Sudan University of Science and Technology
Computer Science and Information Technology

PERFORMANCE EVALUATION OF SUDANESE UNIVERSITIES AND ACADEMIC STAFF USING FUZZY LOGIC TECHNIQUE

تقييم اداء الجامعات السودانية وهيئة التدريس باستخدام تقنية المنطق الضبابي

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"رَبِّ اشْرَحْ لِي صَدْرِي* وَيَسِّرْ لِي أَمْرِي* وَاحْلُلْ عُقْدَةً مِّن لِّسَانِي * يَفْقَهُوا قَوْلِي"

سورة طه - الآية 25-28

وَيَسْأَلُونَكَ عَنِ الرُّوحِ ۖ قُلِ الرُّوحُ مِنْ أَمْرِ رَبِّي وَمَا أُوتِيتُم مِّنَ الْعِلْمِ إِلَّا قَلِيلًا

سورة الإسراء - الآية 85

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To my parents:

Khalid Adam Yousif & Zainab Hassan Igal.

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ABSTRACT (English)

The excellence of Sudanese Universities and Academic Staff members 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 research, suitable quantitative and qualitative performance evaluation criteria are determined and defined, pairwise comparisons and evaluation forms are designed and exploited in order to get experts opinions/preference on the evaluation criteria that are used to measure the universities and academic staff performance using different types of survey.

The research 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.

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 Fuzzy Consistency Algorithm (FCA) 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 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 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) are ranked using the proposed hybrid computational model. The model result is tested by comparing the ranking of previous year admission result that was done by the General Administration for Admissions, Degree Evaluations & Verification.

ABSTRACT (Arabic)

المستخلص

من الممكن تصنيف ومعرفة التميز فى اداء الجامعات السودانية واعضاء هيئة التدريس بنحو فعال وفقا لمعايير تصنيف مصصممة بصورة منهجية و موضوعية مما يساعد فى تطوير العملية التعليمية والرقى بنتائجها المرجوه.

في المرحلة الأولى من هذا البحث، تم تحديد وتعريف معايير تقييم الأداء الكمية والنوعية المناسبة ، تصميم مصفوفات المقارنة الثنائية و استمارات التقييم من أجل الحصول على آراء الخبراء لتقييم وقياس تلك المعايير ومن ثم تقييم وقياس اداء المعاهد والجامعات السودانية وهئيات التدريس اعتمادا على تلك المعايير و باستخدام انواع مختلفة من المسح.

بناء على هذه المسوحات تم تطوير نموذج حسابى باستخدام المنطق الضبابي لقياس وتصنيف أداء الجامعات السودانية وأعضاء هيئة التدريس، والتي تشمل حساب معايير الأوزان والتقييم العام للجامعات السودانية وأعضاء هيئة التدريس باستخدام تقنيات عملية التحليل الهرمى وكذلك بتقنية ترتيب الافضلية وتشابها مع المثالية باستخدام الارقام الضبابية الثلاثية.

يمثل اتساق الحكم الذي يقوم به الخبراء / المشاركون خلال سلسلة من المقارنات الثنائية قضية محورية واساسية فى عملية التقييم وصدقية الناتج النهائي (تقييم الأداء). تقدم هذه الدراسة خوارزمية التناسق باستخدام المنطق الضبابي (FCA) لفحص وتقييم مستوى اتساق حكم الخبراء.
تقترح الخوارزمية قيمة لغوية جديدة متسقة مع ما قرره سابقا من احكام كخيار للخبراء في حالة الحكم المتناقض في تقييم الأداء. استنادا إلى الخوارزمية المقترحة، يقدم البحث أداة جديدة تسمح للخبراء بتتبع وفهم جذور مشكلة التضارب وتحديد الخيار الافضل من ناحية الاتساق. تسمح الخوارزمية للمستخدم بضبط درجة الاتساق. احتوت الدراسة على تطبيق الخوارزمية المقترحة فى تقييم أداء الجامعات السودانية باعتبارها دراسة تجريبية.

شمل اخر الدراسة فحص النتائج النهائية للنموذج الحسابى المقترح لنتائج الترتيب لخمسة عشر جامعة اشتملت على عشر جامعات حكومية و خمس جامعات خاصة ومن ثم مقارنتها بنتائج السنين السابقة لدخول الجامعات السودانية.

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LIST OF ABBREVIATIONS

AC	Academic Criteria
CC	Criteria Code
CI	Consistency Index
CR	Consistency Ratio
DV	Distance Value
FAHP	Fuzzy Analytical Hierarchy Process
FCA	Fuzzy Consistency Algorithm
FNIS	Fuzzy Negative Ideal Solution
FPIS	Fuzzy Positive Ideal Solution
FTOPSIS	Fuzzy, Technique for Order of Preference by Similarity to Ideal Solution
GAADEV	General Administration for Admissions, Degree Evaluations & Verification
HE	Higher Education
IT	Importance Type
LV	Linguistic Degree Value
MaxSR	Maximum Scale Rank
MBO	Management by Objectives
NF	Neuro-Fuzzy
PE	Performance Evaluation
RCI	Random Consistency Index
RCO	Recommended Consistent Option
SN	Serial Number
SR	Scale Rank
TFN	Triangular Fuzzy Number
UC	University Criteria

CHAPTER I

1. INTRODUCTION

1.1 Background

During the past years there have been considerable increases in the number of institutions of higher education in Sudan. The total number raised from 11 institutes in 1980s to more than 127 higher education institutes in 1990s & 2000s (وزارة التعليم العالى والبحث العلمى ، 2016). Figure 1.1 represents the total numbers of different types of institutes and the growth rate of public & private universities with Bar chart and Combo chart respectively. Most of those universities have several faculties such as medicine, engineering, science, arts, etc. There was a critical need for increasing the number of Sudanese institutions to accommodate the accumulated number of applicants. This rapid increase requires continues and enough scientific research in performance evaluation (PE) and proper processed information that can help and guide the following:

- ✓ Education institutes to match up their current capabilities versus the standard requirements and plan for future development.
- ✓ Applicants & Students' Parents to figure out the best education institutions and the best faculty.
- ✓ Ministry of higher education to follow up the required standards and establish future plans.

Globally, also there are significant changes in university system of organization and funding. The classical activities of teaching, research and service are increasingly dedicated to the necessities of society (Etzkowitz, 2003) and universities have been assuming active accountabilities within the economy (Coccia, 2008). Making university, faculty, and academic staff evaluation in line with the changes in the university system has become a priority especially in Sudan and in many other countries around the world. University assessment is becoming more official and complex, and numerous organizations have recommended transparency in standards and procedures, consistency over time between candidates with similar profiles, openness in the evaluation of tenure-track faculty and care for unsuccessful candidates (Huber, 2002).

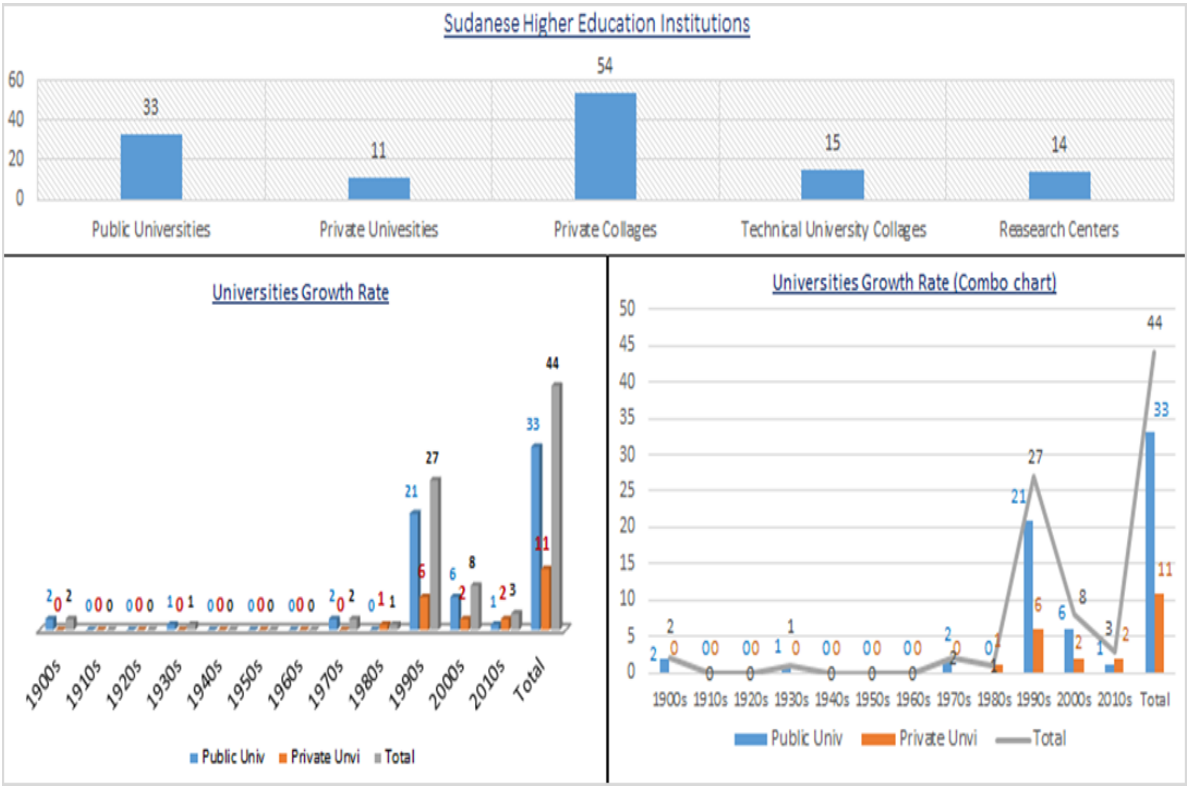


Figure 1. 1: Higher Institution Types and Universities Growth Rate

As an outcome of these changes, there is a chance and a challenge for each university to arrange the activity of its faculty members with its mission and strategic plans. Universities are supposed to make evaluations on promoting, recruiting, granting tenure and compensating excellence based on accepted objective evaluation criteria. However, in spite of the global rising interest in the performance evaluation of university activities, and in particular in faculty assessment, there are only a few researches that attempt to appraise the overall activity of the academic staff (Elmore, 2008) (Costa, Oliveira, 2012). Thus, there is a demand to acquire comprehensive appraisal systems, based on new techniques that can effectively indicate the variances among the academic staff and faculties taking into account the university mission.

Performance evaluation (PE) is an organized and regular process that evaluates an organization or an individual employee's job functioning and output in relative to certain pre-established criteria and organizational goals. In higher educational institutes, the performance evaluation is key factor in improving the quality of work input, inspires staff and make them more engaged. Academic staff is appraised on the basis of definite factors like students feedback, teaching-learning and assessment of related activities, expert development activities such as doing research work, contributing to national and

international conferences, publishing research papers, leading and contributing in technical workshops. The judgments and views of managements, coworkers, and sub-ordinates also plays an essential role in performance measurement. All these factors are jointly used to evaluate an academic staff's performance.

Employee/organization performance is related to job duties which are expected by a worker/organization and how perfectly those duties are accomplished. Many managers assess the employee performance on an annual or quarterly basis in order to help them identify areas for enhancement. PE system depends on the type of the business for an organization. PE mostly relates to the product output of a company or the end users of an organization.

Several appraisal methods are used for employee performance appraisal such as Graphic rating scale method, forced choice distribution method, behavioral check list method, etc. Some methods that were utilized in the past are not currently used like ranking, critical incident, and narrative essays. New methods have been suggested for performance appraisal technique like Management by Objective (MBO) and assessment Centers.

Generally, performance evaluation aims to recognize current skills' status and capabilities of the work force or an organization. Any standard appraisal system consists of collection of data in which information is extracted from then converted into a real number called performance rating. The employees'/organization's contribution to an organization/society depends on the evaluation of his/her/it rating. It is essential to have accurate unbiased appraisal assessment in order to measure the appraisee' contribution to organization objectives. Employers/managers/experts use characteristics such as knowledge in particular field, skills to achieve a goal and target achieving attitude in order to decide on the employee's/organization's performance level. Since these factors mostly are uncertain and vague in nature, a fuzzy performance appraisal method is more appropriate.

Majority of the occurrences that we encounter on a daily basis involve a certain level of ambiguity and fuzziness in the description of their nature. "Khalid's performance is unsatisfied" & "The Weather is warm today". These are examples of fuzzy propositions. What degree of performance is considered unsatisfied? By how much does performance have been increased to be considered excellent, and not unsatisfying? Do we all have the same view about his performance? This type of fuzziness associated with continuous

phenomena is common in any field of study. In the conventional mathematical methods, the logic of these methods is the precise Boolean logic which has two states 1 or 0 which means that each proposition must either be false or true (Shaout & Yousif, 2014/a).

Lotfi Zadeh (1965) introduced fuzzy logic as means to model and handle uncertainty in natural language. Fuzzy logic describes the qualitative nature of the object while conventional logic systems focus on their quantitative aspects.

1.2 Problem Statement

Although many universities and colleges were established in the recent few years in Sudan, but very few of them are truly following proper and regular process that offering quality performance evaluation. The following are some of the current issues facing Sudan's universities:

- There is need to find an accurate technique that can determine the gap between the standards established by the ministry of higher education and the actual status of Sudanese universities.
- The stakeholders (parents, students, education officials, etc.) are in a state of complete confusion in choosing a quality education Institution for their career planning. Furthermore, there is lake of information about the current level of quality in the mature and well established universities in Sudan.
- The lake of effective methods to assess academic staff and proper evaluation information cascade several problems in planning, management and developing the resources.

1.3 Methods

Fuzzy Analytical Hierarchal Process (FAHP) and the technique for order of preference by similarity to ideal solution (FTOPSIS) have been used in developing our evaluation model system. The FAHP is used to construct the Sudanese universities and academic staff hierarchical frameworks of performance evaluation criteria and to determine the relative criteria weights. Fuzzy TOPSIS method is used to obtain the final rank of the

alternative (i.e. Universities & Academic staff). Alternatives' bottom criteria were used by FTOPSIS methods to calculate the distance of each alternative from ideal negative & positive ideal solutions. Microsoft Excel is used to develop and process several operational functions such as calculating the consistency ratio, aggregation, normalizations, preference approximation and separation measures.

1.4 Research Objectives & Outcomes

Given this problem, the base objectives of the proposed research are as follows:

- To identify the performance measurement indicators for evaluating the best academic staffs, faculties and Sudanese academic institutions.
- To design and develop an appropriate Fuzzy performance evaluation model with possibly new theorems and fuzzy data structures which can handle both subjective and objective factors in the evaluation process that can fit the Sudanese culture. This helps evaluators to objectively assess the key entities involved in academic process starting from academic staff, faculty and university.
- To implement and test the proposed system

The evaluation result serves the Sudanese communities as follows:

- Students/Applicants and students' parents will find an accurate source of processed information that guides and helps applicants and students' parents to select the best university for their future study in a specific field.
- Regular ranking process based on agreed performance evaluation criteria will help the Ministry of Higher Education and Research in Sudan to follow up and observe the faculties and universities academic standard level and maintain future plans.
- Regular ranking process based on agreed performance evaluation criteria & appraisal system for academic staff will help university and faculty management to upgrade and promote their staff as well as to bridge any gap and to maintain the future plans.

1.5 Results and Contributions

In this dissertation, nine main criteria and forty-one sub criteria were identified, considered and weighted as performance evaluation criteria for Sudanese high academic institutes. Furthermore, there levels of academic staff evaluation criteria were identified,

considered and weighted. The first level consists of six criteria, the second level consist of twenty-seven criteria and the last level consist 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 allows experts to trace and understand the roots of inconsistency and select the relevant consistent option(s).

1.6 Organization of Thesis

The thesis organized as follows, chapter 1 presents a background of Sudanese higher education institutes, problem statements, methods used, research objectives & research outcomes and a brief results and contributions of this research. The literature review is introduced in chapter 2. The classification model is introduced in chapter 3. The proposed evaluation criteria for Sudanese university and academic staff are presented in chapter 4. Chapters 5 & 6 present survey design, data collection and analysis. The new proposed consistency algorithm is introduced in Chapter 7. Chapter 8 introduces aggregation, normalizations, preference approximation. The final ranking result process is presented in chapter 9. Model testing, discussion, recommendations, conclusion and future work are stated in Chapter 10.

1.7 Summary

This chapter introduced a background overview about Sudanese universities/institutes, institutions growth rate, related issues and challenges, research problem statement, research objectives & outcomes, methods, results & contribution. Furthermore, organization of thesis was defined.

CHAPTER II

2. LITERATURE REVIEW

In this chapter, a review of the following is presented: basic concept of fuzzy logic, performance appraisal methods, traditional & modern methods, comparison of performance appraisal methods, fuzzy related appraisal techniques such as fuzzy analytical hierarchy process, technique for order preference by similarity to ideal solution, multistage fuzzy & cascaded fuzzy technique, fuzzy based multifactorial technique, hybrid neuron-fuzzy technique and type-2 fuzzy evaluation technique.

2.1 Basic Concept of Fuzzy Logic

Majority of the occurrences that we encounter on a daily basis involve a certain level of ambiguity and fuzziness in the description of their nature. "Ali's performance is unsatisfied" & "The Weather is warm today". These are examples of fuzzy propositions. What degree of performance is considered unsatisfied? How much does it require to increase to be considered excellent, and not unsatisfied? Do we all have the same view of his performance? This type of fuzziness associated with continuous phenomena is common in any field of study. In the conventional mathematical methods, the logic of these methods is the precise Boolean logic which has two states 1 or 0 which means that each proposition must either be false or true.

In 1965, Lotfi Zadeh introduced Fuzzy Logic as means to model and handle uncertainty in natural language (Zadeh, 1965). Fuzzy logic describes the qualitative nature of the object while conventional logic systems focus on their quantitative aspects.

2.1.1 Fuzzy Sets

Fuzzy Set is a class with a continuum of membership grades (Zadeh, 1965). To explain the concept of fuzzy set, let us go back to this question "What degree of performance is considered unsatisfied?", and let us define, as an example, a fuzzy set called "Unsatisfied Performance". We need first to specify the universe of discourse (P) as follows:

$P = \{p \mid 0 \leq p \leq 100\}$ where P covers all performance in percentage rating,

Say, the "Unsatisfied Performance" fuzzy set is S. Hence the membership function for S is defined as $\mu s: P \longrightarrow [0,1]$ such that $\mu s(p) \in [0,1]$ is the degree to which an element $p \in P$ belongs to the fuzzy set S.

If we consider 40% to be unsatisfied performance, then $\mu s\ (p \leq 40) = 1$, on the other hand if we consider the performance of 60% and above to be certainly not judged as Unsatisfied Performance and thus not belong to S, then $\mu s(p \geq 60) = 0$.

Therefore, the degree of belongingness to S increases from 0 to 1, as performance decrease from 60% to 40%.

The membership functions are the fundamental blocks of fuzzy set theory. Choice of MF depends on the nature of problem you have to solve. MFs take value between 0 & 1. Some time you may need to allow some of them never reaching 1 in order to represent never certain info. The selection of fuzzy set functions influences how well fuzzy systems approximate functions. The most common fuzzy sets are triangles, trapezoids, and Gaussian bell curves (Mitaim S. 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 membership function has been given minimum error (Manal S. et al. 2012). Barua, Singdha, and Kosheleva (2014) provide a theoretical explanation of the practical success of triangular membership functions. We used triangular MF which is simpler to implement and fast in computation (Pedrycz W, 1994; Barua et al, 2014).

2.2 Performance Appraisal Methods

Performance Appraisal can be generally categorized into two groups: Traditional (Past oriented) methods and Modern (future oriented) methods (Aggarwal, 2013). Other researchers (Jafari, 2009) have classified the existing methods to three groups; absolute standards, relative standards and objectives. The performance appraisal methods are as follows:

2.2.1 Traditional Methods

Traditional methods are comparatively older methods of performance appraisal. These methods were past oriented approaches which concentrated only on the past performance. The following are the topical traditional methods that were used in the past:

a) Ranking Method

A superior ranks his employee based on merit from best to worst (Gary, 2011). However, how best and why best are not elaborated in this method.

b) Graphic Rating Scales

In 1931 a behaviorism enhancement was introduced to graph rating scale (Bracken et al, 2001). According to (Gary, 2011), graphic rating scale is a scale that lists a number of traits and a range of performance for each. The employee is then graded by finding the score that best defines his or her level of performance for each trait.

c) Critical Incident Method

This method is concentrated on certain critical behaviors of employee that makes significant difference in the performance. According to (Gary, 2011), critical incident method keeps a record of unusually employee's work related behavior and revisit it with the employee at prearranged times.

d) Narrative Essay

In this method the administrator writes an explanation about employee's strength and weakness points for improvement at the end of evaluation time. This method primarily attempts to concentrate on behavior (Jafari, 2009). Some of the evaluation criterion are as follows: overall impression of performance, existing capabilities & qualifications, previous performance and suggestions by others.

2.2.2 Modern Methods

Modern Methods were formulated to enhance the conventional methods. It tried to enhance the shortcomings of the old methods such as biasness and subjectivity. The following presents the typical modern methods:

e) Management by Objectives (MBO)

The performance is graded against the achievement of the objectives specified by the management. MBO includes three main processes; object formulation, execution process and performance feedback (Wu B, 2005). Weihrich (2000) proposed the system approach to management by objectives. It consists of seven components; strategic planning and hierarchy of objects, setting objectives, planning for action, implementation of MBO, control and appraisal, subsystems and organizational and management development.

f) Behaviorally Anchored Rating Scales (BARS)

BARS contrast an individual's performance against specific examples of behavior that are anchored to numerical ratings. For example, a level three rating for a doctor may require them to show sympathy to patients while a level five rating may require them to show higher levels of empathy. BARS utilize behavioral statements or solid examples to explain various stages of performance for each element of performance (Elverfeldt, 2005).

g) Humans Resource Accounting (HRA).

