)	0.002)		0.0013)	0.002)
37 UC76	0.0146	(0.0038,	(0.0057,	(0.0038,	(0.0038,	(0.0015,	(0.0015,	(0.0015,	(0.0015,	(0.0038,	(0.0057,	(0.0038,	(0.0038,	(0.0057, 0.0065,	(0.0015,	(0.0038,
		0.0032,	0.0065,	0.0032,	0.0032,	0.0016,	0.0016,	0.0016,	0.0016,	0.0032,	0.0065,	0.0032,	0.0032,	0.0069)	0.0016,	0.0032,
		0.0028)	0.0069)	0.0028)	0.0028)	0.0018)	0.0018)	0.0018)	0.0018)	0.0028)	0.0069)	0.0028)	0.0028)		0.0018)	0.0028)
38 UC81	0	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)
39 UC82	0	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)
40 UC91	0.025002	(0.0038,	(0.0095,	(0.0095,	(0.0038,	(0.0038,	(0.0038,	(0.0038,	(0.0038,	(0.0038,	(0.0095,	(0.0038,	(0.0038,	(0.0143, 0.0162,	(0.0021,	(0.0038,
		0.004,	0.0081,	0.0081,	0.004, 0.0045)	0.004,	0.004,	0.004,	0.004,	0.004,	0.0081,	0.004,	0.004,	0.0168)	0.002, 0.002)	0.004,
		0.0045)	0.0067)	0.0067)		0.0045)	0.0045)	0.0045)	0.0045)	0.0045)	0.0067)	0.0045)	0.0045)			0.0045)
41 UC92	0.028998	(0.0042,	(0.0104,	(0.0104, 0.009,	(0.0042,	(0.0042,	(0.0042,	(0.0042,	(0.0042,	(0.0042,	(0.0104,	(0.0042,	(0.0042,	(0.0156, 0.0181,	(0.0023,	(0.0104,
		0.0045,	0.009,	0.0076)	0.0045,	0.0045,	0.0045,	0.0045,	0.0045,	0.0045,	0.009,	0.0045,	0.0045,	0.0191)	0.0023,	0.009,
		0.0051)	0.0076)		0.0051)	0.0051)	0.0051)	0.0051)	0.0051)	0.0051)	0.0076)	0.0051)	0.0051)		0.0022)	0.0076)

Table 28 It contains the positive & negative ideal solutions from the weighted decision matrix for each bottom criterion.

Criteria	Negative Ideal Solution	Positive Ideal Solution	Criteria	Negative Ideal Solution	Positive Ideal Solution
UC11	(0.0068, 0.0056, 0.0047)	(0.0238, 0.0222, 0.021)	UC53	(0, 0, 0)	(0, 0, 0)
UC12	(0.0034, 0.0028, 0.0024)	(0.0119, 0.0114, 0.0109)	UC61	(0.0053, 0.0046, 0.004)	(0.008, 0.0091, 0.0099)
UC13	(0.0011, 0.001, 0.001)	(0.004, 0.0041, 0.0043)	UC62	(0.005, 0.0042, 0.0035)	(0.0076, 0.0083, 0.0088)
UC14	(0.0036, 0.0033, 0.003)	(0.0127, 0.0132, 0.0137)	UC63	(0.0034, 0.004, 0.0046)	(0.0086, 0.0079, 0.0069)
UC15	(0.0105, 0.0085, 0.0071)	(0.0157, 0.017, 0.0177)	UC64	(0.0044, 0.0034, 0.0027)	(0.0067, 0.0067, 0.0067)
UC21	(0.0042, 0.0045, 0.0047)	(0.0098, 0.009, 0.0084)	UC65	(0.0023, 0.0018, 0.0015)	(0.0035, 0.0036, 0.0037)
UC22	(0.0024, 0.0022, 0.002)	(0.0036, 0.0044, 0.0049)	UC66	(0.0035, 0.0041, 0.0048)	(0.0088, 0.0082, 0.0071)
UC23	(0.0033, 0.0035, 0.0036)	(0.0077, 0.007, 0.0066)	UC67	(0.0025, 0.0027, 0.0031)	(0.0095, 0.0108, 0.0116)
UC24	(0.0029, 0.0025, 0.0021)	(0.0044, 0.0049, 0.0052)	UC68	(0.0017, 0.0017, 0.0019)	(0.0065, 0.0069, 0.007)
UC25	(0.0033, 0.0028, 0.0024)	(0.0117, 0.0113, 0.0109)	UC69	(0.0025, 0.0022, 0.0019)	(0.0038, 0.0044, 0.0047)
UC26	(0.0007, 0.0006, 0.0005)	(0.0011, 0.0012, 0.0013)	UC71	(0.0017, 0.0015, 0.0013)	(0.0026, 0.003, 0.0032)
UC27	(0.0022, 0.0023, 0.0024)	(0.0084, 0.009, 0.0091)	UC72	(0.0016, 0.0017, 0.0018)	(0.0072, 0.0068, 0.0061)
UC31	(0.0065, 0.0049, 0.004)	(0.0097, 0.0099, 0.0099)	UC73	(0.0027, 0.0031, 0.0036)	(0.0067, 0.0062, 0.0053)
UC32	(0.0057, 0.0046, 0.0038)	(0.0086, 0.0092, 0.0095)	UC74	(0.0006, 0.0007, 0.0008)	(0.0023, 0.0026, 0.0028)
UC33	(0.0052, 0.0042, 0.0035)	(0.0078, 0.0084, 0.0087)	UC75	(0.0011, 0.0012, 0.0013)	(0.0041, 0.0047, 0.005)
UC34	(0.007, 0.0057, 0.0048)	(0.0104, 0.0115, 0.0121)	UC76	(0.0015, 0.0016, 0.0018)	(0.0057, 0.0065, 0.0069)
UC41	(0.0074, 0.0081, 0.0085)	(0.0173, 0.0161, 0.0153)	UC81	(0, 0, 0)	(0, 0, 0)
UC42	(0.0267, 0.0308, 0.0358)	(0.0666, 0.0616, 0.0535)	UC82	(0, 0, 0)	(0, 0, 0)
UC43	(0.0039, 0.0034, 0.0029)	(0.0059, 0.0068, 0.0073)	UC91	(0.0021, 0.002, 0.002)	(0.0143, 0.0162, 0.0168)
UC51	(0.0155, 0.0117, 0.0094)	(0.0233, 0.0235, 0.0236)	UC92	(0.0023, 0.0023, 0.0022)	(0.0156, 0.0181, 0.0191)
UC52	(0.0029, 0.0022, 0.0017)	(0.0043, 0.0043, 0.0044)			

Table 29 Shows the distance of each alternative from Ideal negative & positive Ideal Solutions (separation measures).

SR	Alternatives (Universities)	Distance from negative ideal solution	Distance from positive ideal solution
1	University of Gadarif	0.01762	0.09248
2	University of al-Jazirah	0.03975	0.08474
3	Sudan University of Sc. & Tech	0.06787	0.06788
4	Omdurman Islamic University	0.01908	0.09221
5	Blue Nile University	0.01463	0.09340
6	University of Dongola	0.01463	0.09340
7	Kordofan University	0.01474	0.09338
8	Al Fashir University	0.01355	0.09417
9	Red Sea University	0.01537	0.09288
10	University of Khartoum	0.09395	0.01197
11	University of Sc. and Tech.	0.01639	0.09343
12	Ahfad University for Women	0.01842	0.09216
13	University of Medical Sc. & Tech.	0.09299	0.01863
14	Omdurman Ahlia University	0.00560	0.09546
15	National Ribat University	0.05293	0.07915

Table 30 Shows the final ranking result for 15 Sudanese universities (alternatives: 10 public & 5 private). The ranking result presented for public universities, private universities and all universities.

SR.	Alternatives	Relative Closeness to ideal Solution	Group Ranking		General Ranking
1	University of Gadarif	0.16007	Public	5	8
2	University of al-Jazirah	0.31930		3	5
3	Sudan University of Sc. & Tech	0.49996		2	3
4	Omdurman Islamic University	0.17142		4	6
5	Blue Nile University	0.13544		8	12
6	University of Dongola	0.13544		9	13
7	Kordofan University	0.13633		7	11
8	Al Fashir University	0.12577		10	14
9	Red Sea University	0.14201		6	10
10	University of Khartoum	0.88696		1	1
11	University of Sc. and Tech.	0.14921	Private	4	9
12	Ahfad University for Women	0.16659		3	7
13	University of Medical Sc. & Tech.	0.83311		1	2
14	Omdurman Ahlia University	0.05545		5	15
15	National Ribat University	0.40074		2	4

For UC8: Community Service

$V(S_{UC8} \geqslant S_{UC1}) = 0.325,\ V(S_{UC8} \geqslant S_{UC2}) = 0.526,$
$V(S_{UC8} \geqslant S_{UC3}) = 0.401,\ V(S_{UC8} \geqslant S_{UC4}) = 0.000,$

$V(S_{UC8} \geqslant S_{UC5}) = 0.484,\ V(S_{UC8} \geqslant S_{UC6}) = 0.182,$
$V(S_{UC8} \geqslant S_{UC7}) = 0.674,\ V(S_{UC8} \geqslant S_{UC9}) = 0.714.$

For UC9: Quality Management

$V(S_{UC9} \geqslant S_{UC1}) = 0.593,\ V(S_{UC9} \geqslant S_{UC2}) = 0.800,$
$V(S_{UC9} \geqslant S_{UC3}) = 0.678,\ V(S_{UC9} \geqslant S_{UC4}) = 0.246,$

$V(S_{UC9} \geqslant S_{UC5}) = 0.765,\ V(S_{UC9} \geqslant S_{UC6}) = 0.449,$
$V(S_{UC9} \geqslant S_{UC7}) = 0.949,\ V(S_{UC9} \geqslant S_{UC8}) = 1.000$

.

From these calculations; the weight (W) is approximated by minimizing and normalizing V. (i.e. $minV[(M \geqslant M_i)\ where i = 1, \ldots, k]$

Therefore, the weight W is obtained as follows:

Minimizing W_{UC} = (0.683, 0.467, 0.569, 1.000, 0.485, 0.814, 0.335, 0.000, 0.246)

Normalizing W_{UC} = (0.148, 0.102, 0.124, 0.217, 0.105, 0.177, 0.073, 0.000, 0.054)

It means that the weight of the main performance evaluation criteria for Sudanese universities (i.e. UC1: Institutional frame work, UC2: Governance & Administration, UC3: Infrastructure & Services, UC4: Human Resources, UC5: Students & Graduates, UC6: Teaching and Learning Resources, UC7: Scientific Research and Graduate Studies, UC8: Community Service and UC8: Quality Management) are equal to (0.148, 0.102, 0.124, 0.217, 0.105, 0.177, 0.073, 0.000, 0.054), respectively.

Table 31 Comparison Result (2014/2015 vs 2015/2016 vs Proposed Model).

1. Medicine	% Rate (2014/2015) (2015/2016)	Rank (2014/2015) (2015/2016)
University of Khartoum	92.9 92.4	1 1
University of al-Jazirah	92.4 92.0	2 2
Omdurman Islamic Univ.	90.4 90.3	3 3
University of Gadarif	89.7 89.7	4 4
Kordofan University	89.4 89.3	5 6
Red Sea University	89.4 89.4	5 5
University of Dongola	89.0 89.1	7 7
Blue Nile University	87.6 88.6	8 8
Al Fashir University	87.4 88.3	9 9

2. Education	% Rate (2014/2015) (2015/2016)	Rank (2014/2015) (2015/2016)
University of Khartoum	82.4 82.7	1 1
Sudan Univ. of Sc. Tech.	81.6 81.0	2 2
University of al-Jazirah	78.3 76.4	3 3
University of Gadarif	71.4 71.4	4 4
Omdurman Islamic Univ.	70.4 71.4	5 4
Kordofan University	70.3 70.6	6 6
Al Fashir University	70.1 70.0	7 7
University of Dongola	69.4 68.1	8 9
Blue Nile University	67.9 67.3	9 10
Red Sea University	68.3	8

3. Computer Sc.	% Rate (2014/2015) (2015/2016)	Rank (2014/2015) (2015/2016)
University of Khartoum	86.3 86.4	1 1
Sudan Univ. of Sc. Tech.	85.0 85.0	2 2
University of al-Jazirah	79.7 80.3	3 3
Omdurman Islamic Univ.	76.0 76.3	4 4
University of Gadarif	73.4 73.7	5 6
Red Sea University	72.4 75.4	6 5
Kordofan University	71.1 71.7	7 7
University of Dongola	65.0 64.0	8 8

4. Economics	% Rate (2014/2015) (2015/2016)	Rank (2014/2015) (2015/2016)
Univ. of Khartoum	86.3 86.3	1 1
Sudan Univ. of Sc. Tech.	86.0 85.4	2 2
University of al-Jazirah	83.4 80.9	3 3
Omdurman Islamic	79.1 76.0	4 4
University of Gadarif	75.7 74.4	5 5
Kordofan University	74.0 73.1	6 8
Blue Nile University	73.9 73.9	7 6
University of Dongola	69.9 69.3	8 10
Al Fashir University	70.9	9
Red Sea University	73.9	6

5. Engineering	% Rate (2014/2015) (2015/2016)	Rank (2014/2015) (2015/2016)
University of Khartoum	93.1 91.9	1 1
Sudan Univ. of Sc. Tech.	89.1 86.9	2 2
University of al-Jazirah	85.1 83.6	3 3
Omdurman Islamic	83.0 80.6	4 4
Red Sea University	81.6 80.6	5 4
Kordofan University	79.7 77.4	6 6
Blue Nile University	78.6 75.7	7 7

Comparison Test
Admission Ranking Vs. Model Result

Institutes	2014/2015 & 2015/2016		Model Result
University of Khartoum	1	1	1
Sudan Univ. of Sc &Tech	2	2	2
University of al-Jazirah	3	3	3
Omdurman Islamic Univ.	4	4	4
University of Gadarif	5	5	5
Red Sea University	6	6	6
Kordofan University	7	7	7
Blue Nile Univ.	9	8	8
Univ. of Dongola	7	10	9
Al Fashir Univ.	10	9	10

According to this example, the most important criteria is the 'UC4-Human Resources' and the least important criteria is 'UC9-Quality Management'. One criterion 'UC8-Community Service' is not important at all when compared with the others. Fuzzy pair wise comparisons offer that if a criterion is less important than all of the others, then comparatively this criterion has no importance and its weight is zero.

Systematic approach could be considered by using Microsoft Excel & predefined functions in order to design the comparisons matrices and easily & accurately compute the priorities weights.

The main criteria and sub-criteria for universities performance evaluation are compared in Tables 2 to 11. Also, the main criteria and sub-criteria for academic staff performance evaluation are compared in the Tables 12 to 26.

Therefore, similarly the weight vector for sub criteria in Tables 3 to 10 are calculated as follows:

W_{UC1} = (0.325, 0.133, 0.047, 0.150, 0.345), W_{UC2} = (0.202, 0.098, 0.158, 0.132, 0.220, 0.033, 0.158)
W_{UC3} = (0.292, 0.231, 0.211, 0.266), W_{UC4} = (0.182, 0.737, 0.081)
W_{UC5} = (0.844, 0.156, 0.000), W_{UC6} = (0.134, 0.135, 0.116, 0.143, 0.069, 0.120, 0.140, 0.079, 0.064)
W_{UC7} = (0.105, 0.224, 0.219, 0.092, 0.161, 0.200), W_{UC8} = (0.5, 0.5)
W_{UC9} = (0.463, 0.537)

where the weight vector W_{UC1} represents the weights of sub criteria of (UC1) Institutional framework criterion: The 0.363 is weight of (UC11: Strategic Planning), 0.089 is weight of (UC12: Vision), etc. correspondingly as defined in the Table 33.

Similarly for the other weight vectors $W_{UC2,}$ $W_{UC3,}\ldots, W_{UC9}$,

Same procedures were executed to check the consistency, aggregate responses, approximate and get the final weight of the main Academic Staff criteria and sub criteria. Tables from Tables 12 to 26 represents the aggregated comparison matrices for the main criteria and sub criteria of Academic Staff.

The following weights are calculated and obtained for the main criteria and sub criteria:

Main criteria: From Table 12:

$W_{AC} = (0.300, 0.369, 0.058, 0.129, 0.031, 0.114)$

Sub criteria weight (level-1: from Tables 15 to 20)

$W_{AC1} = (0.255, 0.339, 0.087, 0.145, 0.174)$,
$W_{AC2} = (0.189, 0.203, 0.179, 0.198, 0.034, 0.198)$

$W_{AC3} = (0.186, 0.105, 0.604, 0.105)$,
$W_{AC4} = (0.006, 0.242, 0.291, 0.461)$

$W_{AC5} = (0.430, 0.373, 0.040, 0.157)$,
$W_{AC6} = (0.250, 0.250, 0.250, 0.250)$

Sub criteria weights (level-2: from Tables 21–24)

$W_{AC51} = (0.036, 0.156, 0.177, 0.305, 0.143, 0.182)$,
$W_{AC52} = (0.000, 0.077, 0.081, 0.165, 0.156, 0.154, 0.254, 0.270)$

$W_{AC53} = (0.333, 0.333, 0.333)$,
$W_{AC54} = (0.216, 0.249, 0.308, 0.227)$

Sub criteria weights (level-2: from Tables 25–28)

$W_{AC61} = (0.179, 0.188, 0.291, 0.343)$,

$W_{AC62} = (0.049, 0.138, 0.130, 0.109, 0.119, 0.169, 0.132, 0.154)$

$W_{AC63} = (0.007, 0.089, 0.054, 0.097, 0.288, 0.288, 0.176)$,

$W_{AC64} = (0.079, 0.051, 0.056, 0.095, 0.028, 0.099, 0.074, 0.138, 0.142, 0.150, 0.116)$.

9. Apply FTOPSIS to obtain the final ranking

In the prior sections we determined the weights of criteria for universities and academic staff performance. This section, explains the final ranking process for Universities & Academic Staff (alternatives). Since the numbers of alternatives are huge and it is so difficult to construct pairwise comparison and relative priorities due to computational complexity, we use FOTOPSIS technique.

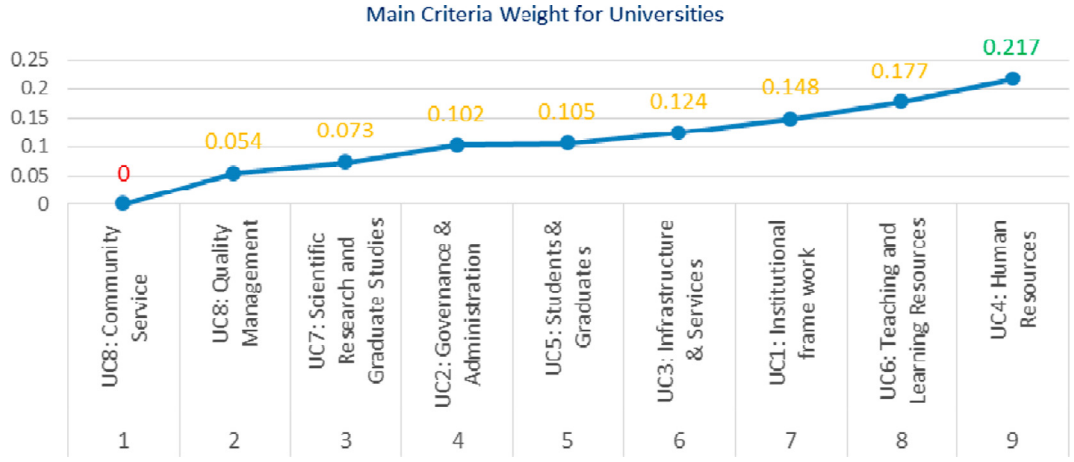


Figure 10 Char compares the weights between the main criteria group for universities.