In this method, the performance is judged in terms of cost and contribution of the employees. Johnson (Johanson et al, 1998) incorporated both HRA models and utility analysis models (UA) to form the concept of human resource costing and accounting (HRCA).

h) Assessment Center

An assessment center is a central location where managers may come together to have their participation in job related exercises evaluated by trained observers. It is more focused on observation of behaviors across a series of select exercises or work samples. Appraisees are requested to participate in in-basket exercises, work groups, computer simulations, fact finding exercises, analysis/decision making problems, role playing and oral presentation exercises (Byham, 1986).

i) 360 Degree

It is a popular performance appraisal technique that includes evaluation inputs from a number of stakeholders like immediate supervisors, team members, customers, peers

and self (Jafari, 2009). 360 Degree provides people with information about the influence of their action on others.

j) 720 Degree

720-degree method concentrates on what matter most, which is the customer or investor knowledge of their work (Mondy, 2008). In 720-degree appraisal feedback is taken from external sources such as stakeholders, family, suppliers, and communities. 720 degree provides individuals with extremely changed view of themselves as leaders and growing individuals. It is 360-degree appraisal method practiced twice. Table 2.1 shows the summary of performance appraisal methods with pros and cons for each method.

Table 2. 1 Appraisal performance Methods Summary

SN	Appraisal Methods	Key Concept	Pros	Cons
a).	Ranking Method	Rank employees from best to worst on a particular trait.	✓ Simple and easy to use. ✓ Fast & Transparent.	× Less objective. × Not suitable for large workforce. × Difficult to determine workers' strengths and weakness.
b)	Graphic Rating Scales	Rating scales consists of several numerical scales representing job related performance criterions such as dependability, initiative, output, attendance, attitude etc. The employee is rated by identifying the score that best define his or her performance for each trait.	✓ Adaptability. ✓ Easy to use and easily constructed. ✓ Low cost. ✓ Every type of job can be evaluated. ✓ Large number of employees covered.	× Rater's bias (subjectivity). × Equal weight for all criteria.
c)	Critical Incident	The method is concentrating on certain critical behaviors of employee that makes all the difference in the performance.	✓ Feedback is easy. ✓ Assessment based on actual job behaviors. ✓ Chances of subordinate improvement are high.	× Analyzing and summarizing data is time consuming. × Difficult to gather info about critical incidents via a survey.

d)	Narrative Essays	Rater writes down the employee description in detail within a no. of general groups such as overall impression of performance, existing capabilities and qualifications of performing jobs, strengths and weaknesses.	✓ Filing information gaps about the employees. ✓ Address all factors. ✓ Provide comprehensive feedback.	× Time consuming. × Easy rater bias. × Required Effective writers.
e)	Management by Objectives	The performance is rated against the objectives achievement stated by the management.	✓ Easy to execute and measure. ✓ Employees have clear understanding of the roles and responsibilities expected of them. ✓ Assists employee advising and direction.	× Difference in goal interpretation. × Possibility of missing integrity, quality, etc. × Difficult for appraise to agree on objectives. × Not applicable to all jobs.
f)	Behaviorally Anchored Rating Scale	BARS links aspects from critical incident and graphic rating scale methods. The manager grades employees' according to items on a numerical scale.	✓ Employee performance is defined by Job behaviors in an expert approach. ✓ Involvement of appraiser and appraisee lead to more acceptance. ✓ Helps overcome rating errors.	× Scale independence may not be valid/ reliable. × Behaviors are activity oriented rather than result oriented. × Time consuming. × Each job requires spate BARS scale.
g)	Human Resource Accounting (HRA)	The people are valuable resources of an organization. Performance is assessed from the monetary incomes yields to his or her organization. It is more reliant on cost and benefit analysis.	✓ Improvement of human resources. ✓ Development and implementation of personnel policies. ✓ Return on investment on human resources. ✓ Enhance the proficiencies of employees.	× No clear-cut guidelines for finding cost and value of human resources. × The method measures only the cost to the organization and ignores employee value to the organization. × Unrealistic to measure employee under uncertainty.
h)	Assessment Centers	Employees are appraised by monitoring their behaviors across a series of selected exercises.	✓ Better forecasts of future performance and progress. ✓ Concepts are simple.	× Costly and difficult to manage. × Needs a large staff and a great deal of time. × Limited number of

			✓ Flexible methodology. ✓ Assists in promotion decisions and diagnosing employee development needs. ✓ Allow multiple traits measurement.	people can be processed at a time.
i)	360 Degree	It depends on the input of an employee's superior, peers, subordinates, sometimes suppliers and customers.	✓ Allows employees to gain a more understanding of their impact on people they interact with every day. ✓ Excellent employee development tool. ✓ Precise and dependable system. ✓ Legally more justifiable.	× Time consuming and very costly. × Difficult to interpret the findings when they differ from group to group. × Difficult to execute in cross-functional teams. × Difficult to maintain confidentiality.

2.2.3 The Comparison of Performance Appraisal Methods

As shown in table 2.1 each method has pros and cons. In order to determine the best appraisal method, you need to answer this question; "Evaluation with respect to what "best"?" The organization goals and performance type are key factors to decide the best method. Jafari et al, (2009) proposed a frame work for the selection of appraisal methods and compared some performance evaluation methods to facilitate the selection process. The framework is based on six criteria which are maintained by an expert as shown in table 2.2 (a: Ranking Method, b: graphic rating scales method, etc.).

Table 2. 2 : Performance appraisal methods' comparison

Methods / *Criteria*	*a*	*b*	*c*	*d*	*e*	*f*	*i*
Training needs evaluation	C	B	A	B	A	A	A
Coincidence with institutes	C	A	A	B	A	A	B
Excite staff to be better	C	C	B	C	B	B	A
Ability to compare	A	B	C	C	A	B	A
Cost of method	A	A	B	A	C	C	B
Free of error	A	C	C	C	B	B	A

The matrix below is extracted from table 2.2 where A is replaced by 3, B with 2 and C with 1.

$$\begin{array}{c} \\ x1 \\ x2 \\ x3 \\ x4 \\ x5 \\ x6 \end{array} \begin{pmatrix} 1 & 2 & 3 & 2 & 3 & 3 & 3 \\ 1 & 3 & 3 & 2 & 3 & 3 & 2 \\ 1 & 1 & 2 & 1 & 2 & 2 & 3 \\ 3 & 2 & 1 & 1 & 3 & 2 & 3 \\ 3 & 3 & 2 & 3 & 1 & 1 & 2 \\ 3 & 1 & 1 & 1 & 2 & 2 & 3 \end{pmatrix}$$

The scores are normalized by a linear scale using one of the following formulas:

Benefits: $r_{ij} = \frac{x_{ij}}{\max(x_i)}$, or

Cost: $r_{ij} = \frac{\min(x_i)}{(x_{ij})}$

The matrix after normalizing with respect to Benefits looks as follows:

$$\begin{array}{c} \\ x1 \\ x2 \\ x3 \\ x4 \\ x5 \\ x6 \end{array} \begin{array}{c} a \quad b \quad c \quad d \quad e \quad f \quad i \\ \begin{pmatrix} 0.33 & 0.67 & 1.00 & 0.67 & 1.00 & 1.00 & 1.00 \\ 0.33 & 1.00 & 1.00 & 0.67 & 1.00 & 1.00 & 0.67 \\ 0.33 & 0.33 & 0.67 & 0.33 & 0.67 & 0.67 & 1.00 \\ 1.00 & 0.67 & 0.33 & 0.33 & 1.00 & 0.67 & 1.00 \\ 0.33 & 0.33 & 0.50 & 0.33 & 1.00 & 1.00 & 0.50 \\ 1.00 & 0.33 & 0.33 & 0.33 & 0.67 & 0.67 & 1.00 \end{pmatrix} \end{array}$$

Then define normalized weight for each criterion using multiple linear regressions to define straight rank of each criterion by using the following formula as shown in table 2.3:

$$\boldsymbol{w_j} = \left(n - r_j + 1\right) / \sum_{k=1}^{n} (n - r_k + 1)$$

Where $\boldsymbol{w_j}$ is the normalized weight for the jth criterion; n is the number of criterion under consideration and r_j is the rank position of criterion.

Then use each criteria weight in table 2.3 with the above normalized matrix to rank the appraisal method as shown in the table 2.4. In this example MBO is on the top of the list, then followed by 360 Degree, etc.

Table 2. 3: Rank, weight and $\boldsymbol{w_j}$ of each criterion

Criteria	*Rank (rj)*	*Weight (n-rj + 1)*	*Wj*
Training needs evaluation	4	3	0.14
Coincidence with institutes	6	1	0.05
Excite staff to be better	5	2	0.1
Ability to compare	1	6	0.29
Cost of method	2	5	0.24
Free of error	3	4	0.19

Table 2. 4: Methods Ranking

Methods	Methods' grades
e. MBO	0.91
i. 360 Degree Feedback	0.87
f. BARS	0.82
a. Ranking	0.66
c. The critical incident	0.54
b. The graphic rating scale	0.51
d. The essay	0.4

2.3 Fuzzy Related Appraisal Techniques

2.3.1 AHP & FAHP

a) Analytic Hierarchy Process (AHP) Technique

Analytic hierarchy process (AHP) is a quantitative technique for ranking decision alternatives using multiple criteria (Russell, Taylor, 2003). Structuring the alternatives into a hierarchical framework is the AHP technique to resolve complicated decisions. The hierarchy is formed through pair-wise comparisons of individual judgments rather than attempting to rank the entire list of decisions and criteria at the same time. This process normally includes six steps (Vahidnia et al, 2009); defining the unstructured problem, specifying criteria and alternatives, recruiting pair wise comparisons among decision elements, using the eigenvalue method to forecast the relative weights of the decision elements, calculating the consistency properties of the matrix and gathering the weighted decision elements.

Deciding and selecting the essential factors for decision-making is the most inventive job in making decision. In the AHP, the selected factors are arranged in a hierarchic structure descending from a global goal through criteria to sub-criteria in their appropriate successive levels (Saaty, 1990), (Saeed et al, 2012).

Saaty (1990) helped introducing AHP. The principles are reviewed giving overall background information on the measurement type utilized, its properties and application. Saaty (1990) also presented how to structure a decision problem, how to drive relative scales utilizing judgment or data from a standard scale and how to execute the subsequent arithmetic operation on such scales avoiding useless number crunching. The

decision is given in the form of paired comparison (Saaty, 1986), (Saaty, 1980), and (Saaty, 1977). The AHP is utilized with two types of measurement which are relative and absolute (Saaty, 1990). The paired comparisons in both measurements are performed to derive priorities for criteria with respect to the goal. Figure 2.1 shows an example for relative measurement for "Choosing the best house to buy" where the paired comparisons are performed throughout the hierarchy. In this example, the problem was to determine which of the three houses to select. The *first step* is to structure the problem as hierarchy (as shown in figure 2.1). The top level is overall objective "Satisfaction with house". The 2nd level contains the eight criteria that contribute to the objective and the bottom level contains the three nominee houses that are to be assessed against the criteria in the 2nd level.

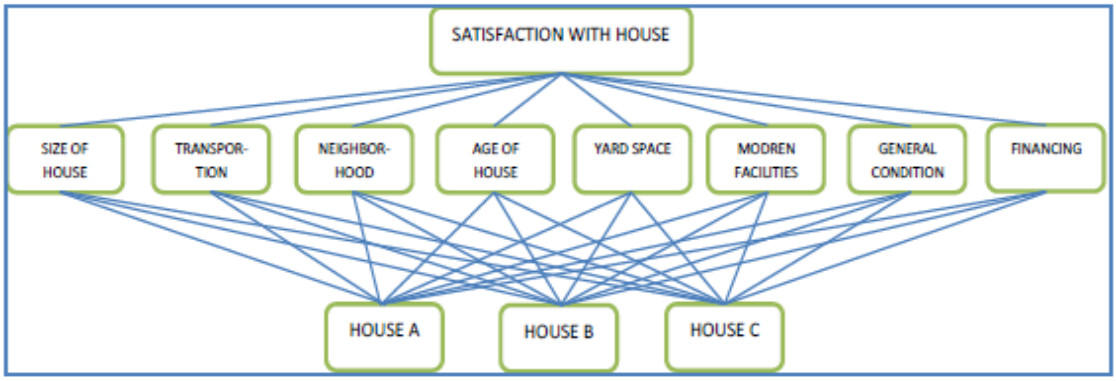


Figure 2. 1: Decomposition of the problem into a hierarchy

The 2nd Step is the gathering of pair-wise comparison judgments using the scale as shown in the table 2.5 and the matrix pair-wise comparison as shown in table 2.6. Instead of naming the criteria, table 2.6 shows a number. The number is 1 for the criteria 'Size of House', 2 for 'Transportation', 3 for 'Neighborhood', etc. Houses are also compared pair-wise with respect to each criterion in the 2nd level as shown in figure 2.1. Hence, there will be eight decision matrices as shown in table 2.7 (i.e. 8 elements in 2nd level and 3 houses to be compared).

Table 2. 5: The fundamental scale

Intensity of importance on an absolute scale	Definition
1	Equal Importance
3	Moderate importance of one over another
5	Essential
7	Very strong importance
9	Extreme importance
2,4,6,8	Intermediate values between adjacent judgments

Table 2. 6: Pair-wise comparison matrix level 1

	1	2	3	4	5	6	7	8	Priority vector
1	1	5	3	7	6	6	1/3	1/4	0.173
2	1/5	1	1/3	5	3	3	1/5	1/7	0.054
3	1/3	3	1	6	3	4	6	1/5	0.188
4	1/7	1/5	1/6	1	1/3	1/4	1/7	1/8	0.018
5	1/6	1/3	1/3	3	1	1/2	1/5	1/6	0.031
6	1/6	1/3	1/4	4	2	1	1/5	1/6	0.036
7	3	5	1/6	7	5	5	1	1/2	0.167
8	4	7	5	8	6	6	2	1	0.333

The 3rd step is to form the houses global priorities. Local priorities will be arranged with respect to each criterion in a matrix. The global priority is calculated by multiplying each column of vectors by the priority of the corresponding criterion then adds across each row. The results will be the desired vector of the houses as shown in table 2.8.

Table 2. 7: Comparison matrices and local priorities

Size of house	A	B	C	Priority vector	Yard Space	A	B	C	Priority vector
A	1	6	8	0.754	A	1	5	4	0.674
B	1/6	1	4	0.181	B	1/5	1	1/3	0.101
C	1/8	1/4	1	0.065	C	1/4	3	1	0.226
Transportation	**A**	**B**	**C**	**Priority vector**	**Modern facilities**	**A**	**B**	**C**	**Priority vector**
A	1	7	1/5	0.233	A	1	8	6	0.747
B	1/7	1	1/8	0.005	B	1/8	1	1/5	0.060
C	5	8	1	0.713	C	1/6	5	1	0.193
Neighborhood	**A**	**B**	**C**	**Priority vector**	**General Condition**	**A**	**B**	**C**	**Priority vector**
A	1	8	6	0.745	A	1	1/2	1/2	0.200
B	1/8	1	1/4	0.065	B	2	1	1	0.400
C	1/6	4	1	0.181	C	2	1	1	0.400
Age of house	**A**	**B**	**C**	**Priority vector**	**Financing**	**A**	**B**	**C**	**Priority vector**
A	1	1	1	0.333	A	1	1/7	1/5	0.072
B	1	1	1	0.333	B	7	1	3	0.650
C	1	1	1	0.333	C	5	1/3	1	0.278

Table 2. 8: local and global priorities

	1 (0.173)	2 (0.054)	3 (0.188)	4 (0.018)	5 (0.031)	6 (0.036)	7 (0.167)	8 (0.333)	
A	0.754	0.233	0.754	0.333	0.674	0.747	0.200	0.072	0.396
B	0.181	0.055	0.065	0.333	0.101	0.060	0.400	0.650	0.341
C	0.065	0.713	0.181	0.333	0.226	0.193	0.400	0.278	0.263

Example of absolute measurement: Employee Performance

In absolute measurement, paired comparisons are also accomplished through the hierarchy with exception of the alternatives. The grades are contained in the level just

above the alternatives. Absolute measurement is suitable for student admission and employee evaluation and in areas where there is agreement on the standards. Table 2.9 shows the hierarchy of employee evaluation where you can see the goal, criteria, intensities and alternatives. The overall score for Mr. X can be calculated as follow: 0.061 x 0.604 (X-score in 1st criterion) + 0.196 x 0.731 (X-score in 2nd criterion) + 0.043 x 0.199 (X-score in 3rd criterion) + 0.071 x 0.750 (X-score in 4th criterion) + 0.162 x 0.188 (X-score in 5th criterion) + 0.466 x 0.750 (X-score in 6th criterion) =0.623.

In the same way, the score for Y and Z can be shown to be 0.369 and 0.478, respectively. Hence, any number of candidates could be ranked along these lines. Vector of relative number under each criterion utilize to weight the vector of criteria priorities which call this a structural rescaling of the priorities (Saaty, 1990).

Table 2. 9: the hierarchy of employee evaluation

Goal:	Employee Performance Evaluation					
Criteria:	Technical	Maturity	Writing Skills	Verbal Skills	Timely Work	Potential (personal)
	[0.061]	[0.196]	[0.043]	[0.071]	[0.162]	[0.466]
Intensities:	Excell.	Very	Excell.	Excell.	Nofollup	Great
	[0.604]	[0.731]	[0.733]	[0.750]	[0.731]	[.750]
	Abov. Avg.	[Accep.]	Avg.	Avg.	On time	Averag.
	[0.245]	[0.188]	[0.199]	[0.171]	[0.188]	[0.171]
	Avg.	Immat.	Poor	Poor	Remind	Bel. Avg.
	[0.105]	[0.181]	[0.068]	[0.078]	[0.081]	[0.078]
	Bel. Avg.					
	[0.046]					
Alternatives						
(1) Mr. X	Excell.	Very	Avg.	Excell.	On time	Great
(2) Mr. Y	Avg.	Very	Avg.	Avg.	Nofollup	Avg.
(3) Mr. Z	Excell.	Immat.	Avg.	Excell.	Remind	Great

The AHP (Saeed et al, 2012), (Cheng et al, 1999), (Shaout & Yousif, 2014/b) helps the decision-makers to organize a complicated problem in the structure of a simple hierarchy and to assess a great number of quantitative and qualitative factors in an organized method under compound criteria environment in collision. The AHP is classified as additive weighting approach.

b) The FAHP Technique

Analytic Hierarchy Process (AHP) has been extensively utilized to solve multiple-criteria decision making problems in both industrial practice and in academic research.

However, due to fuzziness and uncertainty in the decision-maker's judgment, pair-wise comparison, a crisp with a traditional AHP may be incapable to perfectly get the decision-maker's judgment. Hence, fuzzy logic is initiated into the pair-wise comparison in the AHP to overcome this deficiency in the traditional AHP. It is referred to as fuzzy AHP (FAHP) (Ayağ, Z, 2005).

FAHP method is one of the organized approaches to the alternative selection and justification problem. It uses the concepts of fuzzy set and hierarchical structure analysis. In FAHP technique, the preferences about the importance of each performance attribute could be identified in the form of natural language or numerical value by the decision maker. Also, fuzzy numbers are used in pair-wise comparisons in the decision matrix (Gungor et al, 2009).

There are various FAHP techniques which are proposed by several authors. The earliest effort in FAHP appeared in (Laarhoven, Pedrycz, 1983)**.** It used the proposed method at two separate levels; 1st level was used to obtain fuzzy weights for the decision criteria and 2nd level was used to obtain fuzzy weights for the alternatives under each of the decision criteria. The alternative fuzzy scores along with their sensitivities are obtained by a proper combination of those results. The decision-makers should be able to make a choice for one of the alternatives using these fuzzy scores. (Chang, 1996) introduced a new approach to handle fuzzy AHP by using triangular fuzzy membership value for the pair-wise comparison.

Due to the growing enhancements in the field of education, universities all over the world are requiring high quality and expert academic staff. Rouyendegh and Erkan (2012) evaluated a fuzzy Analytic Hierarchy Process (FAHP) for selecting the most appropriate academic staff where five nominees under ten separate sub-criteria are assessed and ranked as shown in figure 2.2. The FAHP technique uses triangular fuzzy functions with their parameters as shown in table 2.10. The AHP inability to deal with the impression and subjectiveness in the pair-wise comparison process has been enhanced in the FAHP. FAHP replaces the crisp value with a range of values to incorporate the decision-makers' uncertainty. Tables 2.11 and 2.12 demonstrate the relevant pair-wise matrix related to weights for factors and one of the sub-factors respectively.

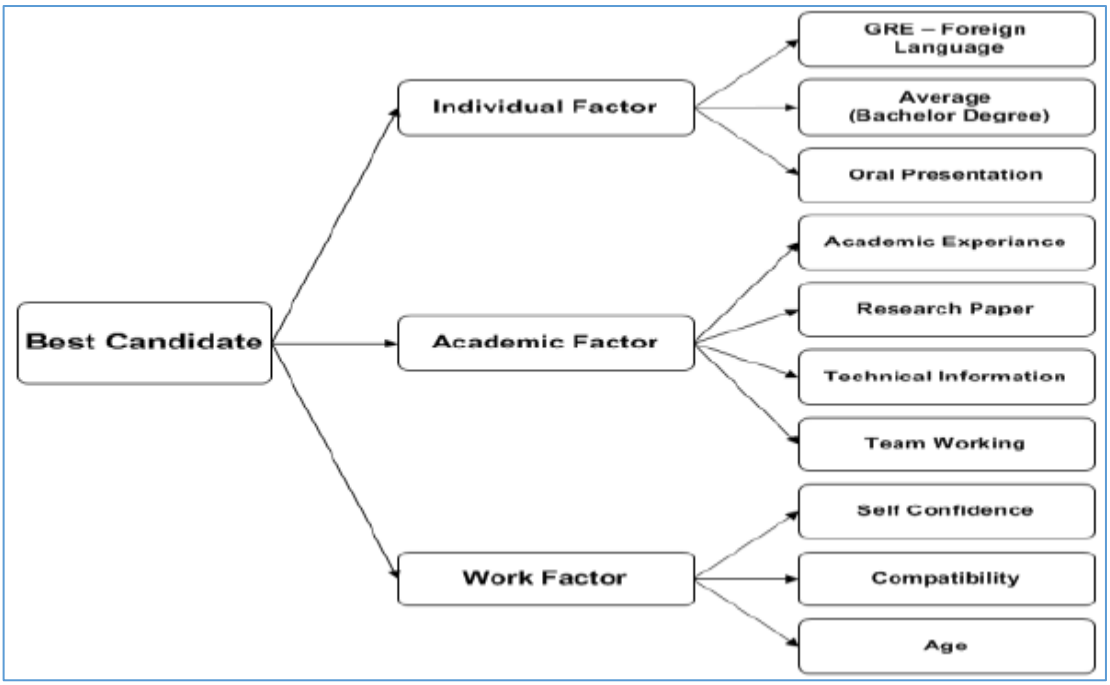


Figure 2. 2: Hierarchy for staff selection problem

Table 2. 10: Fuzzy numbers

Importance intensity	Triangular fuzzy scale
Very good	(3, 5, 5)
Good	(1, 3, 5)
Moderate	(1, 1, 1)
Poor	(1/5, 1/3, 1)
Very poor	(1/5, 1/5, 1/3)

Table 2. 11: Pair-wise comparison matrix and fuzzy weights for factors

DMU	Work factor	Individual factor	Academic factor
Work factor	(1, 1, 1)	(1, 3, 5)	(1, 2, 4)
Individual factor	(1/5, 1/3, 1)	(1, 1, 1)	(1/4, 1/2, 1)
Academic factor	(1/4, 1/2, 1)	(1, 2, 4)	(1, 1, 1)

Table 2. 12: Pair-wise comparison matrix & fuzzy weights for work related sub-factors

Work factor	GRE – Foreign Language	Average (Bachelor degree)	Oral presentation
GRE – Foreign language	(1, 1, 1)	(1, 3, 5)	(1, 5, 7)
Average (Bachelor degree)	(1/5, 1/3, 1)	(1, 1, 1)	(1, 3, 5)
Oral presentation	(1/7, 1/5, 1/3)	(1/5, 1/3, 1)	(1, 1, 1)

c) Comparison of AHP and Fuzzy AHP

Several researchers (Chang, 1996), (Boender et al, 1989), (Buckley, 1985a), (Buckley, 1985b), (Laarhoven et al, 1983), (Lootsma, 1997), (Ribeiro, 1996), (Aþkýn, Güzin, 2007), (Shaout & Yousif, 2014/b), who have revised the fuzzy AHP, which is the expansion of Saaty's theory, have conveyed evidence that fuzzy AHP shows relatively more sufficient description of these kind of decision making processes compared to the conventional AHP methods. Table 2.13 shows the comparison summary points between AHP and FAHP.