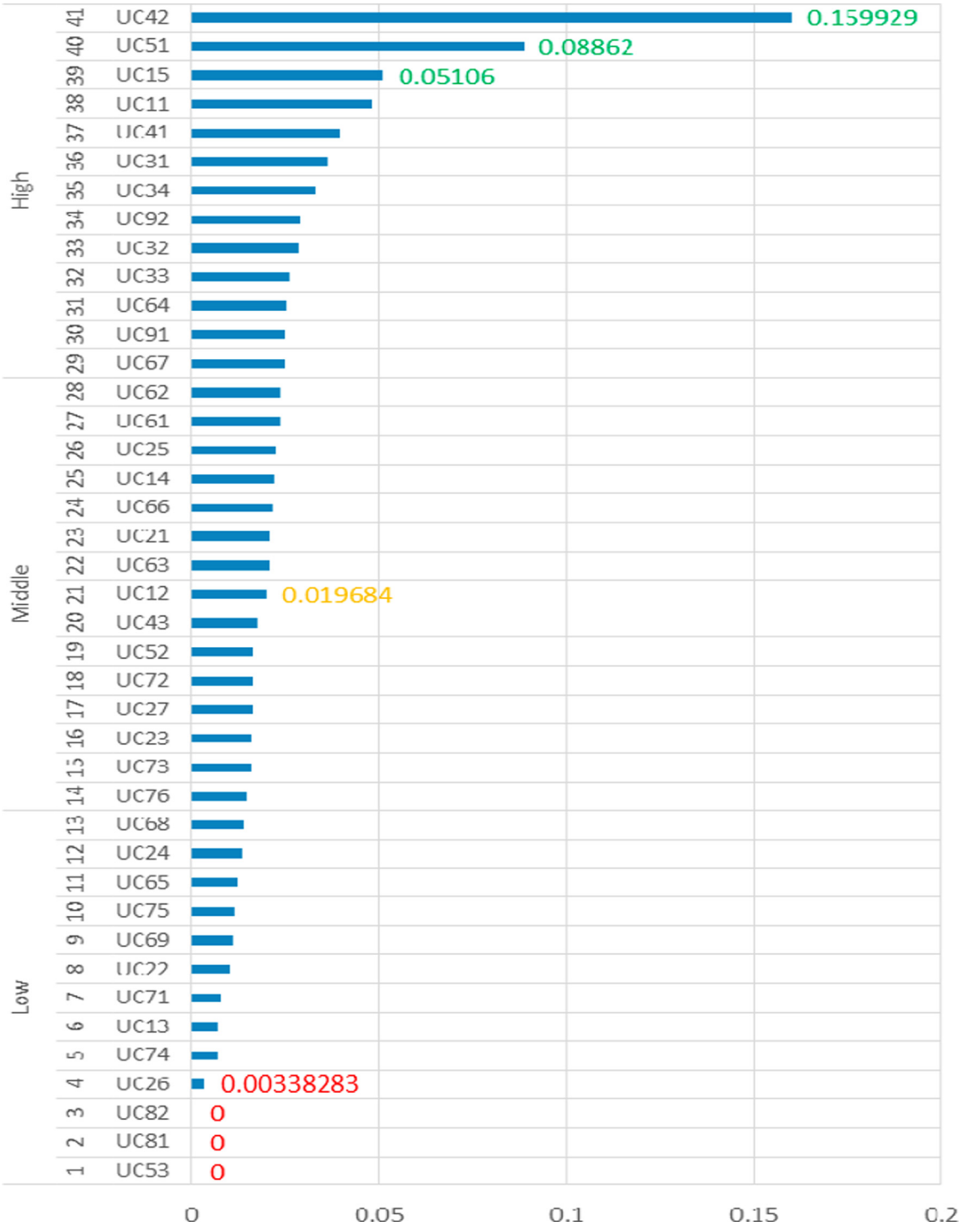


Figure 11 Char compares the weights between the bottom criteria for universities.

The advantage of FTOPSIS is to rank the alternative solutions by sorting the relative distance of the alternative solutions to the ideal solution irrespective of the volume of the universities and academic staff. Furthermore, fuzzy numbers are used to set the relative priorities instead of crisp numbers which allow considering the experts' subjective views. A sample of 15 Sudanese universities (alternatives) were selected, evaluated and ranked.

As mentioned in the classification model (Section 3), the final alternatives to the ranking process is to sort the relative distance of the alternative solutions to the ideal solution by applying the following steps:

1. Obtain the decision matrix between bottom criteria and universities/academic staff (alternatives).

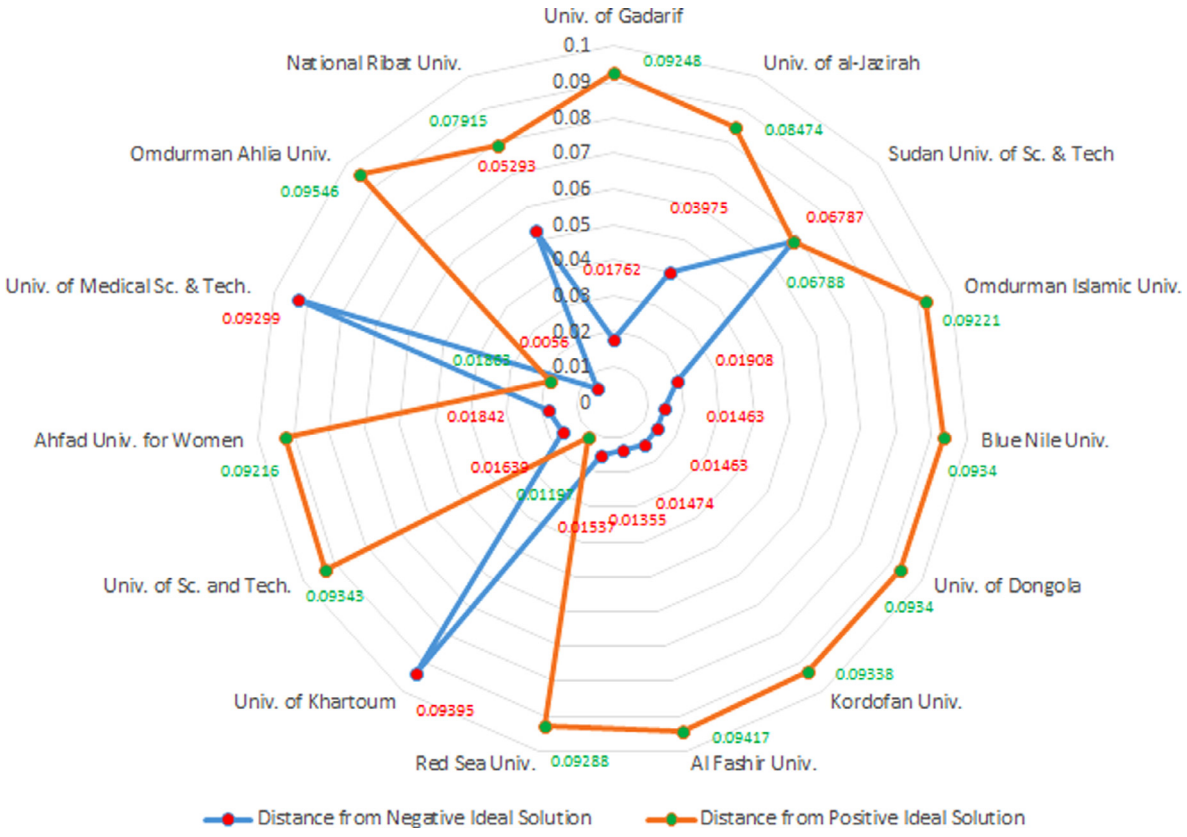
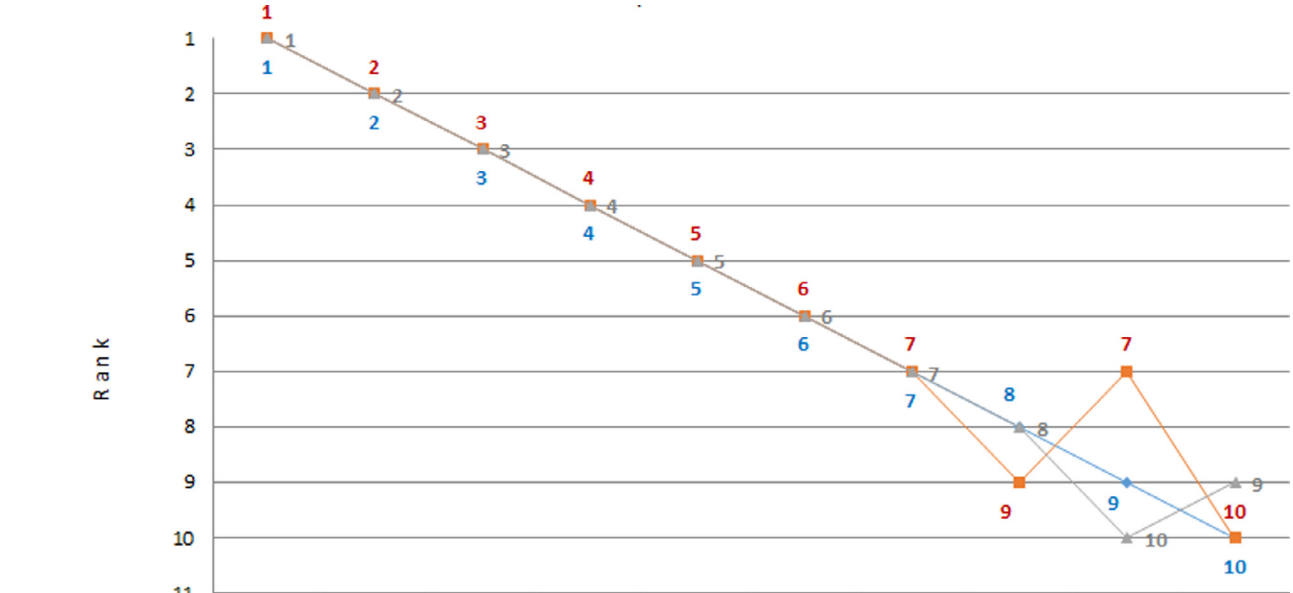


Figure 12 Chart shows the alternatives' distance (universities) from the negative & positive ideal solutions.



	University of Khartoum	Sudan Univ. of Sc &Tech	University of al-Jazirah	Omdurman Islamic Univ.	University of Gadarif	Red Sea University	Kordofan University	Blue Nile University	University of Dongola	Al Fashir University
Model Result	1	2	3	4	5	6	7	8	9	10
2014/2015 Result	1	2	3	4	5	6	7	9	7	10
2015/2016 Result	1	2	3	4	5	6	7	8	10	9

Figure 13 Comparison graphical view (2014/2015 vs 2015/2016 vs Proposed Model).

2. Obtain the normalized decision matrix R, using the relationship defined in Definition 3 in Section 2. The idea behind this logic is to get a fraction number between 0 & 1.
3. Compute and obtain the weighted decision matrix using the bottom criteria weight as shown in Table 27.
4. Compute the positive & negative ideal solutions from the weighted decision matrix (i.e. for each bottom criterion as shown in Table 28).
   $\boldsymbol{I^p} = (i_1^p, i_2^p, \ldots i_j^p)$ where I^p is the set of positive ideal solutions and i_j^p, j is positive ideal solution to the jth criteria at the bottom and
   $\boldsymbol{I^n} = (i_1^n, i_2^n, \ldots i_j^n)$ where I^n is the set of negative ideal solutions and i_j^n, j is positive ideal solution to the jth criteria at the bottom.
5. Compute the separation measures by obtaining the distance between universities/academic staff's (alternatives) solutions with the positive and negative ideal solution using the equation defined in Definition 2 in Section 2.
   Let $d(i_{tj}, i_j^p), d(i_{tj}, i_j^n)$ where i_{tj} is evaluation result of specific university/academic staff t to the jth criteria at the bottom. Table 29 shows the distance result of our sample alternatives from Ideal negative & positive solutions.

$$C_j^p = SQR\left(\sum_{j=1}^{41}(i_{ij} - i_j^p)^2\right),$$

$$C_j^n = SQR\left(\sum_{j=1}^{41}(i_{ij} - i_j^n)^2\right) \text{ For Universities.}$$

$$C_j^p = SQR\left(\sum_{j=1}^{69}(i_{ij} - i_j^p)^2\right),$$

$$C_j^n = SQR\left(\sum_{j=1}^{69}(i_{ij} - i_j^n)^2\right) \text{ For academic Staff.}$$

   where the C_j^p *and* C_j^n are the separation measures from the ideal solutions for all alternatives $j = 1 \ldots 41$ for bottom criteria for university or 69 bottom criteria for academic staff.
6. Compute the relative closeness to ideal solution for each alternative by utilizing the equation below as shown in Table 30.

$$CL_j^n = C_j^n/(C_j^p + C_j^n)$$

7. Classify the alternative universities and academic staff according to the above calculated values.
   In Table 30, there are 15 alternatives sample, which represents 10 public universities and 5 private universities. The ranking was conducted first for each group (public & private) and finally for all of them.

10. Model testing

We compare our model result with result of entrance rates of Sudanese certificates for the previous year which was formulated by Sudanese ministry of higher education according to applicants' requests. We considered the results of 10 public universities for the following colleges: Medicine, Economic, Engineering Education and Computer Science and then, takes the overall average to rank the universities. The comparison output of these 10 universities is satisfactory and acceptable as shown in Table 31. The 1st seven public universities occupy the same ranking position while small difference on the other three universities. The columns '2014 Result' and 'Model Result' in Table 31 are represented in graphical view in Fig. 13.

Currently, there is no official/unofficial organization concerns with universities classifications based on specific agreed criteria in Sudan. But, the General Administration for Admissions, Degree Evaluations & Verification (GAADEV) calculates and publishes every year the minimum admission rates of colleges for all Sudanese universities based on the number of applicants and number of available seats in specific year.

We compared our model result with result of admission rates published by (GAADEV) for the previous years (2014/2015 & 2015/2016). We considered the results of 10 public universities for the following colleges: Medicine, Economic, Engineering Education and Computer Science and then, takes the overall average to rank the universities. The comparison output of those 10 universities is satisfactory and acceptable as shown in Table 31.

As comparison result, the 1st seven public universities (Khartoum university, Sudan University of Science & Technology, University of Al-Jazirah, Omdurman Islamic University, University of Gadarif, Red Sea University, and Kordofan University) occupy the same ranking positions as GAADEV admission rates for both academic years (2014/2015 and 2015/2016) while small difference in the positions of the other three remaining universities (University of Dongle, Blue Nile University and Al Fashir University) as shown in Comparison Test part in Table 31. A graphical view of comparison between the model ranking result and 2014/2015 & 2015/2016 admission ranking result is shown in Fig. 13. The blue line represents the model result while the brown and gray lines represent the admission results for 2014/2015 and 2015/2016 correspondingly.

11. Analysis & observations

As a result, the following observations about evaluation criteria and alternatives (i.e. Sudanese universities) are noted:

- The human Resources criteria group was assigned with the highest weightage (0.217) over the others criteria while community service (0.0) and quality management (0.054) were assigned with lowest weightage. Fig. 10 shows the comparison between all evaluation criteria groups.
- In the bottom criteria, the faculty members (UC42) criterion was assigned with the highest weightage against others bottom criteria while Graduates criterion, management of community service criterion and community service programs criterion were assigned lowest weightage. Fig. 11 shows the comparisons between all bottom evaluation criteria.
- Khartoum University has longest distance from negative ideal solution (0.9395) and shortest distance from negative ideal solution (0.01197) while Omdurman Alhalia University has shortest distance from negative ideal solution (0.00564) and longest distance from positive ideal solution (0.9546). Fig. 12 shows the distance of alternatives

(universities) from negative & positive ideal solutions. The green points in brown line represent the distance from positive ideal solution (center) while the red points in the blue line represent the distance from negative ideal solution (center).

- As result of comparison with admission results, the ranking of the first 7 universities is identical with admission results for two academic years (2014/2015 & 2015/2016) and slightly differs from the other three remaining universities. This result is expected because the admission ranking depends only on the applicants' views and knowledge about university in general, which is expected to be inaccurate for the new universities.
- **If-Scenario:** The final ranking process depends on two main factors, the weight of the bottom criteria which are derived from the main & sub-criteria and alternatives' evaluation factor. This paper presents a detailed analysis through If-Scenario tool, which is designed to analyze the result based on emphasizing on some criteria. For If-scenarios example, the weight of 'Institutional Frame Work' criterion was swapped with 'Human Resources' criterion, which automatically effect on bottom criteria weight, alternatives distances from negative & positive ideal solutions and final ranking result. The detailed scenarios analysis and steps are presented in Appendix D.

12. Conclusion

In this paper, nine main criteria and forty-one sub criteria were identified, considered and weighted as performance evaluation criteria for Sudanese high academic institutes. Furthermore, thee levels of academic staff evaluation criteria were identified, considered and weighted. The first level consists of six criteria, the second level consists of twenty-seven criteria and the last level consists of fifty criteria.

Classification model for performance evaluation of Sudanese university and academic staff was developed and proposed. It consists of all steps required such consistency check, aggregation, approximation and final ranking.

New Fuzzy Consistency Algorithm (FCA) to check and evaluate the consistency level of expert's judgment was designed and proposed. The new algorithm proposes a consistent preference linguistic value(s) as an option to the experts in case of inconsistency judgment in evaluation performance. Based on the proposed algorithm, the research introduces new tools that allow experts to trace and understand the roots of inconsistency and select the relevant consistent option(s).

Appendix A

Table A-1 Related fuzzy techniques summary.

SR.	Techniques	Description & Concept	Key Benefits
1	Analytic hierarchy process (AHP & FAHP)	It is a quantitative technique for rating decision alternatives and selection of the one given multiple criteria. It structures the alternatives into a hierarchical framework to resolve complicated decisions	- Flexible, intuitive and checks inconsistencies - Since problem is constructed into a hierarchical structure, the importance of each element becomes clear - No bias in decision making
2	TOPSIS & FTOPSIS	It is one of the multi-criteria decision making technique that is extensively used to solve MCDM problems. TOPSIS technique based on the concept that selected the alternative is the shortest geometric distance to the positive ideal solution and the longest geometric distance to the negative ideal solution	- It is easy to use - It takes into account all types of criteria (subjective and objective) - It is rational and understandable - The computation processes are straight forward
3	Multistage Fuzzy & Cascaded Fuzzy Technique	The multistage fuzzy logic inference has been proposed in order to decrease the number of fuzzy rules for compound systems	- The option of using fuzzy output from previous layers as fuzzy input for the next fuzzy inference system presents the advantage of preserving the information about uncertainty - Organizations have flexibility to give different important factors to different critical elements as per organizational goal - Reduces number of rules by dividing the whole system into various fuzzy inference stages
4	Fuzzy based Multifactorial Evaluation Technique	The purpose of Multifactorial evaluation is to deliver a synthetic assessment of an object relative to an objective in a fuzzy decision environment that has many factors	- It is easy to make the required changes in the system whenever it is necessary - It is able to constantly generate reliable and valid results for the appraisal process
5	Hybrid Neuro-Fuzzy (NF) Technique	NF is a common framework for solving complicated problems. It uses FIS to resolve an uncertainty and ANN to learn from simulation	- Learning and adaptation capabilities - Human understandable form of knowledge representation - Needs less computational effort than other methods
6	Type-2 Fuzzy Evaluation Technique	Type-2 fuzzy sets generalize type-1 fuzzy sets and systems, thus more uncertainty can be managed and controlled	- More uncertainty can be handled. (i.e. to handle uncertainty about the value of the membership function) - It addresses the criticism of type-1 fuzzy

Appendix B

Table B-1 Key Table for Performance Evaluation Criteria for Sudanese universities as shown in hierarchical (Fig. 2).

C. Code	Main Criteria	C. Code	Sub Criteria
UC1	Institutional Frame Work الاطار المؤسسي	UC11	Strategic Planning (التخطيط الاستراتيجي)
		UC12	Vision (الرؤية)
		UC13	Mission (الرسالة)
		UC14	Goals and Objectives (الغايات والاهداف)
		UC15	Operational Plans (الخطط التنفيذية)
UC2	Governance & Administration الحوكمة والادارة	UC21	Rules and Regulations (النظم واللوائح)
		UC22	Organizational and Functional Structures (الهياكل التنظيمية والوظيفية)
		UC23	Boards (المجالس)
		UC24	Committees (اللجان)
		UC25	Leadership (القيادة)
		UC26	External/Foreign Relations (العلاقات الخارجية)
		UC27	Financial Resources and Management (الموارد المالية وادارتها)
UC3	Infrastructure & Services البنى التحتية	UC31	Sites and Spaces (المواقع والمساحات)
		UC32	Facilities and Equipment (المنشآت وتجهيزاتها)
		UC33	University Services and Departments (الخدمات الجامعية واداراتها)
		UC34	The Structure of Information and Communications Technology (بنية تقانة المعلومات والاتصالات)
UC4	Human Resources الموارد البشرية	UC41	Human Resource Management (ادارة الموارد البشرية)
		UC42	Faculty Members (اعضاء هيئة التدريس)
		UC43	Helping Frames (الاطر المساعدة)
UC5	Students & Graduates الطلاب والخريجون	UC51	Admission and Registration (القبول والتسجيل)
		UC52	Deanship - Student Affairs Administration (عمادة/ادارة شؤون الطلاب)
		UC53	Graduates (الخريجون)
UC6	Teaching and Learning Resources التعليم والتعلم ومصادرهما	UC61	Academic Programs (البرامج الدراسية)
		UC62	Curriculum (المناهج)
		UC63	Academic Advising/Counseling (الارشاد الاكاديمي)
		UC64	Academic Evaluation for Students (التقويم الاكاديمي للطلاب)
		UC65	Libraries (المكتبات)
		UC66	Electronic Libraries (المكتبات الافتراضية)
		UC67	Laboratories (المختبرات)
		UC68	Workshops (workshops / ceremonies) (الورش - المشاغل / المراسم)
		UC69	Centers of Educational Technologies (مراكز التقنيات التعليمية)
UC7	Scientific Research and Graduate Studies **البحث العلمي والدراسات العليا**	UC71	Administration of Scientific Research (ادارة البحث العلمى)
		UC72	Funding of Scientific Research (تمويل البحث العلمى)
		UC73	Marketing Scientific Research (تسويق البحث العلمى)
		UC74	Administration of Graduate Studies (ادارة الدراسات العليا)
		UC75	Admission, Supervision and Evaluation of Postgraduate's Students (القبول والتسجيل والاشراف وتقويم الطلاب بالدراسات العليا)
		UC76	Postgraduate Programs (برامج الدراسات العليا)
UC8	Community Service خدمة المجتمع	UC81	Management of Community Service (ادارة خدمة المجتمع)
		UC82	Community Service Programs (برامج خدمة المجتمع)
UC9	Quality Management ادارة الجودة	UC91	Quality Management (ادارة الجودة)
		UC92	Quality Management Programs (برامج ادارة الجودة)

Table B-2 Key Table for Performance Evaluation Criteria for Academic Staff Main Criteria as shown in Fig. 5.