Table 2. 13: AHP vs. FAHP summary

	Classical AHP	Fuzzy AHP
1	If information / evaluations are certain, then classical method should be selected.	If information / evaluations are not certain, then fuzzy method should be selected.
2	Classical method cannot reflect the human thinking style. It is mainly used in discrete decision applications and creates and deals with a very unbalanced scale of judgment.	The fuzzy AHP was developed to solve the hierarchical fuzzy problems.
3	The pairwise weight values of AHP approach is a significant factor to the differences.	While the range of fuzzy values for Fuzzy AHP approach is not.

2.3.2 TOPSIS & Fuzzy TOPSIS Techniques

Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is one of the multi-criteria decision making (MCDM) technique that is extensively used to solve MCDM problems (Aruldoss et al, 2013). It was firstly initiated by Hwang and Yoon (Akkoç, Vatansever, 2013), (Hwang, Yoon, 1981). TOPSIS technique is based on the concept that selected alternative is the shortest geometric distance to the positive ideal solution and the longest geometric distance to the negative ideal solution [(Akkoç, Vatansever, 2013), (Chen, 2000). In addition to assert the distance of selection alternative to positive and negative ideal solution, TOPSIS also presents ideal and non-ideal solutions (Wang et al, 2009). TOPSIS is mostly used in different areas of multi criteria group decision making due to the following reasons:

1- It is built on the view that it offers the best suitable result as the shortest distance to positive ideal solution or longest distance to negative ideal solution.

2- It is simple, understandable and empirical.

3- It has some advantages matched to other techniques [(Akkoç, Vatansever, 2013). One of these advantages, the performance, is partially affected by the alternatives number and powered by the rising number of alternatives and criteria in rank differences. Also the rank of alternatives may change when non- optimum alternative is entered (Bottani, Rizzi, 2006).

Fuzzy TOPSIS Technique:

The advantage of using a fuzzy approach is to assign the relative importance of attributes using fuzzy numbers instead of exact numbers (Kabir, Hasin, 2012), (Yang, Hung, 2007). This technique is mainly suitable for solving the group decision-making problem under fuzzy circumstances. The fuzzy TOPSIS technique has the following steps (Akkoç, Vatansever, 2013): identify assessment criteria, select appropriate linguistic variables and linguistic score for alternatives according to criteria weight, aggregate criteria weight, construct fuzzy decision matrix and normalized decision matrix, construct weighted normalized fuzzy matrix, form fuzzy positive ideal and fuzzy negative ideal solutions, and calculate the distance of each alternative to fuzzy positive ideal set and fuzzy negative ideal solution set using the vertex method.

Fuzzy TOPSIS method is used in different fields in the literature. Ghosh (2011) applied fuzzy AHP and TOPSIS to evaluate faculty performance in engineering education. The first ten student's response view of a specific department have been considered to appraise four teachers performances based on the following criteria: method of teaching, subject knowledge, accessibility, communication skill, power of explanation, discipline and behavior and attitude. The proposed model produced the ranking of the four faculty members for appraising their performances.

Among several MCDA/MCDM methods developed to solve real-world decision problems, the TOPSIS persists to work acceptably across different application areas. A state-of-the-art literature survey to classify the research on TOPSIS applications and methodologies was conducted in (Behzadian et al, 2012). The classification structure for this study contained 269 scholarly papers from 103 journals from the year 2000 until 2012. The survey divided the papers into nine application areas; 1. Supply Chain Management and Logistics, 2. Design, Engineering and Manufacturing Systems, 3. Business and Marketing Management, 4. Health, Safety and Environment Management,

5. Human Resources Management, 6. Energy Management, 7. Chemical Engineering, 8. Water Resources Management and 9. Other topics. Scholarly papers in the TOPSIS discipline are further interpreted based on publication year, publication journal, and authors' nationality and other methods combined or compared with TOPSIS (see table 2.14 and figure 2.3).

Table 2. 14: Distribution of papers by application areas

Area	Number	%
Supply Chain Management and Logistics	74	27.5
Design, Engineering and Manufacturing Systems	62	23
Business and Marketing Management	33	12.3
Health, Safety and Environment Management	28	10.4
Human Resources Management	24	8.9
Energy Management	14	5.2
Chemical Engineering	7	2.6
Water Resources Management	7	2.6
Other topics	20	7.4
Total	269	

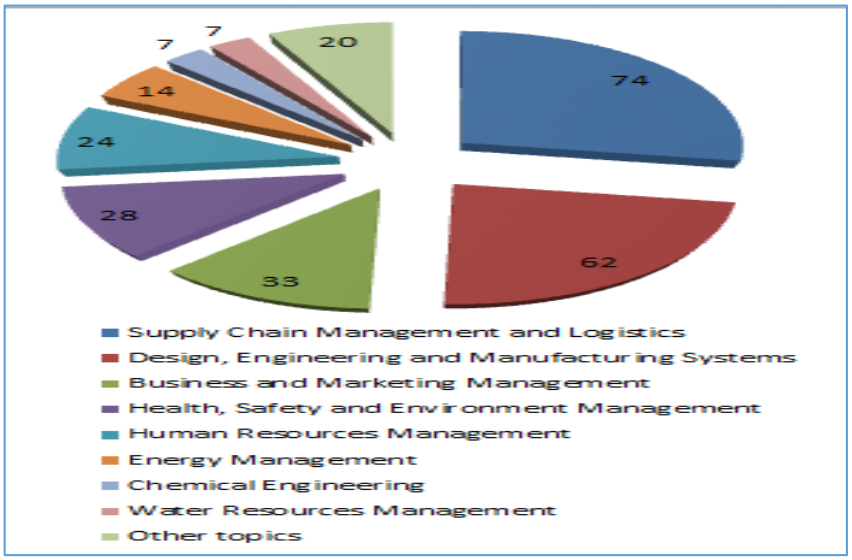


Figure 2. 3: Graphically distribution of TOPSIS papers by application areas

The performance evaluation of banks has valuable results for creditors, investors and stakeholders since it verifies banks' potentials to compete in the sector and has a critical importance for the development of the sector. A fuzzy multi-criteria decision model to evaluate the performances of banks was proposed in (Yalcin et al, 2009). The largest five commercial banks of Turkish Banking Sector were examined and those banks were evaluated in terms of several financial and non-financial indicators. FAHP and TOPSIS methods were integrated in the proposed model.

2.3.3 Multistage Fuzzy & Cascaded Fuzzy Technique

The multistage fuzzy logic inference has been proposed (Shaout et al, 1998), (Shaout et al, 1999), (Yeh, Li, 2004), (Chung, Duan, 2000), (Raju, Zhou, 1993), (Raju et al, 1991), and (Yeh, Chen, 1998) in order to decrease the number of fuzzy rules for compound systems. Besides input and output variables, intermediate variables are adopted in fuzzy rules to mirror human knowledge. The major benefit of utilizing a multistage structure is that the number of fuzzy rules will only grow quadraticly [$O\ (N^2)$] with the number of input variables and membership functions (Bottani, Rizzi, 2006), (Kabir, Hasin, 2012). For example, if a seven inputs and single output fuzzy control system utilizes eight fuzzy values for each input variable, then the maximum number of fuzzy rules will be [$\mathbf{8^7 = 2097152}$] for a single stage fuzzy system. Now considering a multistage inference system which is divided into six stages, the number of fuzzy rules is decreased to [$\mathbf{6 * 8^2 = 384}$]. A systematic approach for designing a multistage fuzzy logic controller (MFLC) for large scale nonlinear systems was proposed in (Yeh, Li, 2004). In designing such a controller, the major tasks were to derive fuzzy rule bases, determine membership functions of input/output variables, and design input/output scaling factors.

There are two fuzzy approaches that can be used to construct a performance appraisal. The first one is using conventional fuzzy approach, which evaluates overall rating from many linguistic fuzzy input variables without any intermediate fuzzy reasoning using many rules. The conventional approach generates too many rules and it is difficult for the expert to take into account all aspects and formulate rules with accurate weight. Sometime an organization may need to weight some factor such as employee safety observation over quantity and employee attitude or any other critical element. In this situation, the whole process will become extremely complicated. Moreover, the function of designing inference rules needs to use high level language instead of using the simple fuzzy toolbox. The second approach defines the relationship between these critical elements and accordingly specifies new large groups (Shaout, Trivedi 2013). Hence performance analysis can be decomposed into multiple processes such as ‘Quality of work’ and ‘Quantity of work’. Both of these processes are used in fuzzy reasoning to determine the intermediate parameter Work. Similarly, ‘Reliability’ and ‘Relationship’ are used in fuzzy reasoning to determine the intermediate parameter person’s attitude and then both processes ‘work’ and ‘attitude’ are combined in a second stage to build work–attitude analysis which is then finally combined with regulatory requirement like

'safety' to generate the overall performance rating as shown in figures 4 and 5. This process is known as stage-wise fuzzy reasoning where it would be possible and flexible to give different weights to different performance processes. However, this approach requires more knowledge about elements' relationships in order to combine the proper elements in one process.

A cascaded fuzzy inference system to produce the performance qualities for some University non-teaching staff that are established on certain performance appraisal criteria was exploited in (Neogi et al, 2011). A cascaded fuzzy inference system (FIS) (Ramirez, Mayorga 2007) with particular features was proposed with the aim of organizing and analyzing the appraisal information of university staff. The proposed cascaded FIS is implemented utilizing Mamdani-type inference. Figure 2.6 explains the cascaded FIS components. It is based on a FIS module that contains five FISs sub-modules in cascade named "Fuzzy communication Block", "Fuzzy motivation Block", "Fuzzy interpersonal Block", "Fuzzy decision making Block" and "Fuzzy knowledge level Block".

In a multi-input multi-output condition where a system contains many subsystems and several outputs are required from each subsystem, an enhanced form of cascaded FIS must be implemented rather than developing FIS for each subsystem. (Mahapatra et al, 2011) proposes a new cascaded Mamdani FIS and its performance is assessed with the assistance of prediction of Indian River water quality index (WQI).

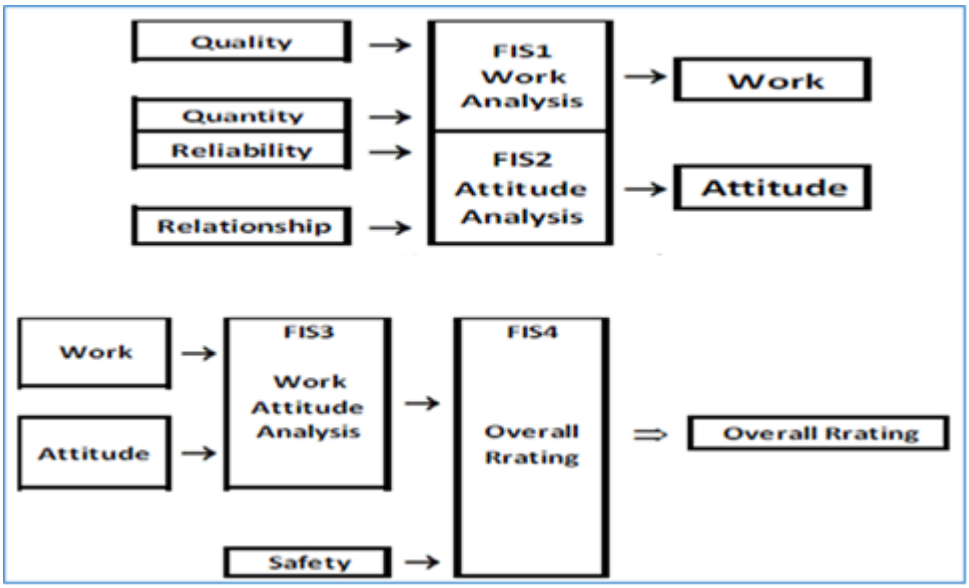


Figure 2. 4: Stage-wise Fuzzy Approach (Shaout, Trivedi 2013).

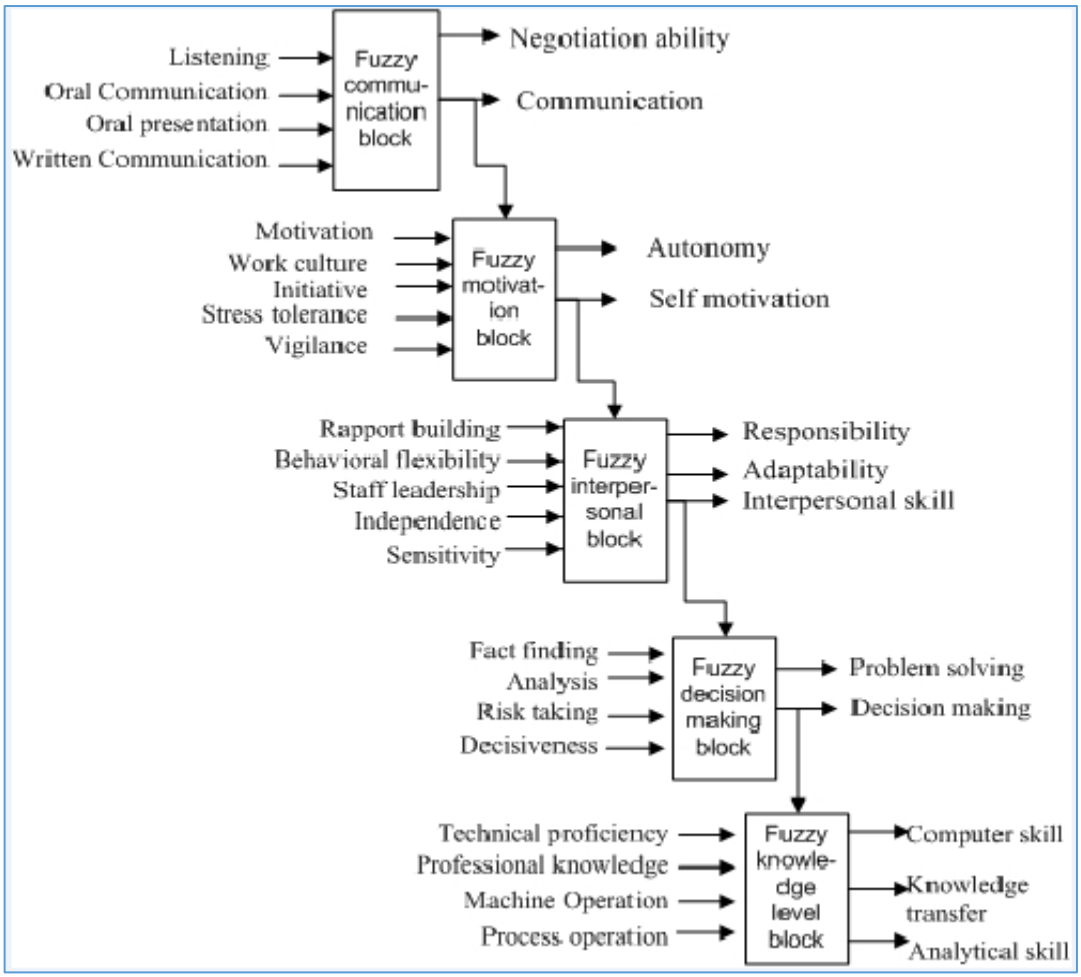


Figure 2. 5: The structure of the proposed Cascaded Fuzzy Inference System

2.3.4 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 (GMeenakshi, 2012). Let U = { $u_1, u_2, u_3 \ldots, u_n$ } be a set of objects for assessment. Let F = { $f_1, f_2, f_3, \ldots, f_m$ } be the set of basic factors in the evaluation process, and let E = { $e_1, e_2, e_3, \ldots, e_n$ } be a set of descriptive grades or qualitative classes used in the assessment. For every object u ϵ U there is a single factor evaluation matrix R (u) with dimension m x n, which is usually the result of a survey. This matrix may be interpreted and used as a 2-D membership function for the fuzzy relation F X E.

Hongxing (1990) stated that most of the mathematical models that are reliant on numerous factors should use multifactorial functions. For example, fuzzy decision-making, fuzzy games, fuzzy programming and fuzzy linear programming with several

objective functions are some of these models that should use multifactorial functions (Hongxing, 1990).

A performance appraisal system has been developed using performance appraisal criteria from Information and communication based company in Malaysia (Yee, Chen, 2010). The system uses multifactorial assessment model in helping top-level management to evaluate their subordinates. The proposed application is the join of four multifactorial evaluation models each of the models denotes aspect to be assessed in the performance appraisal. Once receiving the employees' rating on each aspect from their supervisor, the employees' overall average ratings can be calculated. The concept of four multifactorial evaluation models in the performance appraisal system could be used to ease the changes required in the system every time it is needed. This model develops organized stage in establishing a staff's performance, and thus, it creates a system of appraisal which is able to constantly generate reliable and valid results for the appraisal process. However, others companies require to redefine and evaluate aspects and weightage in order to use this system.

2.3.5 Hybrid Neuro-Fuzzy (NF) Technique

Neuro Fuzzy (NF) is a common framework for solving complicated problems. FIS could be built if there is knowledge expressed in linguistic rules. If we have data, or can learn from simulation then we can use artificial neural networks (ANNs). The integration of ANN and NF is generally categorized into three group's namely concurrent model, fully fused model and cooperative model (Ajith, 2001). A neuro-fuzzy technique is considered as an appropriate methodology for performance appraisal.

It is a perfect technique for processing uncertainty inherent in performance evaluation by using fuzzy logic. The utilization of fuzzy logic in the model lets users express themselves linguistically and to make subjective evaluations. ANN approximates input-output functions without any mathematical model and learns from experience with trial data. ANNs learn employee evaluation parameters based on input/output training data sets and help in the decision making process of employee assessment. Hence, a hybrid neuro-fuzzy technique is completely appropriate for Performance Appraisal (Nisha, Priti, 2013). A neuro-fuzzy technique for performance evaluation that eliminates any emotional components that may have a negative effect on unbiased assessment was

proposed in (Nisha, Priti, 2013). Fuzzy logic processes the ambiguity and uncertainty that is observed in assessment parameters and ANN learns decision making from the available data and experience to provide unbiased decision.

2.3.6 Type-2 Fuzzy Evaluation Technique

Type-2 fuzzy sets take a broad view of type-1 fuzzy sets and systems. Thus, more uncertainty can be controlled. Extreme arithmetic operations are required with type-2 fuzzy sets with respect to type-1. Type-2 fuzzy sets can manage the uncertainty in describing membership functions more efficiently. Each element in type-1 fuzzy sets has degree of membership which is described with a membership function valued in the closed interval [0, 1] (Zadeh, 1965). The idea of a type-2 fuzzy set was initiated by Zadeh in 1975 as an extension of the concept of an ordinary fuzzy set called a type-1 fuzzy set (Zadeh, 1975). A multi-criteria personnel selection based on type-2 fuzzy AHP technique was proposed in (Cengiz, Baþar, 2013). This technique was used to select the best candidate from among three candidates who apply for a position in a manufacturing firm.

Table 2.15 shows the summary list of all fuzzy techniques related to performance appraisal with summary benefits description for each technique.

Table 2. 15: Related Fuzzy Techniques Summary

SN	Techniques	Description & Concept	Key Benefits	Performance Evaluation Paper Samples
A.	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.	(Saaty, 1990) (Rouyendegh, Erkan, 2012)

B.	TOPSIS & FTOPSIS	It is one of the multi-criteria decision making technique that extensively used to solve MCDM problems. TOPSIS technique based on the concept that selected 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.	(Ghosh, 2011).
C.	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 factor to different critical element as per organizational goal. -Reduces number of rules by dividing the whole system into various fuzzy inference stages.	(Shaout, Trivedi 2013). (Neogi et al, 2011)
D.	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.	(Yee, Chen, 2010)

E.	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.	(Nisha, Priti, 2013)
D	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.	(Cengiz, Baþar, 2013)

2.4 Summary

This chapter provided a comprehensive literature review on basic concept of fuzzy logic, performance appraisal methods, traditional & modern methods, comparison of performance appraisal methods, fuzzy related appraisal techniques such as fuzzy analytical hierarchy process, technique for order preference by similarity to ideal solution, multistage fuzzy & cascaded fuzzy technique, fuzzy based multifactorial technique and hybrid neuron-fuzzy technique and type-2 fuzzy evaluation technique

CHAPTER III

3. CLASSIFICATION MODEL FOR PERFORMANCE EVALUATION OF SUDANESE UNIVERSITIES & ACADEMIC STAFF

Perception of academic service quality is important for the service providers (high institutions), customers and ministry of higher and scientific research. In this service model, Fuzzy analytical hierarchal process (FAHP) and fuzzy technique for order of preference by similarity to ideal solution (FTOPSIS) have been used in developing our evaluation model system. The FAHP is used to construct the Sudanese universities and academic staff hierarchical frameworks of performance evaluation criteria, pairwise comparison criteria for all criteria levels, consistency checking, aggregation, aproximate the fuzzy priorities and then to obtain the relative criteria weights. The details process will be explained in the next chapters (i.e. 4 to 9). Fuzzy TOPSIS method is used to obtain the final rank of the alternatives. The bottom criteria weights were used to construct the comparison matrix between bottom criteria and alternatives, obtain the normalized decision matrix, compute the weighted decision matrix, compute the positive & negative ideal solutions, compute the separation measures, calculate the relative closeness, and then classify the alternative universities and academic staff.