CC.	Main Criteria	CC.	Sub Criteria (Level-1)
AC1	Excellence in Research and Scientific Activities (والانشطة العلمية التميز في البحوث)	AC11	Publications (البحوث والمنشورات)
		AC12	Quality of Research (جودة البحوث)
		AC13	Invitation to Lecture in Important Conferences (دعوات لإلقاء محاضرة في المؤتمرات الهامة / ندوات)
		AC14	Supervises postgraduate students and participates in postgraduate thesis examination/Discussion (الاشراف على الطلاب للحصول على درجات متقدمة والمشاركة في مناقشة الاطروحات)
		AC15	Membership in Editorial Boards of Prestigious Journals (العضوية في هيئات تحرير المجلات المرموقة)
AC2	Teaching Quality (التدريس جودة و نوعية)	AC21	Teaching and ability to cover different materials efficiently (التدريس والقدرة على تغطية المواد المختلفة بكفاءة)
		AC22	Commitment to academic work, academic counseling and office hours الالتزام بالعمل والساعات المكتبية والإرشاد الأكاديمية
		AC23	Teaching Attitude (preparation, patient, attendance, etc.) (الاساليب والسلوك المتبع في التدريس)
		AC24	Teaching Advanced Courses (تدريس دورات متقدمة)
		AC25	Counseling Students (الارشادات والاستشارات للطلبة)
		AC26	Designing and Writing Teaching Programs and Syllabi, (تصميم وكتابة البرامج التعليمية و المناهج الدراسية)
AC3	Services & Administration (الخدمات)	AC31	Taking part in Faculty Technical Committees (المشاركة في اللجان الفنية لأعضاء هيئة التدريس)
		AC32	Taking Part on of Managerial Roles (المشاركة في الأدوار الإدارية)
		AC33	Activities that Enhance the Research, Teaching, Educational and Social Endeavors of the Faculty الانشطة التي تعزز البحوث التربوية و التعليمية والجهود الاجتماعية لأعضاء هيئة التدريس
		AC34	Participation in Scientific Community in Sudan (المشاركة في المجتمع العلمي في السودان)
AC4	Knowledge Transfer/Exchange and Engaging Communities Performance (المجتمعات المحلية وإشراك وترقية نقل وتبادل المعرفة)	AC41	Activities & Collaboration with Public groups (الأنشطة والتعاون مع المجموعات العامة)
		AC42	Application of Knowledge to Improve the Performance of Business, Commerce or Industry) (تطبيق المعرفة لتحسين أداء الأعمال والتجارة أو الصناعة)
		AC43	Enhancement of Quality of Life of a Community (i.e. Improving safety and sustainability and protecting the environment) (تحسين وتعزيز نوعية الحياة للمجتمع)
		AC44	Involvement in and Development of Projects Supported by Faculty/University (المشاركة في تطوير المشاريع التي تدعمها الكلية / الجامعة)

CC.	Main criteria	CC.	Sub criteria (Level-1)	CC.	Sub criteria (Level-2)
AC5	Students Feedback (و رأي الطلاب استطلاع وملاحظات)	AC51	Teaching capabilities and preparation for lecture (والاعداد والتحضير لها التدريس في تدريس المادة امكانيات عضو هيئة)	AC511	Distribution of Teaching study plan in the first week (توزيع الخطة الدراسية في الأسبوع الأول)
				AC512	Clear, coherent and systematic way of lectures demonstration (عرض المادة العلمية في المحاضرات بشكل واضح ومترابط ومنظم)
				AC513	Exploits the time of lecture effectively (استغلال وقت المحاضرات بشكل فعال)
				AC514	High experience and skills in the scientific courses (الخبره والمهارة فى المادة العلمية)
				AC515	The compatibility between the plan and what was actually taught. (التوافق التام بين مفردات الخطة وما تم تدريسه فعلاً)
				AC516	Adherence to the dates/times of lectures (الالتزام بمواعيد المحاضرات)
		AC52	Material contribution in the scientific achievement of students (التحصيل العلمي للطلبة مساهمة المادة في)	AC521	Students motivates and participation مشاركة الطلبة وإبداء وجهات نظرهم حول المادة
				AC522	Interest in academic achievement of students in General الاهتمام بالتحصيل الدراسي للطلبة بشكل عام
				AC523	Students respect within the professional standards and ethics التعامل مع الطلبة باحترام ضمن معايير المهنة وآدابها
				AC524	Teaching methods that evoke the thinking and curiosity تستثير التفكير وحب الاستطلاع الاساليب التدريسية التي
				AC525	Illustrative and applied methods in the lecture's presentation الأساليب التوضيحية والتطبيقية لعرض للمادة
				AC526	Diversity in Teaching Methods التنوع في طرق التدريس بما يلائم موضوع المادة وحاجات الطلبة
				AC527	Clear and understandable language in teaching the material استخدم لغة واضحة ومفهومة في تدريس المادة
		AC53	Assess the content of material (تقويم محتوى المادة)	AC531	Compatibility of exam content with terms of the teaching plan. الخطة التدريسية توافق محتوى الامتحانات مع
				AC532	Discussion of exam questions and correct answers النقاش مع الطلبة الإجابات الصحيحة للأسئلة التي تضمنها الامتحان
				AC533	Diversity in measurement techniques to assess student achievement grades التنوع في أساليب قياس تحصيل الطلبة وتقدير علاماتهم
		AC54	Relationship of faculty member and students (التدريس و الطلبة العلاقة بين عضو هيئة)	AC541	Compliance with Teacher's office hours and encourage students to utilize this period. المراجعة خلالها الالتزام بالساعات المكتبية وتشجع الطلبة على
				AC542	Accuracy and fairness in grades الدقة والعدالة في اعطاء العلامات
				AC543	Motivates students to see the different references تحفيز الطلبة للاطلاع على مراجع المادة المختلفة
				AC544	Students' attitudes development اتجاهات وعادات وأخلاق حميدة للطلبة تنمية

(*continued on next page*)

AC6 Peers Feedback **(التدريس اعضاء هيئة و رأي الزملاء استطلاع وملاحظات)**	AC61 Course Content (محتوى الكورس)	AC611	Explanation of subject and main outlines توضيح واستعراض موضوع البحث
		AC612	State of the Art في المجال مواكبة المنهج الدراسي على اخر ما توصل الية العلم والابحاث العلمية
		AC613	Clearness of Course objective وضوح أهداف المقرر
		AC614	Consistency of Course content and Syllabus اتساق محتوى الكورس والمنهج
	AC62 Delivery and Teaching Methods (التقديم وطرق التدريس)	AC621	Transition Between Ideas الانتقال السلس بين الأفكار
		AC622	Using Examples to Clarify Concepts استخدام الامثلة لتوضيح المفاهيم
		AC623	Organized Presentation عرض المادة بطريقة منظمة
		AC624	Instructor's Enthusiasm الحماس والرغبة لتدريس الموضوع
		AC625	Adapting Material to student needs تكييف المادة لتناسب احتياجات الطلاب
		AC626	Using of Supplemental materials/visual aids/technology استخدام المواد التكميلية / الوسائل البصرية / التكنولوجيا بشكل فعال
		AC627	Response to students remark الاهتمام والاستجابة لملاحظات الطلبة
		AC628	Assessment tool/strategy integrated into the lesson للتقييم مدمجة في الدرس وجود أداة / استراتيجية متكاملة
	AC63 Learning Environment (بيئة التعلم)	AC631	Participatory classroom environment البنية التشاركية للفصول الدراسية
		AC632	Students engagement and attention اهتمام ومشاركة الطلاب فى الدرس
		AC633	Encourage questions and checking students' understanding تشجيع الاسئلة والتحقق من فهم الطلاب
		AC634	Ability to identify the cues of boredom and confusion القدرة على تحديد معرفة علامات الملل والارتباك عند الطلاب
		AC635	Thought-provoking and stimulating المحاضرة مثيرة ومحفزة للتفكير
		AC636	Student centered learning and critical thinking environment المحاضرة مواتية للتفكير والتعلم المتمحور حول الطالب
		AC637	Promotion a safe learning environment for students تعزيز بيئة تعليمية امنة
	AC64 Communication, collaboration and	AC641	Genuine interest in work

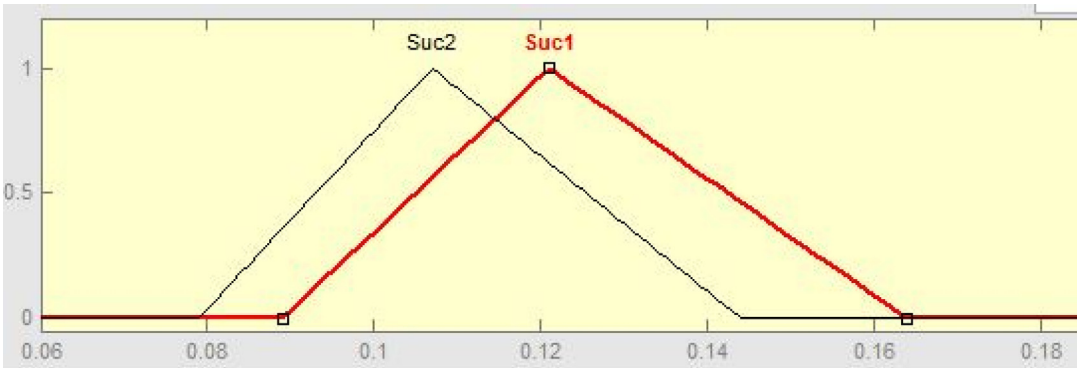
Table B-2 (*continued*)