3.1 Model Overview

In this model, several techniques are adapted and represented as shown in Figure 3.1. 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 value of 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 will be explained in the following sections.

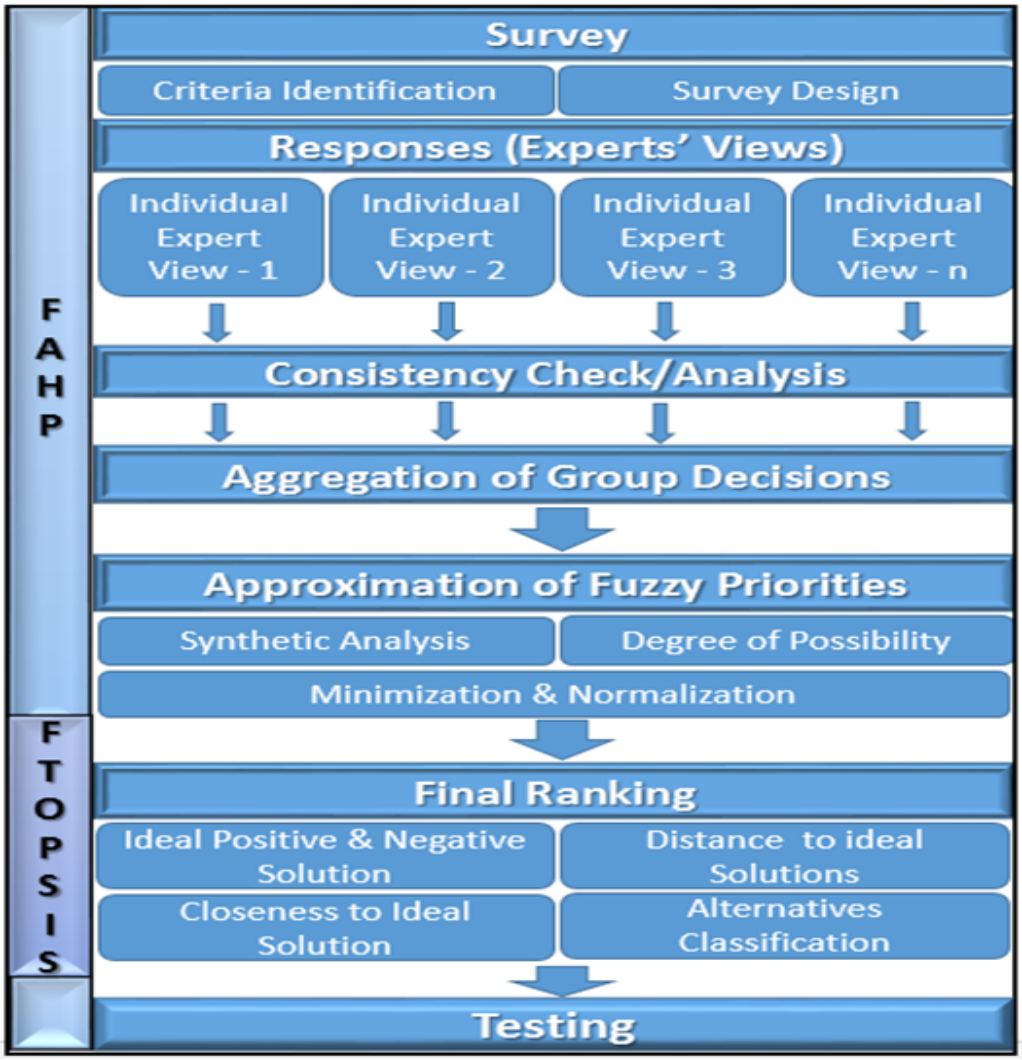


Figure 3. 1: Classification Model for PE of Sudanese Universities & Academic staff

3.2 Process Workflow

This section presents the workflow of processes execution 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 owners) and experts as shown in the following figure 3.2.

3.3 Process Description

The following descriptions give more details about the process workflow and related tasks as shown in figure 3.2

1. Define Project: In this stage, administrator needs to define project name, year, etc. Several types of projects or several projects with same type could be defined.
2. Define Alternatives: It allows administrator to specify the alternatives for specific related project.
3. Define Criteria: It allows you to define criteria and sub criteria for 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 template according to the concerned bottom criteria and alternatives for related specific project.
6. Define Scales: This process allows you to define suitable fuzzy scale for each template. It contains the linguistic values and related fuzzy triangular numbers.
7. Project Initiation: Project initiation process allows business owner to initiate the project by defining the experts/participants in order to start the process, send & 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.

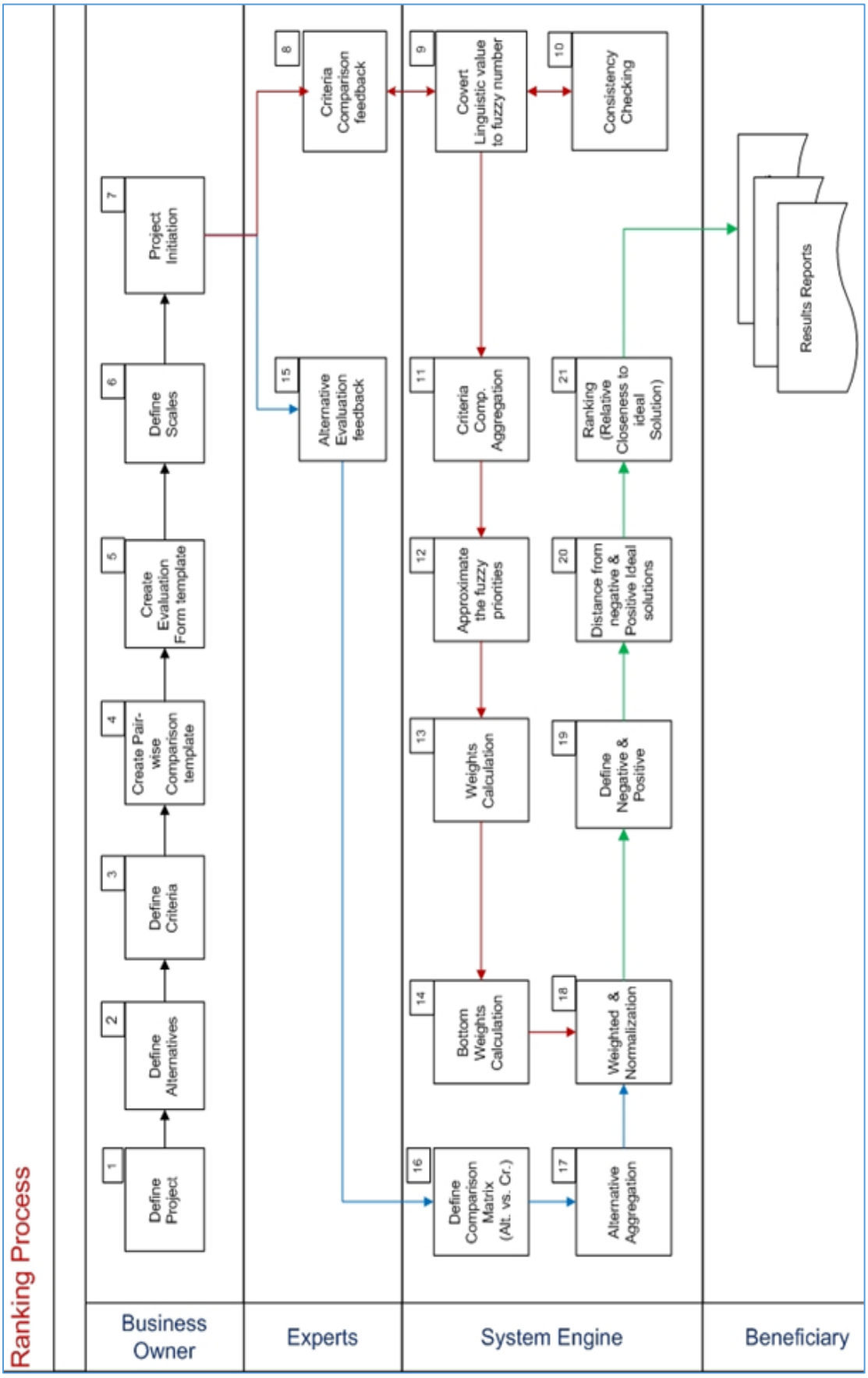


Figure 3. 2 : Process Workflow of the classification Model

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 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 constructs a matrix between alternatives and related bottom criteria.
17. Alternatives Feedback Aggregation: It aggregates expert feedback with 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 (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.

3.4 Summary

This chapter presented the proposed classification model and processes workflow in functional band (i.e. graphical swim lane view). Also, a detail process description was defined for each process.

CHAPTER IV

4. THE PROPOSED EVALUATION CRITERIA

The first section in this chapter introduces the definitions and differences between performance indicators, performance evaluation criteria and performance evaluation process. The others sections focus on determining and defining the performance evaluation criteria for universities & academic staff.

4.1 Performance Indicators, Performance Evaluation Criteria & Performance Evaluation

A performance indicator is, generally, a statement that can be measured on successes to the specific goals of an enterprise (Higgins, 1989). It can also be described as piece of data gathered periodically to trace the performance of a system (Fitz-Gibbon, 1990). While Evaluation Criteria are standard measures formed to assess the accomplishment degree of the expectations and goals in alternative solutions, individuals or proposals through direct comparisons of their strengths and weaknesses.

Performance evaluation is an organized and regular process that evaluates an organization, education institution or an individual employee's job functioning and output in relative to certain pre-established criteria and organizational goals. In Higher educational, Institutes or Universities performance of academic staff is key factor in ranking the universities. It is appraised on the basis of definite factors like students' feedback, teaching-learning and assessment related activities, expert development activities such as doing research work, contributing to national and universal conferences, publishing research papers and research articles, leading and contributing in workshops. The judgments and views of managements, coworkers, sub-ordinates also perform essential role in performance measurement. All these factors are jointly used to evaluate an academic staff's performance. Recently, many researchers all over the world, started to employ fuzzy logic for efficient measurement of academic staff performance. The idea behind Fuzzy logic is to mimic the capability of the human mind to efficiently utilize styles of reasoning that are approximate rather than precise (Bhosale, Kulkarni, 2013).

As outcomes from literature review, two set of criteria were defined (Yousif, Shaout, 2016/a). The first one is for university performance evaluation and the other one is for academic staff performance evaluation.

4.2 University Performance Evaluation Criteria

We concentrated in the main nine factors for university performance evaluation. 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 Commission (EVAC) in the Ministry of Higher Education and Scientific Research (EVAC, 2012). The nine factors/criteria and related sub-factors/criteria were listed in Table 4.1 and structured as AHP in Figure 4.1. The following is a brief description of each:

- **Institutional Frame Work (UC1):** This factor is used as indicator for institute identification, programs, activities and roles in the society. Any development for 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 graduates factor is one of the most importance of 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/counselling, 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 education institution is relationship and services that provided to the community. It includes following sub-criteria: management of community service and community service programs**.**
- **Quality Management (UC9):** This factor concerns about availability of procedures that ensure the compliance of the requirements and standards. This factor includes the following sub criteria: quality management and quality management programs.

Table 4. 1: University performance evaluation criteria and related criteria key code.

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 وادارتها)
		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	UC81	Management of Community Service (ادارة خدمة

	Service خدمة المجتمع		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)

4.3 Academic Staff Performance Evaluation Criteria

As outcomes from literature review, six main criteria were defined for academic staff evaluation (Yousif, Shaout, 2016/a; عماد ابوالرب, 2010). The following are the summary of these criteria and related sub criteria as listed in Table 4.2 and structured as AHP in Figure 4.2.

- **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 journal.
- **Teaching Quality (AC2):** Teaching quality evaluates the teaching aspects such as ability to cover different materials efficiently, commitment to academic work, academic counselling 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 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, enhancement 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.

Table 4. 2: Performance Evaluation Criteria for Academic Staff & related criteria code.

CC.	Main Criteria	CC.	Sub Criteria (Level-1)
AC1	Excellence in Research and Scientific Activities التميز في البحوث) والانشطة العلمية)	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 (جودة و نوعية التدريس)	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 (نقل وتبادل	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)

	المعرفة وإشراك وترقية المجتمعات المحلية)	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 (استطلاع وملاحظات و رأي الطلاب)	AC51	Teaching capabilities and preparation for lecture (امكانيات عضو هيئة التدريس في تدريس المادة والاعداد والتحضير لها)	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 (مساهمة المادة في التحصيل العلمي للطلبة)	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 الاساليب التدريسية التي وحب الاستطلاع
				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. توافق محتوى الامتحانات مع الخطة التدريسية
				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 (العلاقة بين عضو هيئة التدريس و الطلبة)	AC541	Compliance with Teacher's office hours and encourage students to utilize this period. الالتزام بالساعات المكتبية وتشجع الطلبة المراجعة خلالها 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 تنمية للطلبة
AC6	Peers Feedback (استطلاع وملاحظات و رأي الزملاء اعضاء هيئة التدريس)	AC61	Course Content (محتوى الكورس)	AC611	Explanation of subject and main outlines توضيح واستعراض موضوع البحث
				AC612	State of the Art مواكبة المنهج الدراسي على اخر ما توصل الية العلم والابحاث العلمية في المجال
				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 وجود أداة / استراتيجية متكاملة مدمجة في الدرس
		AC63	Learning Environment (بيئة التعلم)	AC631	Participatory classroom environment البئية 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 Professionalism الاتصال والتعاون (والكفاءة المهنية)	AC641	Genuine interest in work 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

4.4 Application of FAHP & FTOPSIS to Universities & Academic Staff Performance Evaluation

The proposed classification model in the prior section (Figure 3.1) is exploited to build structured technique for organizing and analyzing complex decision as shown in Figures 4.2 & 4.3. In our case study, the various elements/criteria are evaluated by comparing them to each other two at time, with respect to their impact on an element/criterion above them in the hierarchy. For example, we compare the (UC11: Strategic Planning) criterion with 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 Figure 4.3. Similar comparisons were designed & 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 4.3 (Tolga et al, 2005). More detail will be presented in the following sections.

Table 4. 3 Triangular Fuzzy Scale (TFN values)

SN	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)

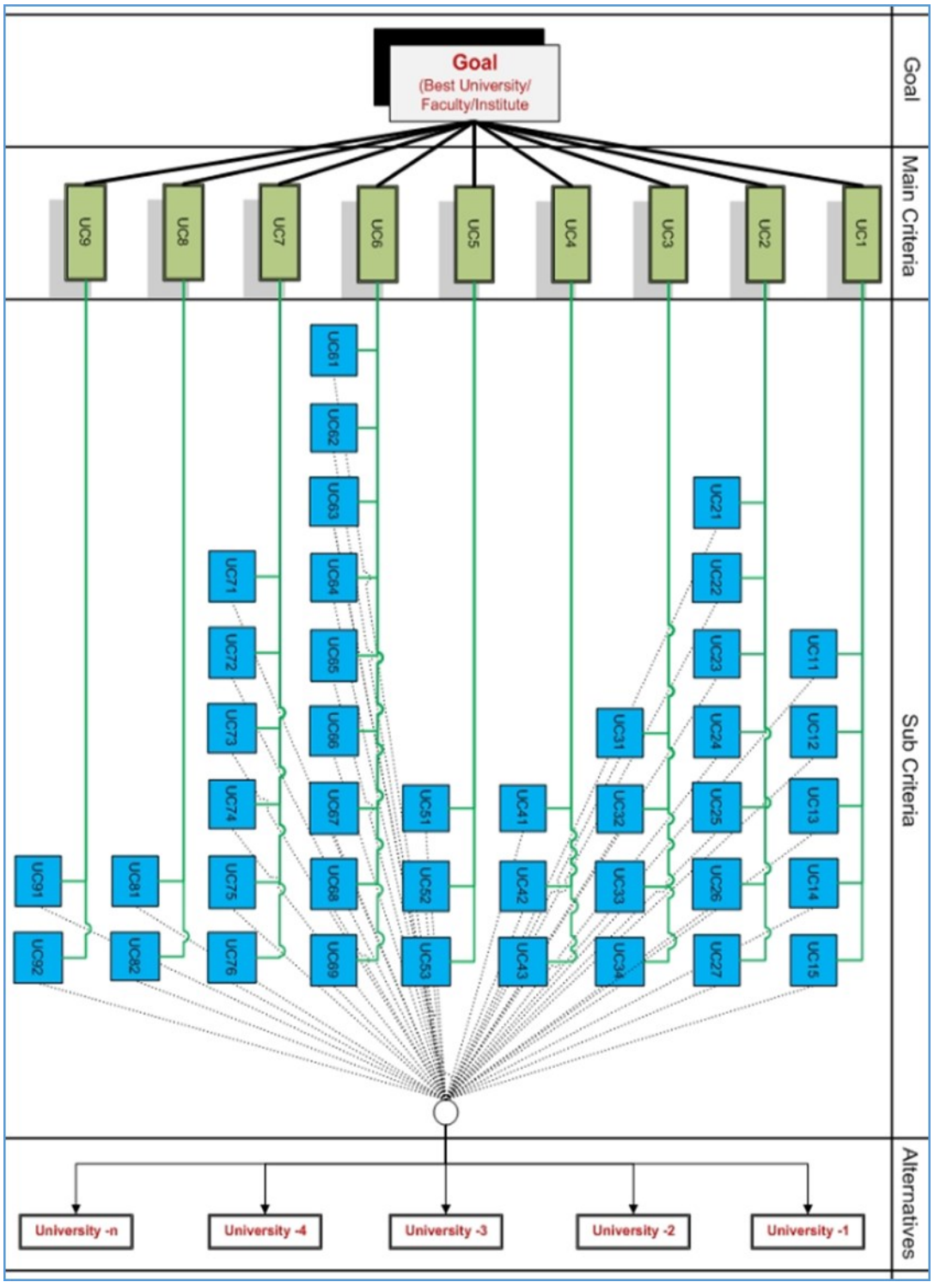


Figure 4. 1: Hierarchical Framework of PE Criteria for Sudanese Universities

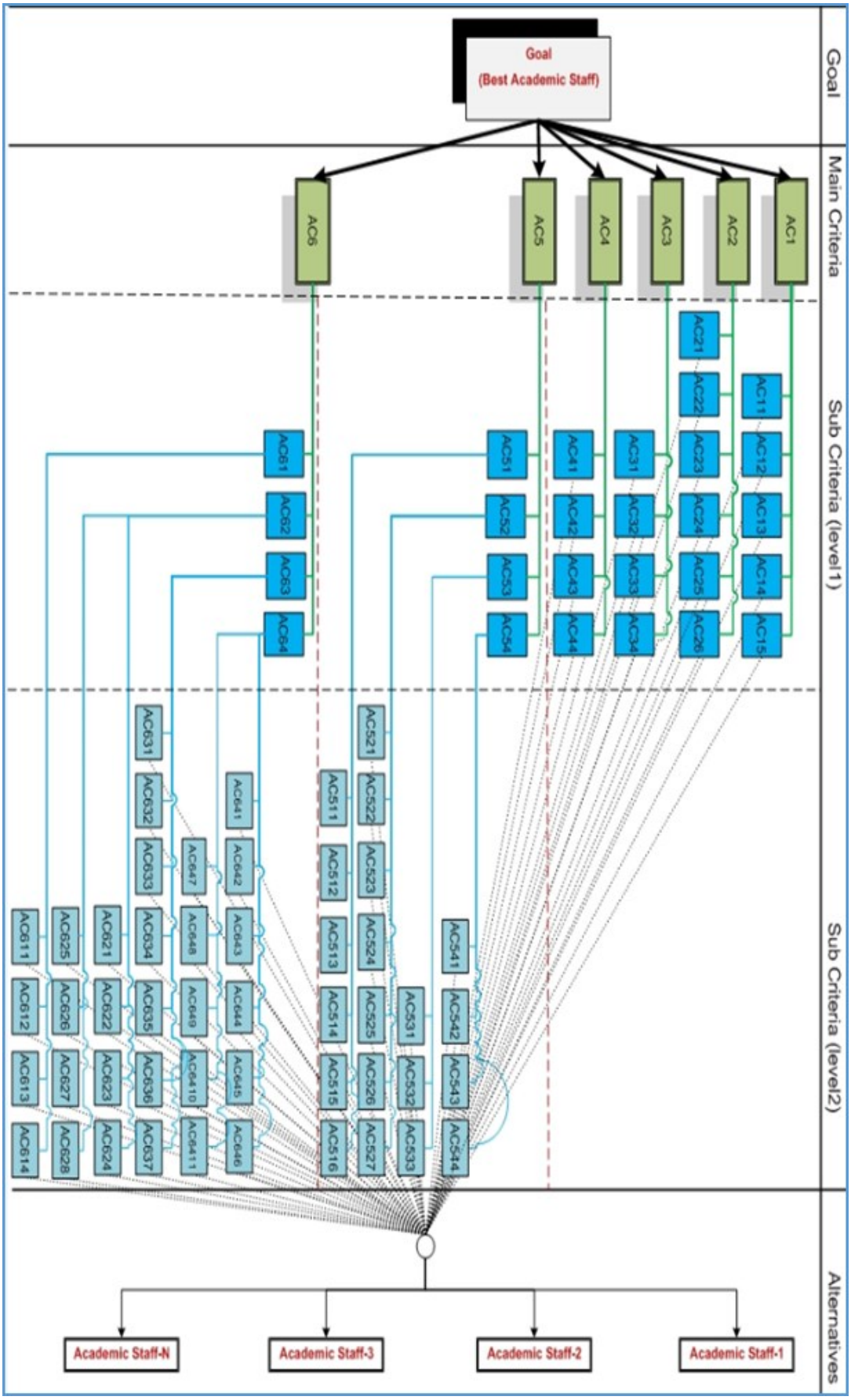


Figure 4. 2: Hierarchical framework of PE criteria for Academic Staff

Figure 4. 3: Pairwise comparison of UC11 with other in same level with respect to UC1

4.5 Evaluation Approach

The 360-degree approach is a popular performance appraisal technique that includes evaluation inputs from a number of people and may include immediate supervisors, team members, customers, peers and self (Jafari, 2009). 360 Degree provides people with information about the influence of their action on others. The following are some features and benefits of this method:

- Academic staff gain more understanding of their impact on people and how they are perceived by others such as students, peers, dean and department's head,
- Increases consistency in the academic performance,
- Provides complete analysis of academic staff,
- Enhanced awareness and importance of competencies, and
- Legally more defensible.