CC.	Main criteria	CC.	Sub criteria (Level-1)	CC.	Sub criteria (Level-2)
			Professionalism (والكفاءة المهنية الاتصال والتعاون)		الاهتمام الحقيقى بالعمل
				AC642	Field Knowledge دراية ومعرفة تامة بمجال العمل
				AC643	Respect for Staff and Students احترام الطلبة والزملاء والموظفين
				AC644	Punctuality and regularity in the workplace/meetings/lectures الالتزام بالمواعيد والانتظام في العمل
				AC645	Communication skills مهارات الاتصال
				AC646	Receptive to different viewpoint تقبل وجهات النظر المختلفة
				AC647	Confidentiality/privacy respect احترام السرية والخصوصية
				AC648	Supporting other department members in positive way دعم اعضاء الاقسام الاخرى بطرق ايجابية
				AC649	Taking an active role in departmental projects القيام بدور نشط وفاعل فى مشاريع القسم
				AC6410	Supporting department & collage in positive way دعم القسم والكلية بطرق ايجابية
				AC6411	Involvement in college activities المشاركة فى انشطة الكلية التى تتعدى حدود القسم

Appendix C

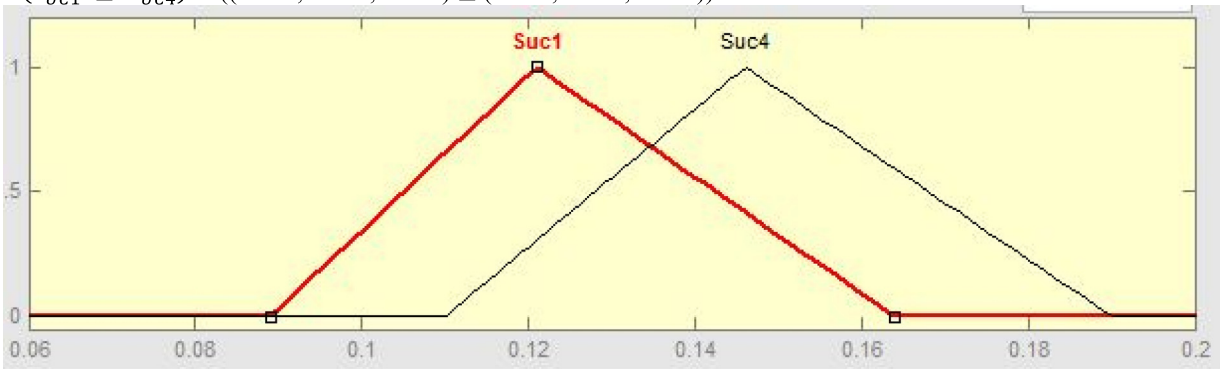
This appendix presents some of the membership function plots for example (Part1) calculation as explained in step 3 in Section 8.

- $(S_{UC1} \geq S_{UC2})$: $V((0.089, 0.121, 0.164) \geq (0.079, 0.107, 0.144)) = 1.000$

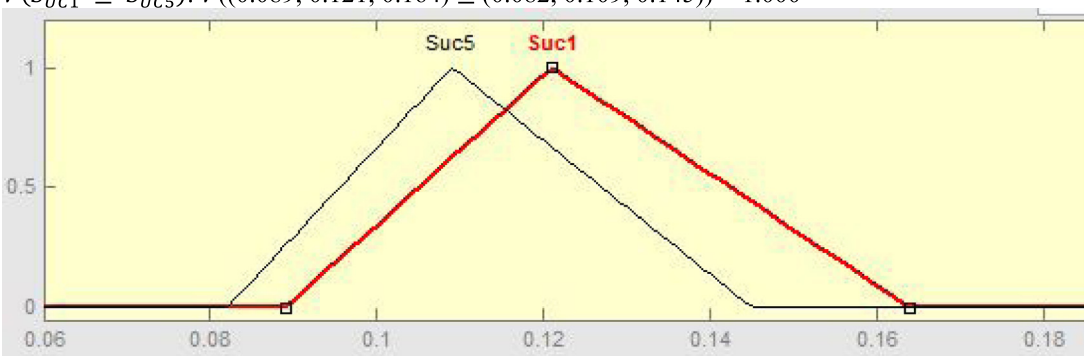


- $V(S_{UC1} \geq S_{UC3})$: $V((0.089, 0.121, 0.164) \geq (0.086, 0.114, 0.152)) = 1.000$

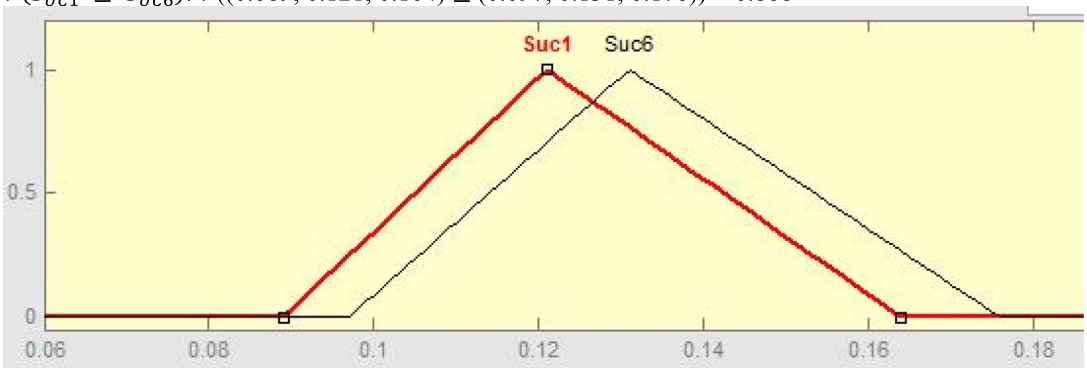
- $V(S_{UC1} \geq S_{UC4})$: $V((0.089, 0.121, 0.164) \geq (0.110, 0.146, 0.190)) = 0.683$



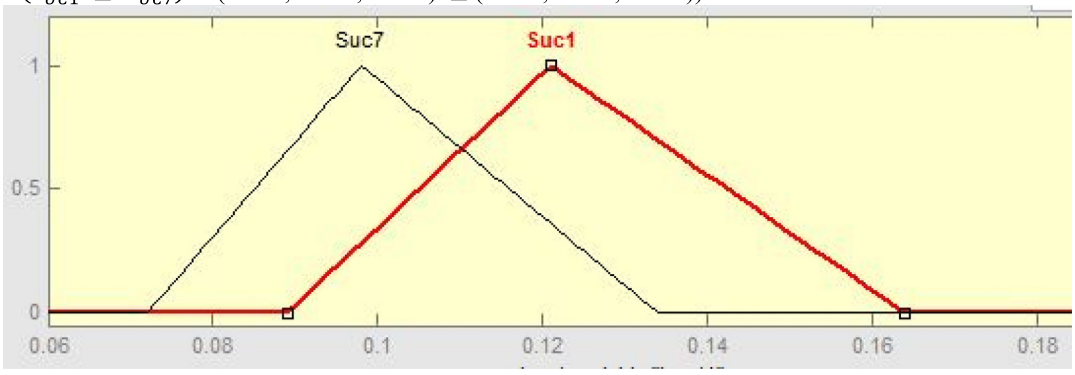
– $V(S_{UC1} \geq S_{UC5})$: $V((0.089, 0.121, 0.164) \geq (0.082, 0.109, 0.145)) = 1.000$



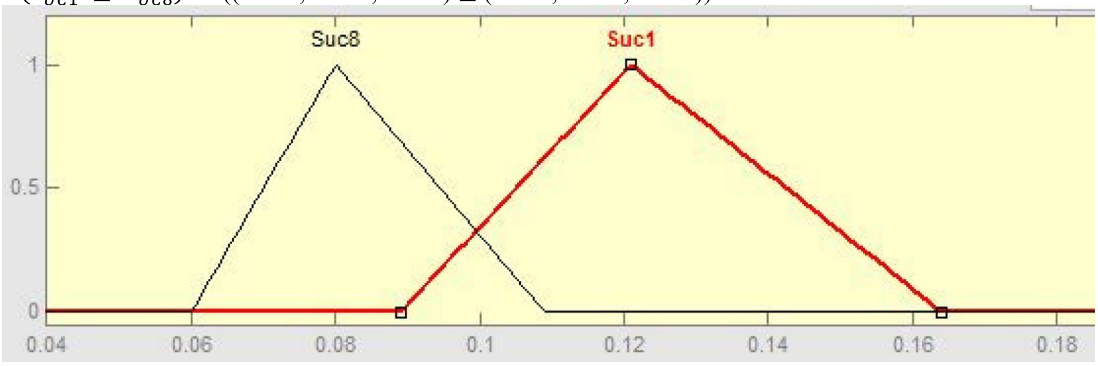
– $V(S_{UC1} \geq S_{UC6})$: $V((0.089, 0.121, 0.164) \geq (0.097, 0.131, 0.176)) = 0.868$



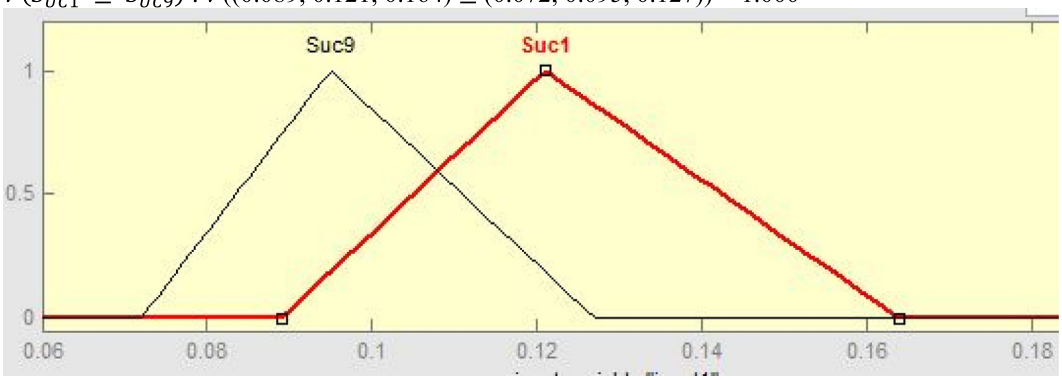
– $V(S_{UC1} \geq S_{UC7})$: $V(0.089, 0.121, 0.164) \geq (0.072, 0.098, 0.134)) = 1.000$



– $V(S_{UC1} \geq S_{UC8})$: $V((0.089, 0.121, 0.164) \geq (0.060, 0.080, 0.109)) = 1.000$



– $V(S_{UC1} \geq S_{UC9}) : V((0.089, 0.121, 0.164) \geq (0.072, 0.095, 0.127)) = 1.000$



Appendix D

The if-Scenario tool provides a detailed analysis of the results. Several scenarios can be executed by emphasizing on some criteria rather than others. The tool automatically displays the impact of the new changes on the bottom criteria, alternatives distance from NIS and PIS and final ranking result. For example, the weight of 'Institutional Frame Work' criterion is swapped with 'Human Resources' criterion, which automatically effects on bottom criteria weight, alternatives distances from negative & positive ideal solutions and accordingly the final ranking result. The following steps show this If-scenario case.

Step1: Define/Swap/Input new values for the main criteria. In this example, the value of **UC1** is swapped with **UC4** (see Table D-1).

Step2: The following analysis graphs and table will be automatically updated and presented. The differences between the

Table D-1 Inputs for the new values of the If-scenarios.

Main Criteria	Criteria Code	Actual Weights	If Scenario Input
Institutional frame work	UC1	0.148	0.217
Governance & Administration	UC2	0.102	0.102
Infrastructure & Services	UC3	0.124	0.124
Human Resources	UC4	0.217	0.148
Students & Graduates	UC5	0.105	0.105
Teaching and Learning Resources	UC6	0.177	0.177
Scientific Research and Graduate Studies	UC7	0.073	0.073
Community Service	UC8	0.000	0.000
Quality Management	UC9	0.054	0.054

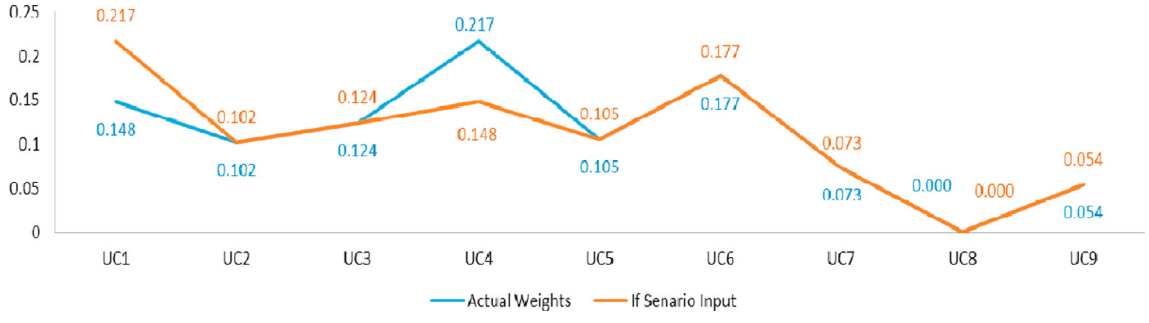


Figure D-1 Main criteria Wight vs. If-Scenario.

Table D-2 Automatic calculation of the new Bottom Criteria.

Main Criteria	Bottom Criteria Code	Sub-Criteria Weights	Main Criteria Weights	Bottom Criteria weight (Actual Output)	Bottom Criteria weight (scenario Output)
UC1	UC11	0.325	0.217	0.0481	0.070525
	UC12	0.133		0.019684	0.028861
	UC13	0.047		0.006956	0.010199
	UC14	0.15		0.0222	0.03255
	UC15	0.345		0.05106	0.074865
UC2	UC21	0.202258828	0.102	0.0206304	0.0206304
	UC22	0.098014336		0.009997462	0.009997462
	UC23	0.157502528		0.016065258	0.016065258
	UC24	0.131685336		0.013431904	0.013431904
	UC25	0.219643278		0.022403614	0.022403614
	UC26	0.033164989		0.003382829	0.003382829
	UC27	0.157730705		0.016088532	0.016088532
UC3	UC31	0.292	0.124	0.036208	0.036208
	UC32	0.231		0.028644	0.028644
	UC33	0.211		0.026164	0.026164
	UC34	0.266		0.032984	0.032984
UC4	UC41	0.182	0.148	0.039494	0.026936
	UC42	0.737		0.159929	0.109076
	UC43	0.081		0.017577	0.011988
UC5	UC51	0.844	0.105	0.08862	0.08862
	UC52	0.156		0.01638	0.01638
	UC53	0		0	0
UC6	UC61	0.134	0.177	0.023718	0.023718
	UC62	0.135		0.023895	0.023895
	UC63	0.116		0.020532	0.020532
	UC64	0.143		0.025311	0.025311
	UC65	0.069		0.012213	0.012213
	UC66	0.12		0.02124	0.02124
	UC67	0.14		0.02478	0.02478
	UC68	0.079		0.013983	0.013983
	UC69	0.064		0.011328	0.011328
UC7	UC71	0.105	0.073	0.007665	0.007665
	UC72	0.224		0.016352	0.016352
	UC73	0.219		0.015987	0.015987
	UC74	0.092		0.006716	0.006716
	UC75	0.161		0.011753	0.011753
	UC76	0.2		0.0146	0.0146
UC8	UC81	0.5	0.000	0	0
	UC82	0.5		0	0
UC9	UC91	0.463	0.054	0.025002	0.025002
	UC92	0.537		0.028998	0.028998

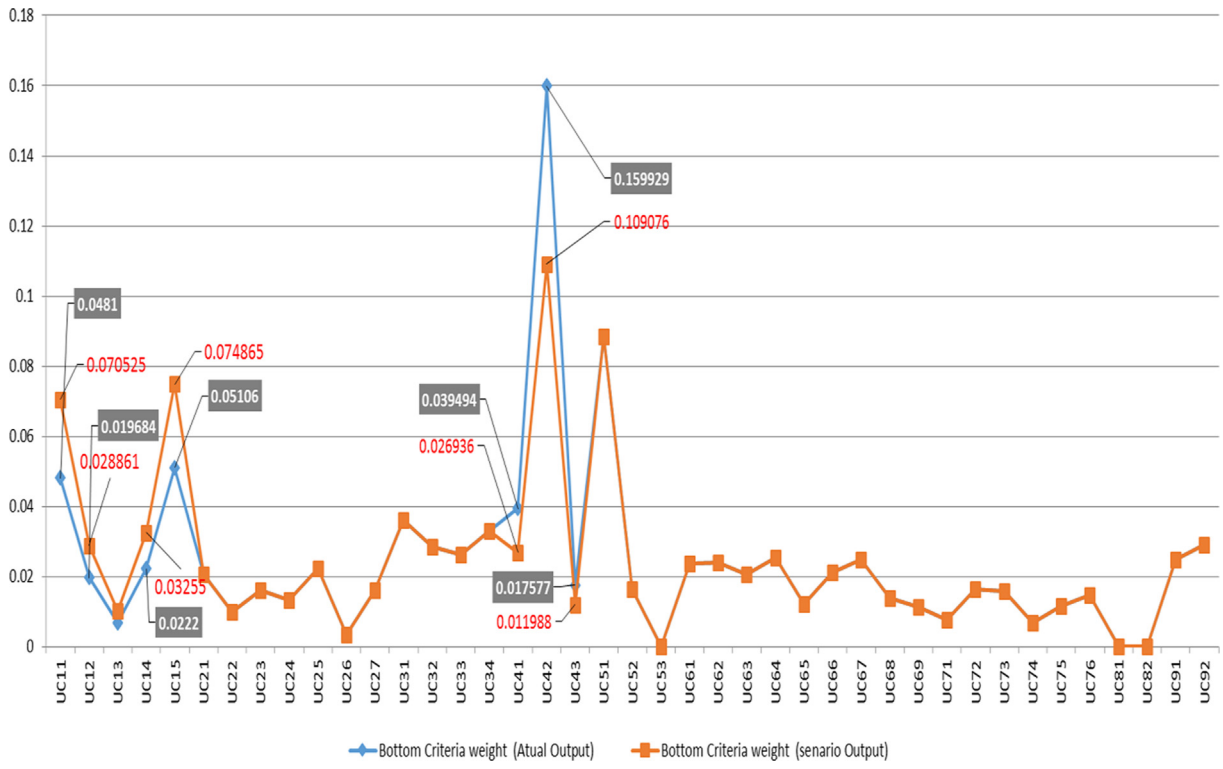


Figure D-2 Actual bottom Criteria Wight vs. If-Scenario.

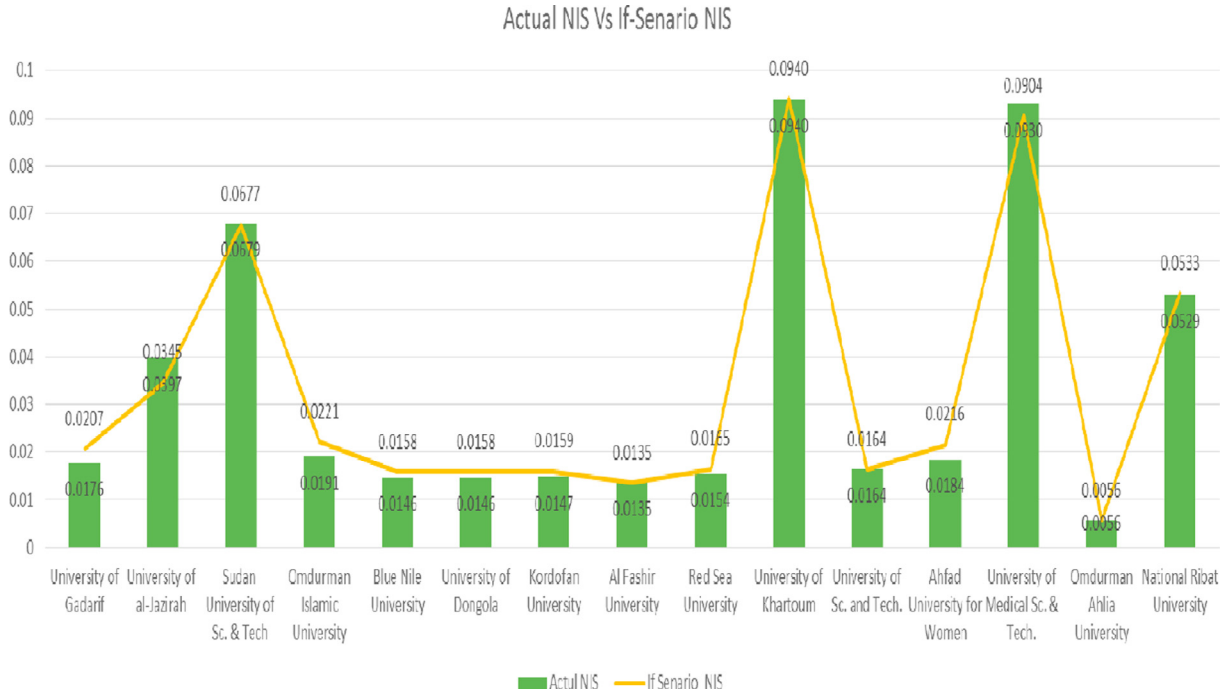


Figure D-3 Actual alternatives distances from NIS vs. If-scenario alternatives distances from NIS.