The disadvantage of this approach as follows: difficult to maintain the confidentiality and time consuming.

In this research, we used 360-degree feed-back approach; also known as multi-rater feedback evaluation approach to conduct the overall evaluation of academic staff (Mahar, 2009). Four entities were involved in the evaluation; self-evaluation, the department head, dean, peers/collogues and students as shown in Figure 4.4. Evaluation forms are formulated for each entity as you will be shown in the chapter 5: Department

head /dean evaluation form, Students feedback evaluation form, Peers/colleagues evaluation form (Figure 5.2, 5.3 & 5.4 respectively).

Figure 4. 4. Academic Staff Evaluation Approach, 360-Degree feedback

4.6 Summary

In this chapter, a detail evaluation criteria and sub-criteria for universities and academic staff performance assessment were specified, defined and coded which is considered as accomplishment for the one of aims of this thesis. Hierarchical frameworks of performance evaluation criteria for Academic Staff and universities were constructed using criteria codes. Finally evaluation approach (i.e. 360 degree) was introduced for academic staff evaluation. This chapter accomplishes one of the aims of this thesis by identifying the evaluation criteria

CHAPTER V

5. SURVEY DESIGN

This chapter is organized to present the goal & objectives of the survey, the target population, and discuss survey reliability and validity checking. Question structure & response format are defined and two types of survey forms are designed and explained.

5.1 Goal & Objectives

A successful survey begins with an understanding of the survey's goals and objectives. The overall goal of this survey is to evaluate performance and rank of Sudanese universities and academic staff. The following are the associative objectives:

- To determine the degree of importance among the proposed evaluation criteria for Sudanese University & academic staff.
- To determine the experts' views towards Sudanese universities performance against each criterion.
- How satisfied is the students with academic staff performance.
- How satisfied is the peers with academic staff performance.
- How satisfied is the department head with academic staff performance.

5.2 Target population

The interested population in this survey includes experts in the high educations, academic staff and students in Sudanese institution. A 'Sampling' process is typically used by selecting only subset of the total population. Hybrid type of survey is used (Recording response, presenting the question & contacting potential respondent).

5.3 Reliability & Validity

Although survey uses simple comparison process between two criteria with predefined responses values (i.e. pairwise comparison technique), the test-retest measurement is used to measure the survey reliability. We test and retest one layer of comparison question for the same responders at different points of time. The degree of stability exhibited when a measurement is repeated under identical condition is acceptable (i.e.

correlation coefficient >=0.7). Hence each survey question will mean the same thing to everyone including those administering the survey. The design is reliable and leads to the same understanding. The predefined responses are linguistic values which suit the uncertainty and fuzziness measurement.

As validity assessment, reviewers who have some knowledge of subject matters are assigned to check how well a survey measures what it sets out to measure. This process consists of an organized review of the survey's content (i.e. ensure that it contains everything it should).

5.4 Question Structure & Response Format

All the survey questions are closed questions where a list of predefined responses is provided as shown in the scale in table 5.1. The "Field test" with a sample of potential respondents is conducted to verify that the process is smooth and completely understandable by our target population.

Simple unified Question structure and response format is used in this survey. The following shows an example:

General sample of question structure:

Q1 How important is "Criteria1"

Q1.1 when it is compared with Criteria2

Q1.2 when it is compared with Criteria3

Q1.3 when it is compared with Criteria4

Sample of Answer Format

Table 5.1 shows a sample answer format where a list of predefined fuzzy linguistic value responses is available.

Table 5. 1 : Sample Answer responses.

		Important									
Questions	Sub-Criteria	More Important				Equal	Less Important				Sub-Criteria
		Absolute	Very Strong	Fairly Strong	Weak	Equal	Weak	Fairly Strong	Very Strong	Absolute	
Q1.1	Criteria-1				✓						Criteria-2
Q1.2						✓					Criteria-3
Q1.3									✓		Criteria-4

Answers Explanation:

- The 1st answer for Q1.1, means that, Criteria-1 is More Important than Criteria-2 by Weak degree.
- The 2nd answer for Q1.2, means that, Criteria-1 is Equal important to Criteria-3.
- The 3rd answer for Q1.3, means that, Criteria-1 is Less Important than Criteria-4 by Very Strong degree.

5.5 Survey Forms

In this study, two types of survey forms were designed. The first survey is to allow experts to provide qualitative assessments for determining the relative importance of the evaluation criteria with respect to the overall objective (selecting university/academic staff). The second survey also is to allow expert to provide the qualitative assessments to determine the performance of each alternative (University/Academic staff) with respect to each criterion.

5.5.1 The 1st Type of Survey (Pairwise Comparison Matrices)

Pairwise comparison is generally used to estimate preference values of criteria among themselves. Since some of the decision data of evaluating university or academic staff can be precisely assessed while others cannot, therefore; linguistic variables were used in our survey. Generally human experts are ineffective in making quantitative estimation, whereas they are comparatively competent in qualitative forecasting (Kulak, Kahraman, 2005). Experts in survey can evaluate and determine the importance levels of these criteria by selecting the related linguistic variable, which will be converted into the following scale including fuzzy numbers (TFN: Triangular fuzzy number) as shown in Table 4.3.

In this type of survey, the views of the experts have been obtained for each level of criteria hierarchy. The following are samples' questions and answers sheets of university and academic staff:

A. Sample of Pairwise Comparison Survey for University Evaluation Criteria:

a. **Main Comparison Questions**:

This question's comparisons represent the pairwise comparisons of the main criteria for university with respect to overall objective. Assume a level with N criteria, and then the number of comparison's layers is equal to N-1. In our example, this level contains 9

criteria and as explained below 8 layers of comparisons are required (i.e. No of layers = N – 1, where N is total number of criteria in the concerned level).

The following 8 comparisons' questions have been designed among the nine main criteria for universities (i.e. UC1 to UC9):

- Comparison between 'UC1: Institutional Framework' criterion and others criteria such as 'UC2: Governance & Administration', 'UC3: Infrastructure & Services' … 'UC9: Quality Management'.
- Comparison between 'UC2: Governance & Administration' criterion and other criteria such as 'UC3: Infrastructure & Services', 'UC4: Human Resources' … 'UC9: Quality Management'.
- Comparison between 'UC3: Infrastructure & Services' criterion and other criteria such as 'UC4: Human Resources', 'UC5: Students & Graduates'… 'UC9: Quality Management'.
- Comparison between 'UC4: Human Resources' criterion and other criteria such as 'UC5: Students & Graduates', 'UC6: Teaching and Learning Resources' ... 'UC9: Quality Management'.
- Comparison between 'UC5: Students & Graduates' criterion and other criteria such as 'UC6: Teaching and Learning Resources', 'UC7: Scientific Research and Graduate Studies' … 'UC9: Quality Management'.
- Comparison between 'UC6: Teaching and Learning Resources' criterion and other criteria such as 'UC7: Scientific Research and Graduate Studies', 'UC8: Community Service', and 'UC9: Quality Management'.
- Comparison between 'UC7: Scientific Research and Graduate Studies' criterion and other criteria such as 'UC8: Community Service' and 'UC9: Quality Management'.
- Comparison between 'UC8: Community Service' criterion and 'UC9: Quality Management'.

The following questions and answers sheet were designed for university evaluation criteria (i.e. pairwise comparison survey). Each point in the above are represented by one compound question:

- Comparison between ‘UC1: Institutional Framework’ criterion and others criteria such as ‘UC2: Governance & Administration’, ‘UC3: Infrastructure & Services’ … ‘UC9: Quality Management’.

Q1: How important is **“Institutional Framework (الاطار المؤسسي)”**

Q1. 1when it is compared with “Governance & Administration (الحوكمة والادارة)”?

Q1.2 when it is compared with “Infrastructure & Services (البنى التحتية)”?

Q1.3 when it is compared with “Human Resources (الموارد البشرية)”?

Q1.4 when it is compared with “Students & Graduates (الطلاب والخرجين)”?

Q1.5 when it is compared with “Teaching and Learning Resources (التعليم والتعلم ومصادرهما)”?

Q1.6 when it is compared with “Scientific Research and Graduate studies (البحث العلمي والدراسات العليا)”?

Q1.7 when it is compared with “Community Service (خدمة المجتمع)”?

Q1.8 when it is compared with “Quality Management (ادارة الجودة)”?

- Comparison between ‘UC2: Governance & Administration’ criterion and other criteria such as ‘UC3: Infrastructure & Services’, ‘UC4: Human Resources’ … ‘UC9: Quality Management’.

Q2: How important is **“Governance & Administration (الحوكمة والادارة)”**

Q2.1 when it is compared with “Infrastructure & Services (البنى التحتية)”?

Q2.2 when it is compared with “Human Resources (الموارد البشرية)”?

Q2.3 when it is compared with “Students & Graduates (الطلاب والخريجون)”?

Q2.4 when it is compared with “Teaching and Learning Resources (التعليم والتعلم ومصادرهما)”?

Q2.5 when it is compared with “Scientific Research and Graduate studies (البحث العلمي والدراسات العليا)”?

Q2.6 when it is compared with “Community Service (خدمة المجتمع)”?

Q2.7 when it is compared with “Quality Management (ادارة الجودة)”?

- Comparison between ‘UC3: Infrastructure & Services’ criterion and other criteria such as ‘UC4: Human Resources’, ‘UC5: Students & Graduates’… ‘UC9: Quality Management’.

Q3: How important is “**Infrastructure & Services (البنى التحتية)**”

Q3.1 when it is compared with “Human Resources (الموارد البشرية)”?

Q3.2 when it is compared with “Students & Graduates (الطلاب والخريجون)”?

Q3.3 when it is compared with “Teaching and Learning Resources (التعليم والتعلم ومصادرهما)”?

Q3.4 when it is compared with “Scientific Research and Graduate studies (البحث العلمي والدراسات العليا)”?

Q3.5 when it is compared with “Community Service (خدمة المجتمع)”?

Q3.6 when it is compared with “Quality Management (ادارة الجودة)”?

- Comparison between ‘UC4: Human Resources’ criterion and other criteria such as ‘UC5: Students & Graduates’, ‘UC6: Teaching and Learning Resources’ ... ‘UC9: Quality Management’.

Q4: How important is **“Human Resources (الموارد البشرية)”**

Q4.1 when it is compared with “Students & Graduates (الطلاب والخريجون)”?

Q4.2 when it is compared with “Teaching and Learning Resources (التعليم والتعلم ومصادرهما)”?

Q4.3 when it is compared with “Scientific Research and Graduate studies (البحث العلمي والدراسات العليا)”?

Q4.4 when it is compared with “Community Service (خدمة المجتمع)”?

Q4.5 when it is compared with “Quality Management (ادارة الجودة)”?

- Comparison between ‘UC5: Students & Graduates’ criterion and other criteria such as ‘UC6: Teaching and Learning Resources’, ‘UC7: Scientific Research and Graduate Studies’ … ‘UC9: Quality Management’.

Q5: How important is **“Students & Graduates (الطلاب والخريجون)”**

Q5.1 when it is compared with “Teaching and Learning Resources (التعليم والتعلم ومصادرهما)”?

Q5.2 when it is compared with “Scientific Research and Graduate studies (البحث العلمي والدراسات العليا)”?

Q5.3 when it is compared with “Community Service (خدمة المجتمع)”?

Q5.4 when it is compared with “Quality Management (ادارة الجودة)”?

- Comparison between ‘UC6: Teaching and Learning Resources’ criterion and other criteria such as ‘UC7: Scientific Research and Graduate Studies’, ‘UC8: Community Service’, and ‘UC9: Quality Management’.

Q6: How important is **"Teaching and Learning Resources (التعليم والتعلم ومصادرهما)"**

Q6.1 when it is compared with "Scientific Research and Graduate studies (البحث العلمي والدراسات العليا)"?

Q6.2 when it is compared with "Community Service (خدمة المجتمع)"?

Q6.3 when it is compared with "Quality Management (ادارة الجودة)"?

- Comparison between 'UC7: Scientific Research and Graduate Studies' criterion and other criteria such as 'UC8: Community Service' and 'UC9: Quality Management'.

Q7: How important is **"Scientific Research and Graduate studies (البحث العلمي والدراسات العليا)"**

Q7.1 when it is compared with "Community Service (خدمة المجتمع)"?

Q7.2 when it is compared with "Quality Management (ادارة الجودة)"?

- Comparison between 'UC8: Community Service' criterion and 'UC9: Quality Management'.

Q8: How important is **"Community Service (خدمة المجتمع)"**

Q8.1 when it is compared with "Quality Management (ادارة الجودة)"?

b. **Main Comparison Answer Sheet**

The answers sheets were designed to allow experts to indicate his/her preference for the focal criterion which was mentioned in the main question (i.e. left side criterion in the answer sheet) to other criteria mentioned in the sub-questions (i.e. right side criteria in the answer sheet). The answers are represented to indicate the expert preference on the main criterion mentioned in beginning of the questions. For example, in Q1, the answers represent the important degree of "Institutional Framework" criterion with respect to others criteria. The below table is sample of answer sheet for the main criteria for university criteria.

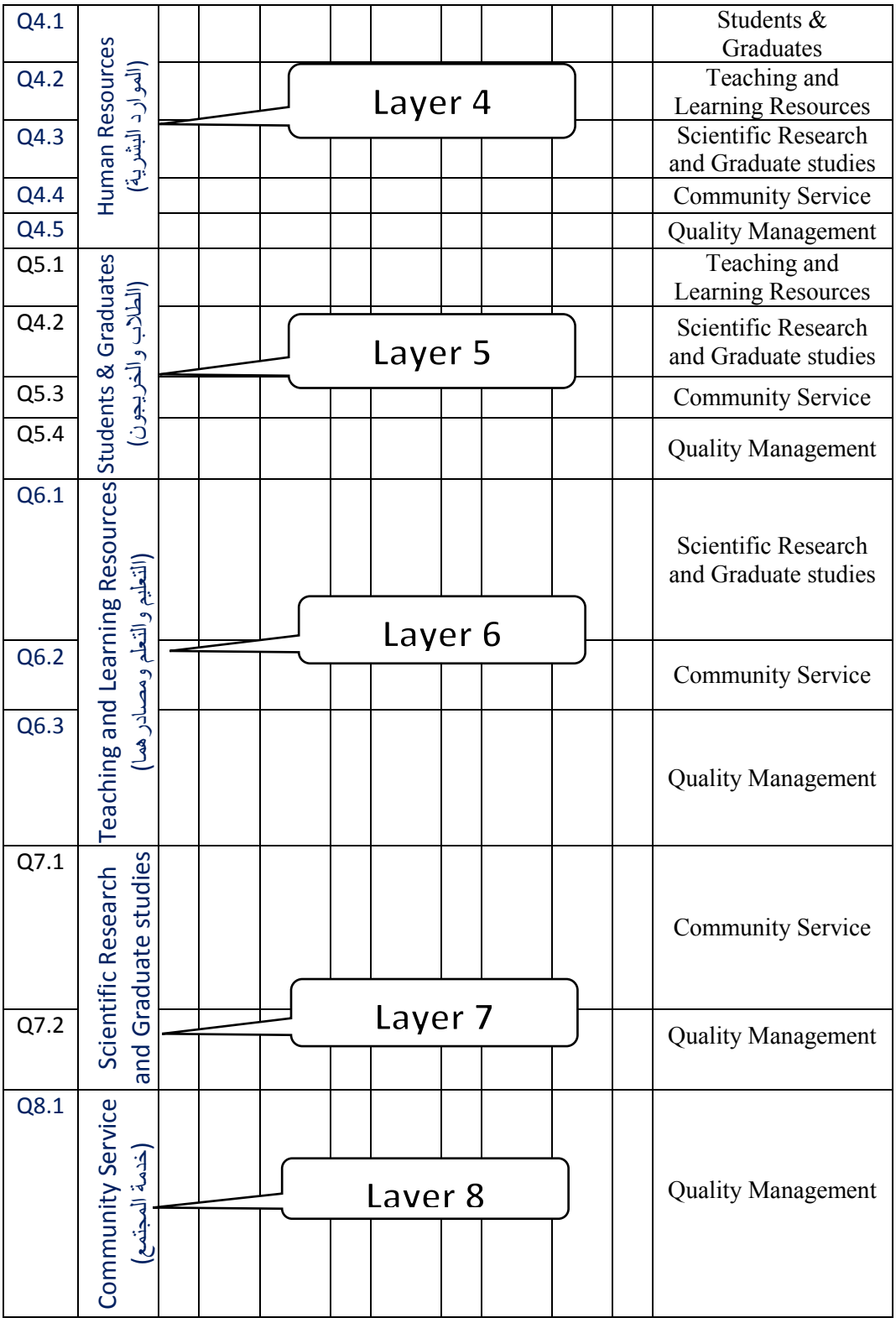
Table 5. 2: Answer Sheet Sample for the main university criteria evaluation survey

		Important									
Questions	Criteria	More Important				Eql.	Less Important				Criteria
		Absolute	Very Strong	Fairly Strong	Weak	Equal	Weak	Fairly Strong	Very Strong	Absolute	
Q1.1	Institutional Framework (الإطار المؤسسي)					✓					Governance & Administration
Q1.2					✓						Infrastructure & Services
Q1.3							✓				Human Resources
Q1.4										✓	Students & Graduates
Q1.5									✓		Teaching and Learning Resources
Q1.6				✓							Scientific Research and Graduate studies
Q1.7			✓								Community Service
Q1.8		✓									Quality Management
Q2.1	Governance & Administration (الحوكمة و الإدارة)										Infrastructure & Services
Q2.2											Human Resources
Q2.3											Students & Graduates
Q2.4											Teaching and Learning Resources
Q2.5											Scientific Research and Graduate studies
Q2.6											Community Service
Q2.7											Quality Management
Q3.1	Infrastructure & Services (البنى التحتية)										Human Resources
Q3.2											Students & Graduates
Q3.3											Teaching and Learning Resources
Q3.4											Scientific Research and Graduate studies
Q3.5											Community Service
Q3.6											Quality Management

Layer 1

Layer 2

Layer 3



c. Answerers Meaning

The answers (check marks) in layer 1 indicate the following meaning:

Answer of Q1.1: The "*Institutional Framework*" Criterion has **Equal Importance** with "*Governance & Administration*" Criterion.

Answer of Q1.2:

The "*Institutional Framework*" Criterion has **More Important** than "*Infrastructure & Services*" criterion by **Weak** degree.

Answer of Q1.3:

The "*Institutional Framework*" Criterion has **Less Important** than "Human Resources" by **Fairly Strong** degree.

Answer of Q1.4:

The "*Institutional Framework"* Criterion has **Less Important** than "*Students & Graduates*" by **Absolute** degree.

Answer of Q1.5:

The "*Institutional Framework*" Criterion has **Less Important** than "*Teaching and Learning Resources"* by **Very Strong** degree.

Answer of Q1.6:

The "*Institutional Framework*" Criterion has **More Important** than "*Scientific Research and Graduate studies*" by **Fairly Strong** degree.

Answer of Q1.7:

The "*Institutional Framework*" Criterion has **More Important** than "*Community Service"* by **Very Strong** degree.

Answer of Q1.8:

The "*Institutional Framework*" Criterion has **More Important** than "*Quality Management"* by **Absolute** degree.

d. Level 1 Comparison Questions (sub criteria):

It is comparison among the sub criteria with respect to the related main criterion. For example, the comparison's questions for sub-criteria with respect to the main criterion "Institutional Framework" as follow:

Q1 How important is **"Strategic Planning (التخطيط الاستراتيجي)"**

Q1.1.1 when it is compared with "Vision (الرؤية)"?

Q1.1.2 when it is compared with "Mission (الرسالة)"?

Q1.1.3 when it is compared with "Goals and Objectives (الغايات والاهداف)"?

Q1.1.4 when it is compared with "Operational Plans (الخطط التنفيذية)"?

Q2: How important is **"Vision (الرؤية)"**

Q1.2.1 when it is compared with "Mission (الرسالة)"?

Q1.2.2 when it is compared with "Goals and Objectives (الغايات والاهداف)"?

Q1.2.3 when it is compared with "Operational Plans (الخطط التنفيذية)"?

Q3: How important is **"Mission (الرسالة)"**

Q1.3.1 when it is compared with "Goals and Objectives (الغايات والاهداف)"?

Q1.3.2 when it is compared with "Operational Plans (الخطط التنفيذية)"?

Q4: How important is **"Goals and Objectives (الغايات والاهداف)"**

Q1.4.1 when it is compared with "Operational Plans (الخطط التنفيذية)"?

e. **Level 1 Comparison Answer Sheet (sub-criteria)**

The answers sheets were designed to allow experts to indicate his/her preference for the focal criterion which was mentioned in the main question (i.e. left side criterion in the answer sheet) to other criteria mentioned in the sub-questions (i.e. right side criteria in the answer sheet). The answers are represented to indicate the expert preference on the main criterion mentioned in beginning of the questions. For example, in Q1.1.1, the answers represent the importance degree of 'Strategic Planning' criterion with respect to others criteria. Table 5.3 is shows sample of answer sheet for the sub criteria.

Table 5. 3: Answer Sheet Sample for sub criteria related to UC1 criterion

With respect to the main criteria : Institutional Framework (الاطار المؤسسي)											
		Important									
Questions	Sub-Criteria	More Important				Eql.	Less Important				Sub-Criteria
		Absolute	Very Strong	Fairly Strong	Weak	Equal	Weak	Fairly Strong	Very Strong	Absolute	
Q1.1.1	Strategic Planning (التخطيط الاستراتيجي)										Vision
Q1.1.2											Mission
Q1.1.3											Goals and Objectives
Q1.1.4											Operational Plans
Q1.2.1	Vision (الرؤية)										Mission
Q1.2.2											Goals and Objectives

Q1.2.3											Operational Plans
Q1.3.1	Mission (الرسالة)										Goals and Objectives
Q1.3.2											Operational Plans
Q1.4.1	Goals and Objectives (الغايات و الاهداف)										Operational Plans

Similarly, comparison's questions and answers were designed for all other sub criteria in level-2 with respect to specific criterion in the main criteria as shown in table 5.3.