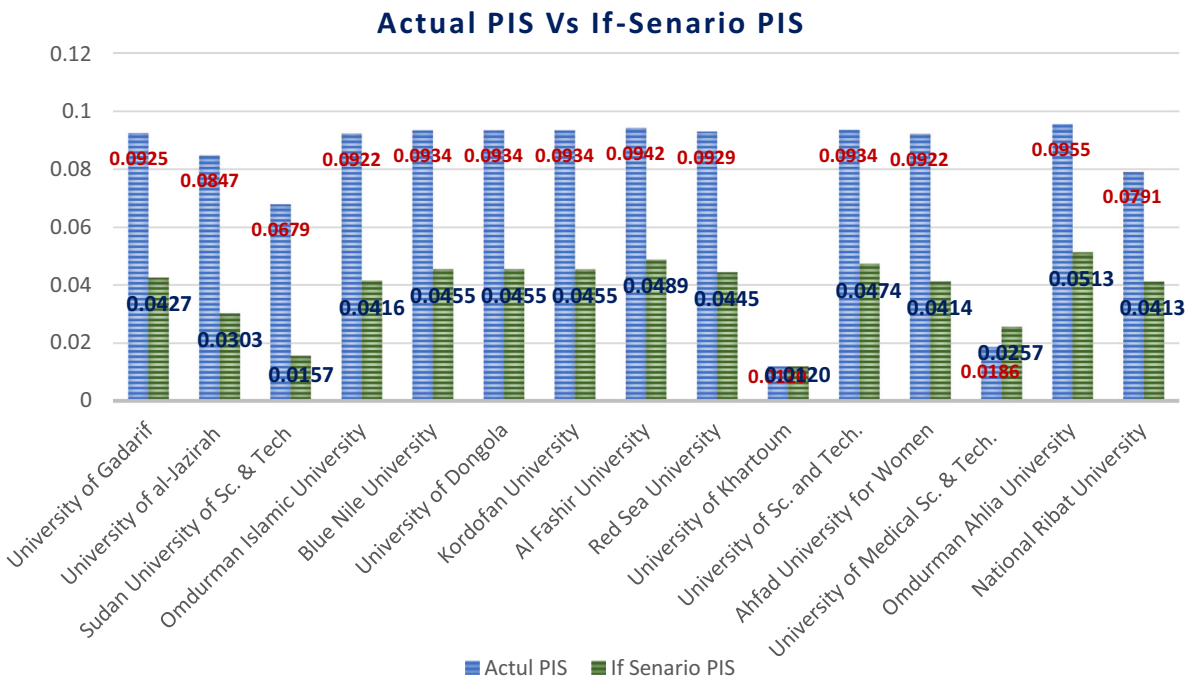


Figure D-4 Actual alternatives distances from PIS vs. If-scenario alternatives distances from PIS.

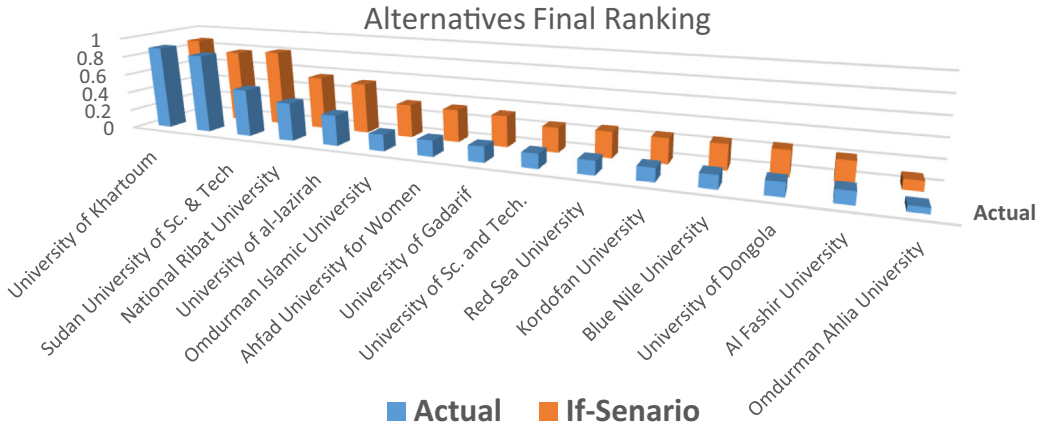


Figure D-5 Actual final ranking vs. If-scenario final ranking.

actual study and if-scenario case can be observed in the following graphs & table:

- Main criteria weight vs. If-Scenario case – (Figure D-1): It reflects the difference between actual main criteria and if-scenario values. In our example, only the values of criteria UC1 and UC2 are changed.
- Automatic calculation of the new bottom Criteria – (Table D-2): It calculates and displays the new bottom criteria based on the changes in the main criteria. For example these bottom criteria (UC11, UC12, UC13, UC14, UC15 and, UC41, UC42, UC43) were affected by the changes in the main criteria (UC1 and UC4)
- Actual bottom Criteria Wight vs. If-Scenario (Figure D-2)
- Actual alternatives distance from Negative Ideal Solution (NIS) vs. If-Scenario alternatives distance from Negative Ideal Solution (NIS) – (Figure D-3)
- Actual alternatives distance from Positive Ideal Solution (NIS) vs. If-Scenario alternatives distance from Positive Ideal Solution (NIS) - (Figure D-4)
- Actual Final Ranking vs. If-scenario Final (Figure D-5 & Figure D-6): It displays and compares the actual final ranking and if-scenario final ranking. In our example, the 'University of Medical Sc. & Tech.' occupied the 2nd position in the actual ranking process with relative closeness to ideal solution (0.833110828909821) while 'Sudan University of Sc. & Tech' occupied the 3rd position with relative closeness to ideal solution (0.499964831308306). In If-scenario

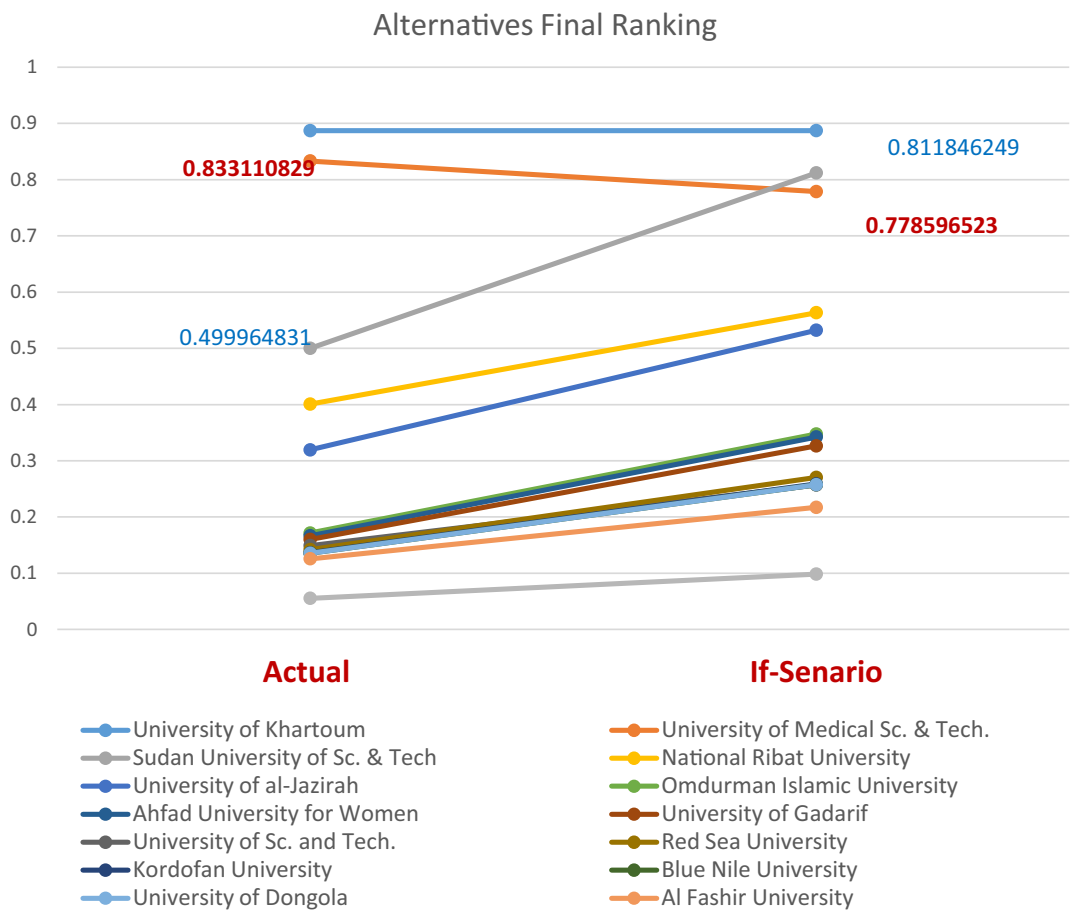


Figure D-6 Actual Final Ranking vs. If-scenario Final (University of Medical is swapped with Sudan University of Sc.).

Test, the 'University of Medical Sc. & Tech.' occupied the 3rd position with relative closeness to ideal solution (0.778596522949184) while the 'Sudan University of Sc. & Tech' occupied the 2nd position with relative closeness to ideal solution (0.811846249121775).

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