B. Sample of Pairwise Comparison Survey for Academic Staff Evaluation Criteria:

a. Main Comparison Questions

These comparisons represent the pairwise comparisons for the main criteria of academic staff with respect to overall objective. The following 5 comparisons have been designed among the six main criteria for academic staff (i.e. AC1, AC2, AC3, AC4, AC5, and AC6):

- Comparison between 'AC1: Excellence in Research' criterion and others criteria such as 'AC2: Teaching Quality', 'AC3: Services & Administration' … 'AC6: Peers Feedback'.
- Comparison between 'AC2: Teaching Quality' criterion and other criteria such as 'AC3: Services & Administration', 'AC4: Knowledge Transfer and Engaging Communities Performance' … 'AC6: Peers Feedback'.
- Comparison between 'AC3: Services & Administration' criterion and other criteria such as 'AC4: Knowledge Transfer and Engaging Communities Performance', 'AC5: Students Feedback' and 'AC6: Peers Feedback'.
- Comparison between 'AC4: Knowledge Transfer and Engaging Communities Performance' criterion and other criteria such as 'AC5: Students Feedback', and 'AC6: Peers Feedback'.

- Comparison between ‘AC5: Students Feedback’ criterion and ‘AC6: Peers Feedback’.

The following questions and answers sheet were designed for the main criteria of academic staff evaluation (i.e. pairwise comparison survey):

- Comparison between ‘AC1: Excellence in Research’ criterion and others criteria such as ‘AC2: Teaching Quality’, ‘AC3: Services & Administration’ … ‘AC6: Peers Feedback’.

Q1: How important is “Excellence in Research (التفوق و التميز في الابحاث)”

Q1.1 when it is compared with “Teaching Quality (جودة و نوعية التدريس)”?

Q1.2 when it is compared with “Service Performance (أداء الخدمات)”?

Q1.3 when it is compared with “Knowledge transfer/exchange and engaging communities Performance

(نقل وتبادل المعرفة وإشراك وترقية المجتمعات المحلية)”?

Q1.4 when it is compared with “Students Feedback (استطلاع وملاحظات و رأي الطلاب)”?

Q1.5 when it is compared with “Peers Feedback (استطلاع وملاحظات و رأي الزملاء اعضاء هيئة التدريس)”?

- Comparison between ‘AC2: Teaching Quality’ criterion and other criteria such as ‘AC3: Services & Administration’, ‘AC4: Knowledge Transfer and Engaging Communities Performance’ … ‘AC6: Peers Feedback’.

Q2: How important is “Teaching Quality (جودة و نوعية التدريس)”

Q2.1 when it is compared with “Service Performance (أداء الخدمات)”?

Q2.2 when it is compared with “Knowledge transfer/exchange and engaging communities Performance (نقل وتبادل المعرفة وإشراك وترقية المجتمعات المحلية)”?

Q2.3 when it is compared with “Students Feedback (استطلاع وملاحظات و رأي الطلاب)”?

Q2.4 when it is compared with “Peers Feedback (استطلاع وملاحظات و رأي الزملاء اعضاء هيئة التدريس)”?

- Comparison between ‘AC3: Services & Administration’ criterion and other criteria such as ‘AC4: Knowledge Transfer and Engaging Communities Performance’, ‘AC5: Students Feedback’ and ‘AC6: Peers Feedback’.

Q3: How important is "Service Performance (أداء الخدمات)"

Q3.1 when it is compared with "Knowledge transfer/exchange and engaging communities Performance (نقل وتبادل المعرفة وإشراك وترقية المجتمعات المحلية)"?

Q3.2 when it is compared with "Students Feedback (استطلاع وملاحظات و رأي الطلاب)"?

Q3.3 when it is compared with "Peers Feedback (استطلاع وملاحظات و رأي الزملاء اعضاء هيئة التدريس)"?

- Comparison between 'AC4: Knowledge Transfer and Engaging Communities Performance' criterion and other criteria such as 'AC5: Students Feedback', and 'AC6: Peers Feedback'.

Q4: How important is "Knowledge transfer and engaging communities (نقل وتبادل المعرفة وإشراك وترقية المجتمعات المحلية)"

Q4.1 when it is compared with "Students Feedback (استطلاع وملاحظات و رأي الطلاب)"?

Q4.2 when it is compared with "Peers Feedback (استطلاع وملاحظات و رأي الزملاء اعضاء هيئة التدريس)"?

- Comparison between 'AC5: Students Feedback' criterion and 'AC6: Peers Feedback'.

Q5: How important is "Students Feedback (استطلاع وملاحظات و رأي الطلاب)"

Q5.1 when it is compared with "Peers Feedback (استطلاع وملاحظات و رأي الزملاء اعضاء هيئة التدريس)"?

b. Main Comparison Answer Sheet

The answers sheets were designed to allow experts to indicate his/her preference for the focal criterion (i.e. left side criterion in the answer sheet) which was mentioned in the main question to other criteria (i.e. right side criteria in the answer sheet) mentioned in the sub-questions for example in Q1, answers represent the important degree of 'Excellence in Research' criterion with respect to others criteria. Table 5.4 shows sample of answer sheet for the main criteria for main academic staff criteria.

Table 5. 4: Answer Sheet for the main Academic Staff criteria evaluation survey

		Important									
Questions	Criteria	More Important				Eql.	Less Important				Criteria
		Absolut	Very Strong	Fairly Strong	Weak	Equal	Weak	Fairly Strong	Very Strong	Absolut e	
Q1.1	Excellence in Research (التفوق و التميز في الابحاث)										Teaching Quality
Q1.2											Service Performance
Q1.3											Knowledge transfer/exchange and engaging communities Performance
Q1.4											Students Feedback
Q1.5											Peers Feedback
Q2.1	Teaching Quality (جودة و نوعية التدريس)										Service Performance
Q2.2											Knowledge transfer/exchange and engaging communities Performance
Q2.3											Students Feedback
Q2.4											Peers Feedback
Q3.1	Service & Administration Performance (أداء الخدمات)										Knowledge transfer/exchange and engaging communities Performance
Q3.2											Students Feedback
Q3.3											Peers Feedback
Q4.1	Knowledge transfer/exchange and engaging communities Performance (نقل وتبادل المعرفة و إشراك وترقية المجتمعات المحلية)										Students Feedback
Q4.2											Peers Feedback

Q5.1	Students Feedback (استطلاع وملاحظات و رأي الطلاب)										Peers Feedback

c. Level-1 Comparisons' Questions (sub- criteria):

It is comparison of sub criteria with respect to the related main criterion. For example, the comparison's questions for sub-criteria (AC61, AC62, AC63, and AC64) with respect to the main criterion "AC6: Peers Feedback" as follow:

Q6.1 How important is Course Content (البحوث والمنشورات)

Q6.1.1 when it is compared with "Delivery and Teaching Methods (التقديم وطرق التدريس)"?

Q6.1.2 when it is compared with "Learning Environment (بيئة التعلم)"?

Q6.1.3 when it is compared with "Communication, collaboration and Professionalism (الاتصال والتعاون والكفاءة المهنية)"?

Q6.2 How important is "Delivery and Teaching Methods (التقديم وطرق التدريس)"

Q6.2.1 when it is compared with "Learning Environment (بيئة التعلم)"?

Q6.2.2 when it is compared with "Communication, collaboration and Professionalism (الاتصال والتعاون والكفاءة المهنية)"?

Q6.3 How important is "Learning Environment (بيئة التعلم)"

Q6.3.1 when it is compared with "Communication, collaboration and Professionalism (الاتصال والتعاون والكفاءة المهنية)"?

Answer sheet was designed for the above questions as shown in table 5.5. It represents a sample answer sheet of pairwise comparison of sub criteria for criterion "Peers Feedback"

Table 5. 5: Answer Sheet Sample for sub criteria related to 'Peers Feedback' criterion

With respect to the main criteria: Peers Feedback (استطلاع وملاحظات و رأي الزملاء اعضاء هيئة التدريس)											
		I m p o r t a n t									
Questions	Sub-Criteria	More Important				Eql.	Less Important				Sub-Criteria
		Absolute	Very Strong	Fairly Strong	Weak	Equal	Weak	Fairly Strong	Very Strong	Absolute	
Q6.1.1	Course Content (محتوى الكورس)										Delivery and Teaching Methods
Q6.1.2											Learning Environment
Q6.1.3											Communication, collaboration and Professionalism
Q6.2.1	Delivery and Teaching Methods (التقديم وطرق التدريس)										Learning Environment
Q6.2.2											Communication, collaboration and Professionalism
Q6.3.1	Learning Environment (بيئة التعلم)										Communication, collaboration and Professionalism

d. Level-2 Comparisons' Questions (sub- criteria):

It is comparison of sub sub-criteria with respect to the related main sub criterion. For example, the comparison's questions for sub sub-criteria (AC611, AC612, AC613, and AC614) with respect to the main sub criterion "AC61: Course Content" as follow:

Q6.1.1 How important is Explanation of subject and main outlines (توضيح واستعراض موضوع البحث)

Q6.1.1.1 when it is compared with "State of the Art (مواكبة المنهج الدراسي على اخر ما توصل اليه العلم والابحاث العلمية في المجال)"?

Q6.1.1.2 when it is compared with “Clearness of Course objective (وضوح أهداف المقرر)”?

Q6.1.1.3 when it is compared with “Consistency of Course content and Syllabus (اتساق محتوى الكورس والمنهج)”?

Q6.1.2 How important is State of the Art (مواكبة المنهج الدراسي على اخر ما توصل الية العلم والابحاث العلمية في المجال)

Q6.1.2.1 when it is compared with “Clearness of Course objective (وضوح أهداف المقرر)”?

Q6.1.2.2 when it is compared with “Consistency of Course content and Syllabus (اتساق محتوى الكورس والمنهج)”?

Q6.1.3 How important is Clearness of Course objective (وضوح أهداف المقرر)

Q6.1.3.1 when it is compared with “Consistency of Course content and Syllabus (اتساق محتوى الكورس والمنهج)”?

Answer sheet was designed for the above questions as shown in table 5.6. It represents a sample answer sheet of pairwise comparison of sub criteria of criterion “Course Content”

Table 5. 6: Answer Sheet Sample for sub sub-criteria related to ‘Course Content’

Sub sub-criteria with respect to the sub-criteria : Course Content (محتوى الكورس)											
		I m p o r t a n t									
Questions	Sub Sub-Criteria	More Important				Eql.	Less Important				Sub Sub-Criteria
		Absolute	Very Strong	Fairly Strong	Weak	Equal	Weak	Fairly Strong	Very Strong	Absolute	
Q61.1.1	Explanation of subject and main outlines توضيح واستعراض موضوع البحث										State of the Art
Q61.1.2											Clearness of Course objective
Q61.1.3											Consistency of Course content and Syllabus

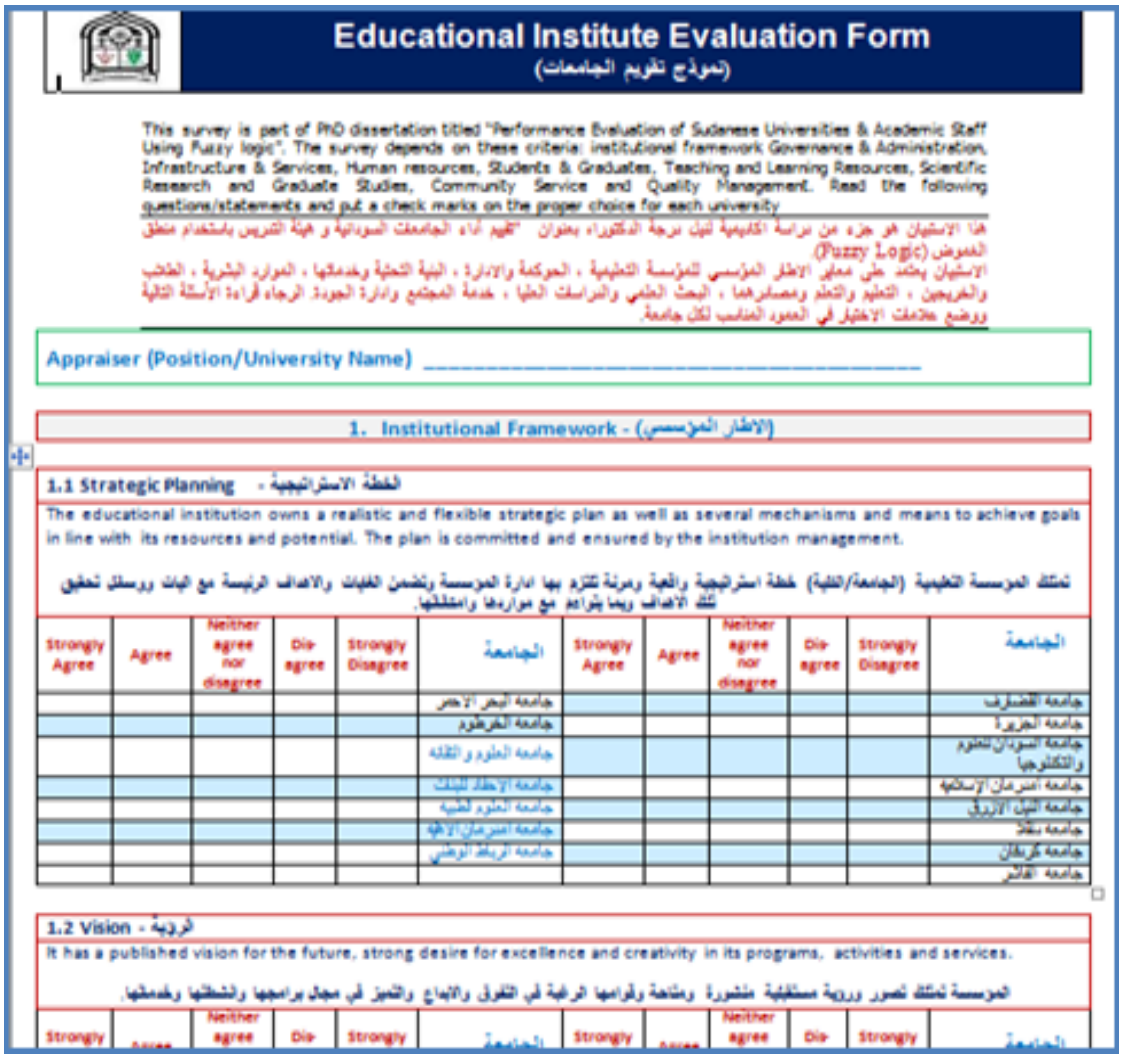
Q61.2.1	State of the Art مواكبة المنهج الدراسي لاخر ما توصل اليه العلم والابحاث العلمية في المجال										Clearness of Course objective
Q61.2.2											Consistency of Course content and Syllabus
Q61.3.1	Clearness of Course objective وضوح أهداف المقرر										Consistency of Course content and Syllabus

5.5.2 The 2nd Type of Survey (Evaluation Forms)

In the first type of survey (Pairwise Comparisons), we aimed to obtain the expert assessment view about the criteria itself; while in the second survey type (Evaluation Forms), the experts views about alternatives (universities & academic staff) with respect to each criterion has been obtained.

Sample of Evaluation Form for University Performance Evaluation:

This form includes list of questions that were designed and arranged under lower level of each criterion (i.e. bottom criteria). Furthermore, set of main public and private Sudanese universities were selected to be as alternative samples. Figure 5.1 shows the evaluation form used to assess the Sudanese universities against the bottom criteria such as strategic planning, vision, etc.



Educational Institute Evaluation Form
(نموذج تقويم الجامعات)

This survey is part of PhD dissertation titled "Performance Evaluation of Sudanese Universities & Academic Staff Using Fuzzy logic". The survey depends on these criteria: institutional framework Governance & Administration, Infrastructure & Services, Human resources, Students & Graduates, Teaching and Learning Resources, Scientific Research and Graduate Studies, Community Service and Quality Management. Read the following questions/statements and put a check marks on the proper choice for each university

هذا الاستبيان هو جزء من دراسة اكاديمية لنيل درجة الدكتوراه بعنوان "تقييم أداء الجامعات السودانية و هيئة التدريس باستخدام منطق الفضوض (Fuzzy Logic)
الاستبيان يعتمد على معايير الاطار المؤسسي للمؤسسة التعليمية ، الحوكمة والادارة ، البنية التحتية وخدماتها ، الموارد البشرية ، الطلاب والخريجين ، التعليم والتعلم ومصادرهما ، البحث العلمي والدراسات العليا ، خدمة المجتمع وادارة الجودة. الرجاء قراءة الأسئلة التالية ووضع علامات الاختيار في العمود المناسب لكل جامعة.

Appraiser (Position/University Name) _____

1. Institutional Framework - (الاطار المؤسسي)

1.1 Strategic Planning - الخطة الاستراتيجية

The educational institution owns a realistic and flexible strategic plan as well as several mechanisms and means to achieve goals in line with its resources and potential. The plan is committed and ensured by the institution management.

تمتلك المؤسسة التعليمية (الجامعة/الكلية) خطة استراتيجية واقعية ومرنة تلتزم بها ادارة المؤسسة وتضمن الغايات والاهداف الرئيسة مع اليات ووسائل تحقيق تلك الأهداف وبما يتواءم مع مواردها وامكاناتها.

Strongly Agree	Agree	Neither agree nor disagree	Dis-agree	Strongly Disagree	الجامعة	Strongly Agree	Agree	Neither agree nor disagree	Dis-agree	Strongly Disagree	الجامعة
					جامعة البحر الاحمر						جامعة القضارف
					جامعة الخرطوم						جامعة الجزيرة
					جامعة العلوم و التقنية						جامعة السودان للعلوم والتكنلوجيا
					جامعة الاحفاد للبنات						جامعة امدرمان الإسلامية
					جامعة العلوم الطبية						جامعة النيل الازرق
					جامعة امدرمان الاهلية						جامعة بحري
					جامعة الرباط الوطني						جامعة كردفان
											جامعة الفاشر

1.2 Vision - الرؤية

It has a published vision for the future, strong desire for excellence and creativity in its programs, activities and services.

المؤسسة تمتلك تصور ورؤية مستقبلية منشورة ومتاحة وقوامها الرغبة في التفوق والابداع والتميز في مجال برامجها وانشطتها وخدماتها.

Strongly		Neither agree	Dis-	Strongly		Strongly		Neither agree	Dis-	Strongly	

Figure 5. 1 : Sample of Universities Evaluation Form (Alternative Evaluation)

Sample of Evaluation Forms for Academic Staff Performance Evaluation:

We used the 360-degree evaluation approach to assess the academic staff. Therefor set of evaluation forms were designed as follow:

- Department Head / Dean Evaluation Form (Figure 5.2): This form includes questions related to Excellence in research and scientific activities, Teaching Quality, Services & Administration, and Knowledge Transfer criteria.

- Students Feedback Evaluation Form (Figure 5.3): This form determines the student feedback which includes questions related to Teaching capabilities and preparation for lecture, Material contribution in the scientific achievement of students, Material Content Assessment and Relationship of academic staff member and students.

- Peers/Colleagues Feedback Evaluation (Figure 5.4): This form includes the assessment of academic staff member's peers in the following aspects: Course content, Delivery and teaching methods, learning environment, and communication, collaboration and professionalism.

- Academic staff self-assessment evaluation form: This form will be filled by appraisee (academic staff member). It includes information related to publications & scientific research, materials that have been taught, supervision of postgraduate students, administration positions occupied, memberships, awards, community services and activities, etc.

Faculty Member Evaluation Form (PhD)
(نموذج تقويم اعضاء هيئة التدريس)
Department Head / Dean Model
رئيس القسم و العميد

This survey is part of PhD dissertation titled "Performance Evaluation of Sudanese Universities & Academic Staff Using Fuzzy logic". The Head of department and Dean fill in this part of the model to evaluate the Excellence in Research and Scientific Activities, Teaching Quality, Service administration Performance, and Knowledge Transfer/Exchange and Engaging Communities Performance

هذا الاستبيان هو جزء من دراسة اكاديمية لنيل درجة الدكتوراه بعنوان "تقييم أداء الجامعات السودانية و هيئة التدريس باستخدام منطق الغموض (Fuzzy Logic).
يقوم رئيس القسم والعميد بتعبئة هذا الجزء من النموذج لتقيم امكانيات عضو هيئة التدريس في التميز في البحوث والانشطة العلمية ، جودة ونوعية التدريس ، الخدمات الإدارية و نقل وتبادل المعرفة والشراك وترقية المجتمعات المحلية

Appraiser (Department Head/Dean) Name/position	Appraisee Name/position

1. Excellence in Research and Scientific Activities
(التميز في البحوث والانشطة العلمية)

SR	Criteria Disc.	Strongly Agree	Agree	Neither agree nor disagree	Disagree	Strongly Disagree	المعيار
1.1	Lecturer published acceptable number of papers that suit the current and previous job title						لقد تم نشر عدد مقبول من الأوراق التي تتناسب مع المسمى الوظيفي الحالي والسابق
1.2	Maintain high quality of Research. (*i.e. Number of citations, the impact factor values, etc.*)						الحفاظ والمداومة على الجودة العالية للأبحاث. (عدد الاستشهاد ، نوعية المجلات وقيم معامل التاثير للمجلات)
1.3	Gets invitations to provide Lectures in Important Conferences						يتلقى دعوات لتقديم محاضرات في المؤتمرات الهامة
1.4	Supervises postgraduate students and participates in postgraduate thesis examination/Discussion						يشرف على طلاب الدراسات العليا ويشارك في أطروحة الدراسات العليا الفحص / مناقشة
1.5	Membership in Editorial Boards of Prestigious Journals						يشارك في هيئات تحرير بعض المجلات المرموقة

2. Teaching Quality
(جودة و نوعية التدريس)

Figure 5. 2: Sample of Department Head / Dean Evaluation form

Student's College/Grade/Subject	Appraisee Name/Position

1. Teaching capabilities and preparation for lecture
(امكانيات عضو هيئة التدريس في تدريس المادة والاعداد والتحضير لها)

SR	Criteria Disc.	Strongly Agree	Agree	Neither agree nor disagree	Disagree	Strongly Disagree	المعيار
1.1	Distributes the study plan in the first week						يوزع الخطة الدراسية في الأسبوع الأول
1.2	Presents scientific subjects in lectures in a clear, coherent and systematic way						يعرض المادة العلمية في المحاضرات بشكل واضح ومترابط ومنظم
1.3	Exploits the time of lecture effectively						يستغل وقت المحاضرات بشكل فعال
1.4	high experience and skills in the scientific courses						المحاضر خبير ومتمكن من المادة العلمية
1.5	The compatibility between the plan and what was actually taught.						التوافق التام بين مفردات الخطة وما تم تدريسه فعلاً
1.6	Adhere to the dates of his lectures						يلتزم بمواعيد محاضراته

2. Material contribution in the scientific achievement of students
(مساهمة المادة في التحصيل العلمي للطلبة)

SR	Criteria Disc.	Strongly Agree	Agree	Neither agree nor disagree	Disagree	Strongly Disagree	المعيار
2.1	Motivates students to participate and express their views on the material.						يحفز الطلبة على المشاركة وإبداء وجهات نظرهم حول المادة
2.2	Shows interest in academic achievement of students in						يبدي اهتماماً بالتحصيل الدراسي للطلبة بشكل عام

Figure 5. 3: Sample of Students Feedback evaluation Form

Appraiser (Peer) name/position:	Appraisee Name/position

1. Course Content
(محتوى الكورس)

SR	Criteria Disc.	Strongly Agree	Agree	Neither agree nor disagree	Disagree	Strongly Disagree	المعيار
1.1	The instructor demonstrates and explains the subject title and outlines						المحاضر يوضح ويستعرض موضوع البحث
1.2	The course content reflects "state of the art" and current research findings.						المنهج الدراسي يحتوي على اخر ما توصل اليه العلم والابحاث العلمية في المجال
1.3	The purpose of the course is evident						الغرض من الدورة واضح
1.4	The course content is consistent with the course syllabus						المحتوى يتفق مع المنهج الدراسي

2. Delivery and Teaching Methods
(التقديم وطرق التدريس)

SR	Criteria Disc.	Strongly Agree	Agree	Neither agree nor disagree	Disagree	Strongly Disagree	المعيار
2.1	Smooth transition between ideas						انتقال سلس بين الأفكار
2.2	Relevant examples are given and used to clarify concepts						يتم إعطاء الأمثلة ذات الصلة واستخدامها لتوضيح المفاهيم
2.3	Presents subject in organized way						يعرض المادة بطريقة منظمة
2.4	The instructor is enthusiastic about the subject						المحاضر متحمس لتدريس الموضوع
2.5	Material is adapted to student						يتم تكييف المادة لتناسب احتياجات

Figure 5. 4: Sample of Peers/Colleagues Feedback evaluation form

5.6 Summary

The Survey Design chapter began with an understanding of the survey's goal and objectives, target population definition and survey reliability and validity checking. Question structure and response format were defined. Furthermore, two types of survey forms were designed and presented. The first survey type was designed to allow experts to assess the relative importance of evaluation criteria with respect to overall objective through pairwise comparison matrices survey. The second survey is to allow experts to assess the alternatives based on these criteria. Samples of several survey types were presented and explained including questions and answers sheets using several evaluation forms.

CHAPTER VI

6. DATA COLLECTION & ANALYSIS

Appropriate set of criteria of universities and academic staff evaluation were incorporated in pairwise comparisons and evaluation survey. Figure 4.4 and table 5.2 to 5.6 show sample of different level of comparison questions and related answer sheet. Forty-six questionnaires survey out of seventy were returned. Removing inconsistent questionnaire, we were left with thirty-five consistent questionnaires after consistency checking as shown 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 we 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 provided 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) was calculated and checked for each individual expert's responses. The consistency ratio (CR) is described as 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:

$$CI = (\lambda \max - n)/(n-1) \quad and \quad CR = CI/RCI \leq 01.0$$

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 were developed to check the comparison consistency and aggregate the consistent judgments. Table 6.1 includes all these functions and related operation.

Table 6. 1: List of the Excel Functions that used in consistency, aggregation, etc.

SR.	Function	Usage
1	IF()	- This function is used to convert the experts' preference from linguistic values into numerical interval (i.e. Fuzzy Triangular Number: FTN) in all comparison matrices. For example *[=IF(X=1, 0.22, IF(X =2, 0.29, IF(X =3, 0.4, IF(X =4, 0.67, IF(X =5, 1, IF(X =6, 0.67, IF(X =7, 1.5, IF(X =8, 2.5, IF(X =9, 3.5, 0))))))))]* - It used to determine the intersections points by comparing each couple (i.e. membership value / degree of possibility)
2	SUM()	- It is used to normalize comparison matrices.
3	GEOMEAN()	- It is used to aggregate the consistent fuzzy comparisons matrices
4	Min()	- It is used to determine the minimum degree of possibility for a specific criterion - It is used to determine the negative ideal solution for specific criterion
5	Max()	- It is used to determine the positive ideal solution for specific criterion
6	SQRT()	- It used to obtain the distance between universities/academic staff's (alternatives) solutions with the positive and negative ideal solution

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

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, 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.

2. Sum each column of the reciprocal matrix and divide each element of the matrix with the sum of its column (normalize relative weight).
3. Average across the rows to obtain Principal Eigen vector (priority vector).
4. Obtain principle Eigen value (λ) by adding of products between each element of Eigen vector and the sum of columns of the reciprocal matrix (step2).
5. Calculate consistency Index (CI) as follows:

$$CI = (\lambda \max - n)/(n-1) \quad where\ n\ is\ Judegment\ matrix\ order.$$

6. Calculate consistency ratio (CR) as follows:

$$CR = CI\ /RCI \quad where\ RI\ is\ Random\ Index.$$

7. Defuzzify the TFN and compare the output crisp value with 0.1

(Result <=0.10: acceptable level of inconsistency).

Theorem 6.1

Inconsistent Preference will lead to Incorrect Calculated Weight, which will lead to Incorrect Alternatives Classification.

As deductive reasoning theory, a consistent pairwise comparison matrix is one that does not contain a contradiction. Say C1, C2, C3, …, Cn are the evaluation criteria with weights w1, w2, …, wn for specific goal for alternatives a1, a2, a3,…,am. Assume the importance level granted to the Ci criterion in the 1st layer of comparison as follows:

Ci more important than Ci+1 (i.e. Ci>Ci+1), Ci is less important than Ci+2 (i.e. Ci<Ci+2), Ci is less important than Ci+3 (i.e. Ci<Ci+3) and Ci is more important than Ci+4 (i.e. Ci> Ci+4)

AND in the next comparison layer the Ci+1 criterion is granted with the following importance: *Ci+1 > Ci+2, Ci+1> Ci+3 and Ci+1 > Ci+4.*

We can notice, the following [*(Ci+1 > Ci+2, (Ci+1 > Ci+3)*] decisions contradict the previous experts' preference in 1st layer (i.e. *Ci > Ci+1, Ci<Ci+2, Ci<Ci+3).*

In the first layer of pairwise comparison, Assume the importance level value of *Ci* is 'Very good' in a specific scale […, Good, Very good, Excellent,...]

When Ci > Ci+1, then Ci+1 is 'Good' as maximum.

When Ci < Ci+2, then Ci+2 is 'Excellent' as minimum

When Ci < Ci+3, then Ci+3 is 'Excellent' as minimum

When Ci > Ci+4, then Ci+4 is 'Good' as maximum, *Where '>' means more important and '<' mean less important*

In the next layer: The preference Ci+1 > Ci+2 is inconsistent due to the previous preferences made in the first layer: (i.e. Ci > Ci+1 ➔ Ci+1 is 'Good' as maximum and Ci < Ci+2 ➔ Ci+2 is 'Excellent' as minimum).

How a criterion with linguistic value of "Good" be more important than a criterion with linguistic value "Excellent" ? which leads to contradiction (i.e. inconsistency).

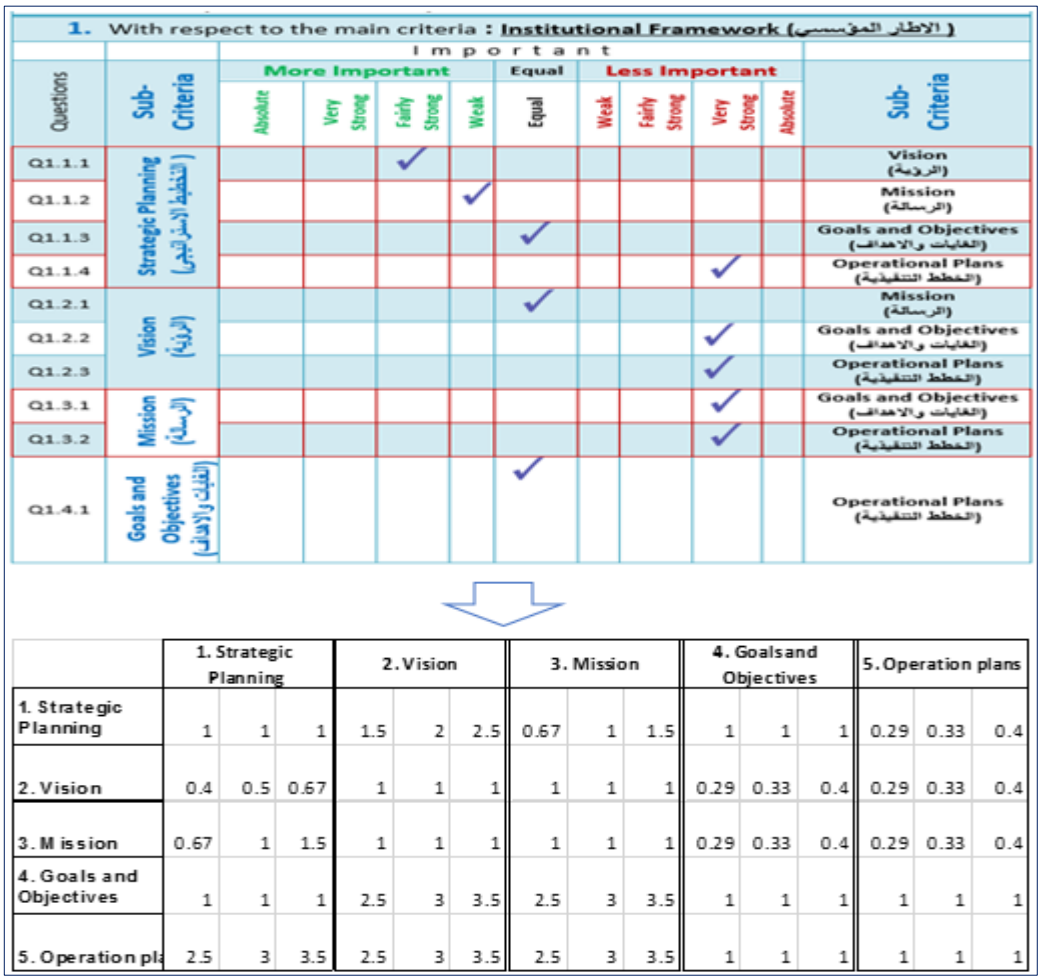
This theorem state that if an expert's preferences for comparing a group of criteria are inconsistent, then it leads to incorrect calculated criteria weights and accordingly to unsatisfactory result in the final alternatives classification/ranking. Generally, if a group of criteria (C1, C2… Cn) are compared in pairwise comparison with inconsistent preference values, the output of criteria weighs (w1, w2,…,wn) reflects incorrect weight and unsatisfactory final classification based on those criteria for alternatives (a1, a2, …,am).

Consistency Checking Example:

This example demonstrates consistency checking process of pairwise judgment response of comparing the sub-criteria of Institutional framework criterion. Figure 6.1 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 Figure 6.2, the seven steps are explained. The comparison matrix is constructed and linguistic values are converted into fuzzy triangular numbers as a first step (1), then column summation & normalization as in steps 2 & 3, etc. As final stage (step 7), the consistency ratio is calculated and found that the expert's preference is consistent (i.e. CR = 0.03 < = 0.1). Excel functions & 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 comparisons evaluation.



1. With respect to the main criteria : **Institutional Framework (الاطار المؤسسي)**

Important

Questions	Sub-Criteria	More Important: Absolute	More Important: Very Strong	More Important: Fairly Strong	More Important: Weak	Equal	Less Important: Weak	Less Important: Fairly Strong	Less Important: Very Strong	Less Important: Absolute	Sub-Criteria
Q1.1.1	Strategic Planning (التخطيط الاستراتيجي)			✓							Vision (الرؤية)
Q1.1.2					✓						Mission (الرسالة)
Q1.1.3						✓					Goals and Objectives (الغايات والأهداف)
Q1.1.4									✓		Operational Plans (الخطط التنفيذية)
Q1.2.1	Vision (الرؤية)					✓					Mission (الرسالة)
Q1.2.2									✓		Goals and Objectives (الغايات والأهداف)
Q1.2.3									✓		Operational Plans (الخطط التنفيذية)
Q1.3.1	Mission (الرسالة)								✓		Goals and Objectives (الغايات والأهداف)
Q1.3.2									✓		Operational Plans (الخطط التنفيذية)
Q1.4.1	Goals and Objectives (الغايات والأهداف)					✓					Operational Plans (الخطط التنفيذية)

	1. Strategic Planning			2. Vision			3. Mission			4. Goals and Objectives			5. Operation plans		
1. Strategic Planning	1	1	1	1.5	2	2.5	0.67	1	1.5	1	1	1	0.29	0.33	0.4
2. Vision	0.4	0.5	0.67	1	1	1	1	1	1	0.29	0.33	0.4	0.29	0.33	0.4
3. Mission	0.67	1	1.5	1	1	1	1	1	1	0.29	0.33	0.4	0.29	0.33	0.4
4. Goals and Objectives	1	1	1	2.5	3	3.5	2.5	3	3.5	1	1	1	1	1	1
5. Operation pl	2.5	3	3.5	2.5	3	3.5	2.5	3	3.5	1	1	1	1	1	1

Figure 6. 1 Shows the part of feedback for responder #25

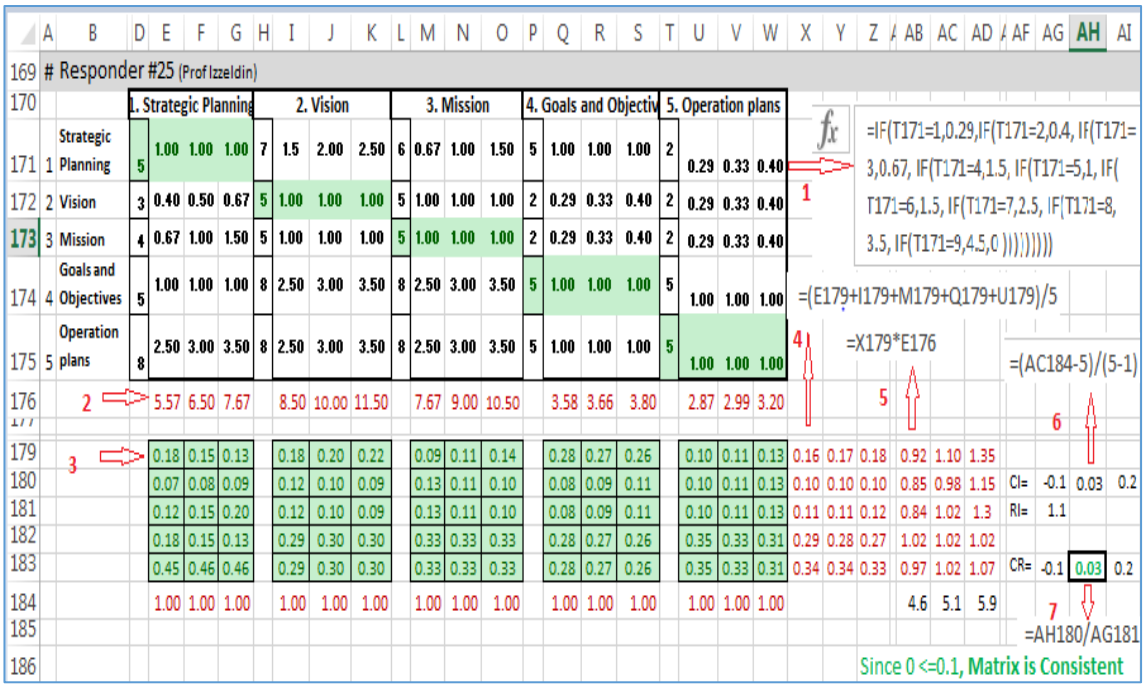


Figure 6. 2: Consistency checking calculation and result for UC1criteria (responder #25)

6.1.2 On-line Consistency Checking Fuzzy Consistency Algorithm (FCA):

One of the challenges faced in analyzing the surveyed data was 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 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 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 and suggested correction. Details of the algorithm is explained in the next chapter (Yousif, & Shaout, 2016/b).

6.2 Summary

The chapter pointed out the statistical info of survey data collection and analysis such as distributed questioners, returned, returned percentage and consistent returned. The chapter also highlighted the consistency issues and methods of checking the consistency offline and online. It introduced a new algorithm for online consistency checking

CHAPTER VII

7. THE PROPOSED ALGORITHM FOR CONSISTENCY ASSESSMENT IN PAIRWISE COMPARISON

This chapter explains new proposed algorithm for online consistency checking in pairwise comparison survey. It includes the scale definition, detail algorithm steps and empirical example for evaluating the performance of Sudanese universities.

7.1 Scale & Definitions

Table 7.1 shows the suggested scale for consistency evaluation which is proposed to be a base reference for our proposed algorithm in this chapter. The scale table consists of five columns as follows:

- Scale Rank (SR) which defines the number for less important values (from 1 to 4), equal important value (5), and more important values (from 6 to 9),
- Importance Type (IT) which shows the importance description types (Less/Equal/More Important),
- Linguistic Degree Value (LV) which represents the degree of preference,
- Distance Value (DV) which shows the distance and direction of importance from the neutral point (Equal point), and
- TFN column is the triangular fuzzy number scale, which will be used in later evaluation process.

Where SRx = {1,2, …,9}, MaxSR= 9, ITx = {Less important, Equal important, More Important}, DVx ={-4,-3,-2,-1,0,1,2,3,4} and LVx = {Absolute, Very Strong, Fairly Strong, Weak, Equal}.

Table 7. 1: Suggested Scale for consistency evaluation

Scale Rank (SR)	Importance Type (IT)	Linguistic Degree Value (LV)	Distance Value (DV)	TFN
1	Less Important	Absolute	-4	(2/9, 1/4, 2/7)

2	Less Important	Very Strong	-3	(2/7, 1/3, 2/5)
3	Less Important	Fairly Strong	-2	(2/5, 1/2, 2/3)
4	Less Important	Weak	-1	(2/3, 1, 3/2)
5	Equal Important	Equal	0	(1, 1, 1)
6	More Important	Weak	1	(2/3, 1, 3/2)
7	More Important	Fairly Strong	2	(3/2, 2, 5/2)
8	More Important	Very Strong	3	(5/2, 3, 7/2)
9	More Important	Absolute	4	(7/2, 4, 9/2)

7.2 Fuzzy Consistency Algorithm (FCA)

In this section a new fuzzy consistency algorithm (FCA) will be introduced. The Proposed Algorithm FCA will be used for detecting inconsistency and provide consistency options.

Assume that pairwise comparisons are required for n criteria (C1, C2, C3… Cn). Using the proposed scale in table 7.1 and input of the first layer of expert's judgment (i.e. preference of criterion C1 with all other criteria C2 to Cn), then the new proposed FCA algorithm can be used to determine the preference values of the second layer of comparison (i.e. C2 with all other criteria C3 to Cn, C3 with all other criteria C4 to Cn, C4 with all other criteria C5 to Cn, etc.).
The following are the steps of the FCA proposed algorithm:

Step1:

Determine the scale rank value (SRxy) of preference for criterion Cx over Cy (i.e. Cxy) and simultaneously calculate the preference of Cy over Cx (i.e. Cyx) by adding one to the maximum scale rank and subtract the preference of Cxy. This step constructs the base data table to check the consistency of all comparison layers' data.

$$If\ C_{xy} = SR_{xy},\ then\ C_{yx} = MaxSR + 1 - C_{xy} \ldots (1.0)$$

$where\ SRxy = 1,2,3, \dots 9\ \ and\ MaxSR =$
$Maximumn\ number\ in\ the\ scale\ rank\ (i.e. 9)$

Step2:

For each x, y and z as elements/criteria, where the C_{xy} denotes the preference level of element/criterion x over element y and C_{xz} denotes the preference level of element/criterion x over element/$criterion$ z,

Calculate the C_{yz} using the preference of criterion x as base. This can be done as follows:

$$C_{xy} = SR_{xy}\ ,\ then\ C_{yx} = SR_{yx}\quad where\ SRyx = maxSR + 1 - SRxy\ \ .\ (1.1)$$

$$C_{xz} = SR_{xz}\ then\ \ C_{zx} = SR_{zx}\ \ where\ SRzx = maxSR + 1 - SRxz\ \ \ \dots\ \ (1.2)$$

$Now,\ we\ need\ to\ find\ C_{yz}\ \ according\ to\ (1.0) and\ Scale\ (Tabl\ 1)$

Step2.1: Find the distance value from scale table for $SR_{yx}\ and\ \ SR_{zx}$

$$The\ distance\ of\ Criterion_y\ \ to\ \ Criterion_{\ x}\ \ is\ \ DV\left(SR_{yx}\right)$$

$$and\ distance\ of\ Critrion_{\ z}\ \ to\ \ Critrion_x\ \ is\ \ DV(SR_{zx})$$

Step2.2: Determine preference level of criterion y over critrion z (C_{yz})

by calculating the difference between $DV\left(SR_{yx}\right)$ and $V(SR_{zx})$

$$(C_{yz}) = SR\ \left(DV\left(SR_{yx}\right) - DV(SR_{zx})\right)\ \ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\ (2.0)$$

Step 3: Determine the importance type of the preference between criterion y and criterion z by checking the value of equation 2 as shown below:

$$Importanat\ Type\ (IT) = \begin{cases} More\ Important\ ,\ if\quad DV\left(SR_y\right) - DV(SR_z) > 0 \\ Less\ Important\ ,\ if\quad DV\left(SR_y\right) - DV(SR_z) < 0 \\ Equally\ Important\ , if\quad DV\left(SR_y\right) - DV(SR_z) = 0 \end{cases}\ \ \dots\dots\dots\dots\dots\dots\ (3.0)$$

Example 1:

$If\ C_{12} = 4\ \ (i.e.\ C_1\ is\ Less\ important\ than\ C_2\ by\ Weak\ degree\ )$

$Then,\ C_{21=}9 + 1 - 4 = 6\ \ \ (i.e.\ C_2\ is\ More\ important\ than\ C_1\ by\ Weak\ degree).$

Example2:

(For three Criteria/elements where x = 1, y = 2, z = 3)

The aim of this example is to find the preference level of element 2 over element 3. Let us assume that preference of 1 over 2 is given and then drive the opposite preference (2 over 1). Also, assume that preference 1 over 3 and drive the opposite preference (3 over 1) using equation (1.1 & 1.2). Finally, use equations (2.0) and (3.0) to find the preference of 2 over 3.

$If\ \ C_{12} = SR_{12}\ = 4\ (i.e.\ C_1\ is\ Less\ important\ than\ C_2\ by\ Weak\ degree\ )$

$Then,\ C_{21} =\ SR_{21}\ = 9 + 1 - 4 =$
$6\ (i.e.\ C_2\ is\ \ More\ important\ than\ C_1\ by\ Weak\ degree)$

$Also,\ If\ C_{13} = SR_{13}\ = 7$

$(i.e.\ C_1\ is\ More\ important\ than\ C_3\ by\ Fairly\ Strong\ degree\ )$

$Then,\ C_{31} = SR_{31}\ = 9 + 1 - 7 = 3$

$(i.e.\ C_3\ is\ \ Less\ important\ than\ C_1\ by\ Fairly\ strong\ degree)$

$Distance\ of\ C_2\ \ from\ C_1 =\ \ DV(SR_{21}) = DV(6)\ =\ 1,$

$Distance\ of\ C_3\ \ from\ C_1 =\ \ DV(SR_{31}) = DV(3) =\ -2$

Then: $DV(SR_{21})\ -\ DV(SR_{31}) = (1) - (-2) =\ 3.$

$Hence, SR(DV(3)) =\ C_{23}\ = 8$

$(i.e. C_2\ is\ More\ important\ than\ C_3\ by\ Very\ Strong\ degree)$

7.3 Empirical Study - The performance of Sudanese universities

In this empirical study, we use the new FCA algorithm and the proposed scale table (Table 7.1) to enhance and enforce the consistency of pairwise comparison in the survey to measure the performance of Sudanese universities. We have designed a pairwise

comparison for nine criteria and have shown how we could assist the experts to reevaluate their inconsistent judgments/decisions.

We use pairwise comparison to estimate preference values of these criteria among themselves. Initially, an expert fills the first level of pairwise comparison which will be used as base for other pairwise comparisons without any enforcement and guidance. The first pairwise comparisons occur between institutional framework criterion with the other eight criteria such as Governance & administration, Infrastructure & services, Human resources, student & graduates, Teaching and Learning Resources, Scientific Research and Graduate studies, Community Service and Quality Management as shown in Figure 7.1. The first layer of pairwise comparison does not require consistency check since it purely reflects the expert views.

The first layer represents the initial expert's view which is not correlate or depend on other expert's preference for the same criteria while the expert's preference in the others layers may contradict with the previous expert's preference. This is why the consistency considerations are required from the second layer/level of comparisons.

Hence, in this example the, figure 7.1 represents the expert's input/views for 1st layer of pairwise comparison for Institutional frame work criterion with others criteria. This expert's input data is translated into table 7.2 as a base data which will be used for consistency checking for comparing other criteria in the others layers of the pairwise comparisons process.

		Important									
Questions	Criteria	More Important					Eq.	Less Important				Criteria
		Absolute	Very Strong	Fairly Strong	Weak		Equal	Weak	Fairly Strong	Very Strong	Absolute	
Q1.1	C1: Institutional Framework			×								C2: Governance & Administration
Q1.2							×					C3: Infrastructure & Services
Q1.3									×			C4: Human Resources
Q1.4					×							C5: Students & Graduates
Q1.5				×								C6: Teaching and Learning Resources
Q1.6					×							C7: Scientific Research & Graduate studies
Q1.7			×									C8: Community Service
Q1.8			×									C9: Quality Management

Figure 7. 1: 1st layer: Inputs of experts for pairwise comparison for criterion (C1/ UC1).

Table 7. 2: 1st layer Expert's Input: Comparison of UC1 criterion with others criteria.

Qs No.	Description (as indicated by expert)	(SRxy) Given	Inference from Eq-1	
			SRyx = SRmaxScale+1-SRxy	Description
Q1.1	C1: Institutional framework is More important than C2: Governance & Administration by Fairly Strong degree	$C_{12} = 7$	$C_{21} = 3$	C2:Governance & Administration is less important than C1:Institutional framework by Fairly Strong degree
Q1.2	C1: Institutional framework is Equally important with C3: Infrastructure & Services	$C_{13} = 5$	$C_{31} = 5$	C3:Infrastructure & Services is Equally important with C1:Institutional framework
Q1.3	C1:Institutional framework is Less important than C4:Human Resources by Fairly Strong degree	$C_{14} = 3$	$C_{41} = 7$	C4:Human Resources is More important than C1:Institutional framework by Fairly Strong degree
Q1.4	C1:Institutional framework is More important than C5:Students & Graduates by Weak degree	$C_{15} = 6$	$C_{51} = 4$	C5:Students & Graduates is Less important than C1:Institutional framework by Weak degree
Q1.5	C1:Institutional framework is More important than C6:Teaching and Learning Resources by Fairly Strong degree	$C_{16} = 7$	$C_{61} = 3$	C6:Teaching and Learning Resources is Less important than C1:Institutional framework by Fairly Strong degree
Q1.6	C1:Institutional framework is More important than C7:Scientific Research & Graduate studies by Weak degree	$C_{17} = 6$	$C_{71} = 4$	C7:Scientific Research & Graduate studies is Less important than C1:Institutional framework by Weak degree
Q1.7	C1:Institutional framework is More important than C8:Community Service by Very Strong degree	$C_{18} = 8$	$C_{81} = 2$	C8:Community Service is Less important than C1:Institutional framework by Very Strong degree

Q1.8	C1:Institutional framework is More important than C9:Quality Management by Very Strong degree	$C_{19} = 8$	$C_{91} = 2$	C:9 Quality Management is Less important than C1:Institutional framework by Very Strong degree

In the pairwise comparisons of C2 with all other criteria C3 to C9 (2nd layer) as shown in Figure 7.2, a consistency check is required to review the expert answers and propose a consistent option.

		Important									
Questions	Criteria	More Important				Eq.	Less Important				Criteria
		Absolute	Very Strong	Fairly Strong	Weak	Equal	Weak	Fairly Strong	Very Strong	Absolute	
Q1.1	C2 Governance & Administration										C3: Infrastructure & Services
Q1.2											C4: Human Resources
Q1.3											C5: Students & Graduates
Q1.4											C6: Teaching and Learning Resources
Q1.5											C7: Scientific Research & Graduate studies
Q1.6											C8: Community Service
Q1.7											C9: Quality Management

Figure 7. 2: 2nd layer of pairwise comparison & consistency checking (C2=:UC2).

In the 2nd layer, we calculate and present the expected consistent options in pairwise comparisons based on the scale in table 7.1 and inputs from experts in the first layer (Table 7.2) using the proposed algorithm FCA. Hence, Tables 7.3 to 7.9 present the detail calculation for the expected consistent results of comparing criterion C2 with all others remaining criteria (C3 to C9), criterion C3 with all others criteria remaining (C4 to C9), criterion C4 with others remaining criteria (C5 to C9), criteria C5 with others remaining criteria (C6 to C7), criterion C6 with others remaining criteria (C7 to C9), criterion C7 with others remaining criteria (C8 to C9) and finally criterion C8 with criterion C9.

Table 7. 3: Expected consistent comparisons result of Governance & Admin criterion

Comp. of C2 with others	From Table-7.2		DV(SR_{xy})	DV(SR_{yx})	DV(SR_x) – DV(SR_y)	Scale Rank SR(DV)	(IT) Eq3	Description of Expected Consistent Result
	Scale Rank (Cxy) SR_{xy}	Scale Rank (Cyx) SR_{yx}						
C_{23}	$C_{21} = 3$	$C_{31} = 5$	-2	0	-2	3	Less important	C2:Governance & Administration is **Less important** than C3:Infrastructure & Services by **Fairly Strong** degree
C_{24}	$C_{21} = 3$	$C_{41} = 7$	-2	2	-4	1	Less important	C2:Governance & Administration is **Less important** than C4:Human Resources by **Absolute degree**
C_{25}	$C_{21} = 3$	$C_{51} = 4$	-2	-1	-1	4	Less important	C2:Governance & Administration is **Less important** than C5:Students & Graduates by **Weak degree**
C_{26}	$C_{21} = 3$	$C_{61} = 3$	-2	-2	0	5	Equal	C2:Governance & Administration is **Equally important** with C6:Teaching and Learning Resources
C_{27}	$C_{21} = 3$	$C_{71} = 4$	-2	-1	-1	4	Less important	C2:Governance & Administration is **Less important** than C7:Scientific Research & Graduate studies by **Weak degree**
C_{28}	$C_{21} = 3$	$C_{81} = 2$	-2	-3	1	6	More Important	C2:Governance & Administration is **More important** than C8:Community Service by **Weak degree**
C_{29}	$C_{21} = 3$	$C_{91} = 2$	-2	-3	1	6	More Important	C2:Governance & Administration is **More important** than C9:Quality Management by **Weak degree**

Table 7. 4: Expected consistent comparisons result of Infrastructure & Services

Comp. of C3 with others	From Table-7.2		**DV(SR_{xy})**	**DV(SR_{yx})**	**DV(SR_x) – DV(SR_y)**	**Scale Rank SR(DV)**	**IT Eq3**	**Description of Expected Consistent Result**
	Scale Rank (Cxy) SR_{xy}	Scale Rank (Cyx) SR_{yx}						
C_{34}	$C_{31} = 5$	$C_{41} = 7$	0	2	-2	3	Less important	C3:Infrastructure & Services is **Less important** than C4:Human Resources by Fairly Strong degree
C_{35}	$C_{31} = 5$	$C_{51} = 4$	0	-1	1	6	More important	C3:Infrastructure & Services is **More important** than C5:Students & Graduates by **Weak degree**
C_{36}	$C_{31} = 5$	$C_{61} = 3$	0	-2	2	7	More important	C3:Infrastructure & Services is **More important** than C6Teaching and Learning Resources by **Fairly Strong** degree
C_{37}	$C_{31} = 5$	$C_{71} = 4$	0	-1	1	6	More important	C3:Infrastructure & Services is **More important** than C7:Scientific Research & Graduate studies by **Weak degree**
C_{38}	$C_{31} = 5$	$C_{81} = 2$	0	-3	3	8	More Important	C3:Infrastructure & Services is **More important** than C8:Comm-unity Service by Very **strong** degree
C_{39}	$C_{31} = 5$	$C_{91} = 2$	0	-3	3	8	More Important	C3:Infrastructure & Services is **More important** than C9:Quality Manag. by **Very strong** degree

Table 7. 5: Expected consistent comparisons result of Human Resources

Comp. of C4 with others	From Table-7.2		**DV(SR_{xy})**	**DV(SR_{yx})**	**DV(SR_x) – DV(SR_y)**	**Scale Rank SR(DV)**	**IT Eq3**	**Description of Expected Consistent Result**
	Scale Rank (Cxy) SR_{xy}	Scale Rank (Cyx) SR_{yx}						
C_{45}	$C_{41} = 7$	$C_{51} = 4$	2	-1	3	8	More important	C4:Human Resources is **More important** than C5:Students & Graduates by **Very strong** degree
C_{46}	$C_{41} = 7$	$C_{61} = 3$	2	-2	4	9	More important	C4:Human Resources is **More important** than C6:Teaching and Learning Resources by **Absolute** degree
C_{47}	$C_{41} = 7$	$C_{71} = 4$	2	-1	3	8	More important	C4: Human Resources is **More important** than C7: Scientific. Research & Graduate studies by **Very strong** degree
C_{48}	$C_{41} = 7$	$C_{81} = 2$	2	-3	5	9*	More Important	C4:Human Resources is **More important** than C8:Commu-nity Service by **Absolute*** degree
C_{49}	$C_{41} = 7$	$C_{91} = 2$	2	-3	5	9*	More Important	C4:Human Resources is **More important** than C9:Quality Management by **Absolute*** degree

Table 7. 6: Expected consistent comparisons result of Students & Graduates

Comp. of C5 with others	From Table-7.2		**DV(SR_{xy})**	**DV(SR_{yx})**	**DV(SR_x) – DV(SR_y)**	**Scale Rank SR(DV)**	**IT Eq3**	**Description of Expected Consistent Result**
	Scale Rank (Cxy) SR_{xy}	Scale Rank (Cyx) SR_{yx}						
C_{56}	$C_{51} = 4$	$C_{61} = 3$	-1	-2	1	6	More important	C5:Students & Graduates is **More important** than C6:Teaching and Learning Resources by **Weak degree**
C_{57}	$C_{51} = 4$	$C_{71} = 4$	-1	-1	0	5	Equal important	C5:Students & Graduates is **Equally** important with C7:Scientific Research & Graduate studies
C_{58}	$C_{51} = 4$	$C_{81} = 2$	-1	-3	3	8	More Important	C5:Students & Graduates is **More important** than C8:Commun-ity Service by **Very strong** degree
C_{59}	$C_{51} = 4$	$C_{91} = 2$	-1	-3	3	8	More Important	C5:Students & Graduates is **More important** than C9:Quality Management by **Very strong** degree

Table 7. 7: Expected consistent comparisons result of Teaching and Learning Resources

Comp. of C6 with others	From Table-2		**DV(SR_{xy})**	**DV(SR_{yx})**	**DV(SR_x) – DV(SR_y)**	**Scale Rank SR(DV)**	**IT Eq3**	**Description of Expected Consistent Result**
	Scale Rank (Cxy) SR_{xy}	Scale Rank (Cyx) SR_{yx}						
C_{67}	$C_{61} = 3$	$C_{71} = 4$	-2	-1	-1	4	Less important	C6:Teach. and Learning Resources is **Less important** than C7:Scienti-fic Research & Graduate studies by **Weak** degree
C_{68}	$C_{61} = 3$	$C_{81} = 2$	-2	-3	1	6	More Important	C6:Teach. and Learning Resources is **More important** than C8:Community Service by **Weak** degree
C_{69}	$C_{61} = 3$	$C_{91} = 2$	-2	-3	1	6	More Important	C6:Teach. and Learning Resources is **More important** than C9:Quality Management by **Weak** degree

Table 7. 8: Expected consistent comparisons result of Scientific Research

Comp. of C7 with others	From Table-2		**DV(SR_{xy})**	**DV(SR_{yx})**	**DV(SR_x) – DV(SR_y)**	**Scale Rank SR(DV)**	**(IT) Eq3**	**Description of Expected Consistent Result**
	Scale Rank (Cxy) SR_{xy}	Scale Rank (Cyx) SR_{yx}						
C_{78}	$C_{71} = 4$	$C_{81} = 2$	-1	-3	2	7	More Important	C7:Scientific Research & Graduate Studies is **More important** than C8:Commun. Service by **Fairly strong**

C_{79}	$C_{71} = 4$	$C_{91} = 2$	-1	-3	2	7	More Important	C7:Scientific Research & Graduate Studies is **More important** than C9:Quality Management by **Fairly Strong** degree

Table 7. 9: Expected consistent comparisons result of Community Service

Comp. of C8 with others	From Table-7.2		**DV(SR_{xy})**	**DV(SR_{yx})**	**DV(SR_x) – DV(SR_y)**	**Scale Rank SR(DV)**	(IT) Eq3	**Description of Expected Consistent Result**
	Scale Rank (Cxy) SR_{xy}	Scale Rank (Cyx) SR_{yx}						
C_{89}	$C_{81} = 2$	$C_{91} = 2$	-3	-3	0	5	Equal Important	C8:Comm. Service is **Equally** important with C9: Quality Management.

In the above example, we used FCA to calculate the expected consistent preference values for all pairwise comparisons within each layers. Tables 7.3 to 7.9 contain the expected consistent values for layers 2 to 8 respectively.

As shown in table 7.8, the expected values of comparing C7 with C8 (i.e. C_{78}) and expected value of comparing C7 with C9 (i.e. C_{79}) are as follows "C7: Scientific Research & Graduate Studies is More Important than C8: Community Service by Fairly Strong degree" and "C7: Scientific Research & Graduate Studies is More important than C9: Quality Management by Fairly Strong degree. Also, table 7.9 contains the expected values of comparing C8 with C9 (i.e. C_{89}) is as follows "C8: Community Service is Equally important with C9:Quality Management"

This example presented and explained the detail mechanism of using the FCA to calculate the expected consistent values based on the expert's inputs in the first layer and propose those values in case of inconsistent response from expert during the survey.

7.4 Design Online Embedded Pairwise Comparison Consistency Check & Options

The experts/participants are frequently not able to express consistent preferences in case of several criteria. This fact requires more effort and time to apply different methods to check the level of inconsistency for each expert's view/form. In most cases, the majority of these views require revisions by mitigating the inconsistency, returned to the expert for review, or excluded from the study. Therefore, embedded online solution with inconsistency checking functionalities is required. Checking for inconsistent judgments and providing optimal consistent options will speed up the evaluation process.

Table 7.10 and Figure 7.3 present the features and process workflow of the main application's components that used and applied the proposed algorithm FCA to check and recommend consistent options.

Table 7. 10: Table 3- High level functionality of consistency checking application

Sr.	Application Function	Comments
1	Setup Tables: Scale values & Consistency range.	Scale as define in Table 7.1 or it could be any other scale. Consistency range determines the accepted inconsistency level.
2	Base inference data: the initial expert input (i.e. the first layer of comparison between the first criteria and all other criteria).	In our empirical example, Refer to figure 7.1 and table 7.2 data.
3	Generate the optimal consistent option for other pairwise comparisons based on the first criteria comparisons (i.e. the 2nd layer of criteria).	Reference figure 7.2 and tables 7.3 to 7.9.
4	Check the expert preference/input in the 2nd layer comparisons with the optimal solution that was already generated in the step. In case of inconsistent input, propose the optimal consistent preference/option.	This step allows experts to choose the consistent option, know the root of the inconsistency and give option to reset his initial based data that caused the inconsistency.

As a result of the application used (the performance of Sudanese universities) which was based on the proposed algorithm FCA, a consistency checking recommendation and inconsistency reason tool will be provided to the expert/participant as shown in Figure 7.4.

Figures 7.3 to 7.11 show the entire recommended consistent options in our empirical example. The figures reflect the calculated recommended results from tables 7.3 to 7.9 in the same order in the survey format.

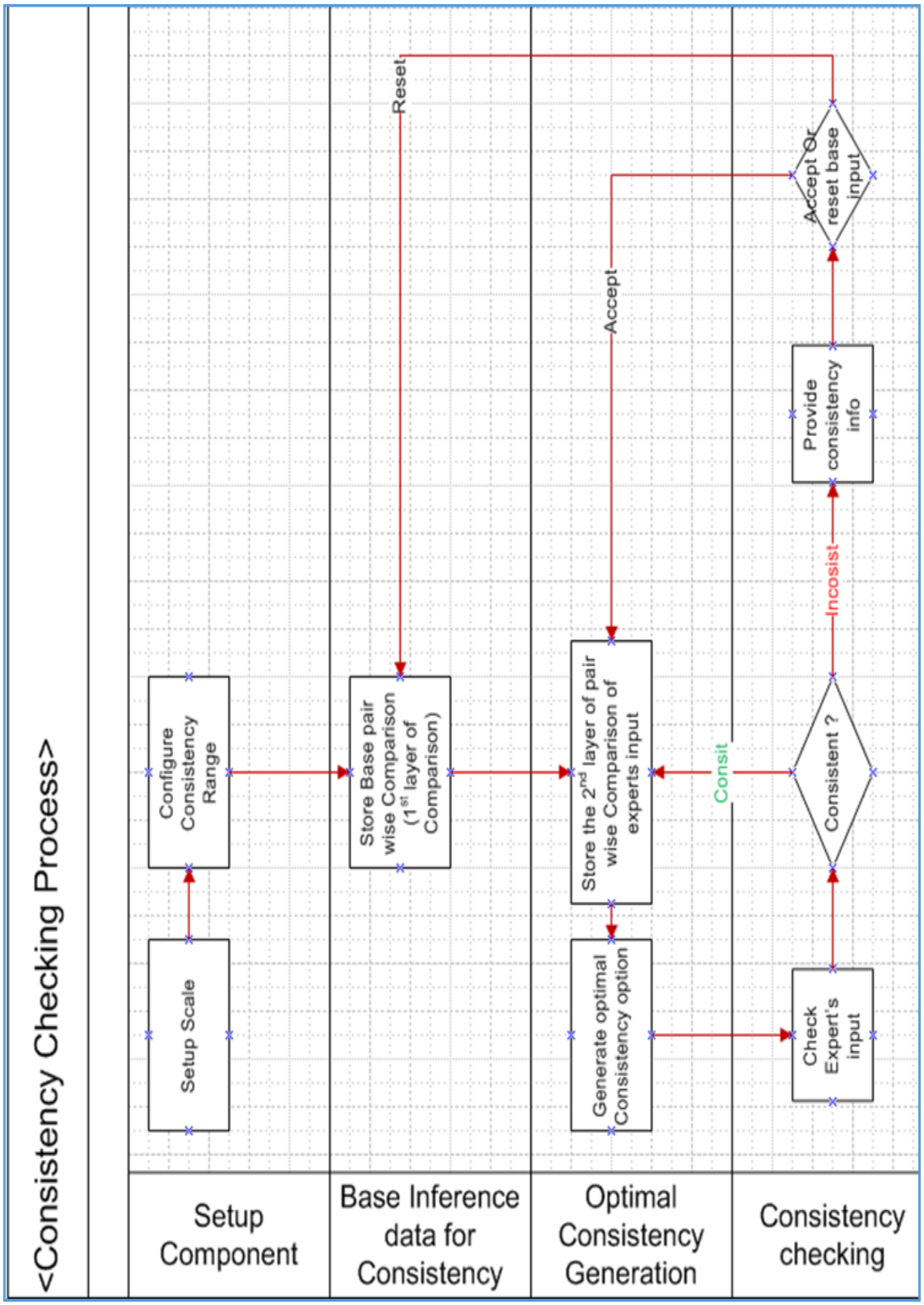


Figure 7. 3: High level of consistency checking workflow processes.

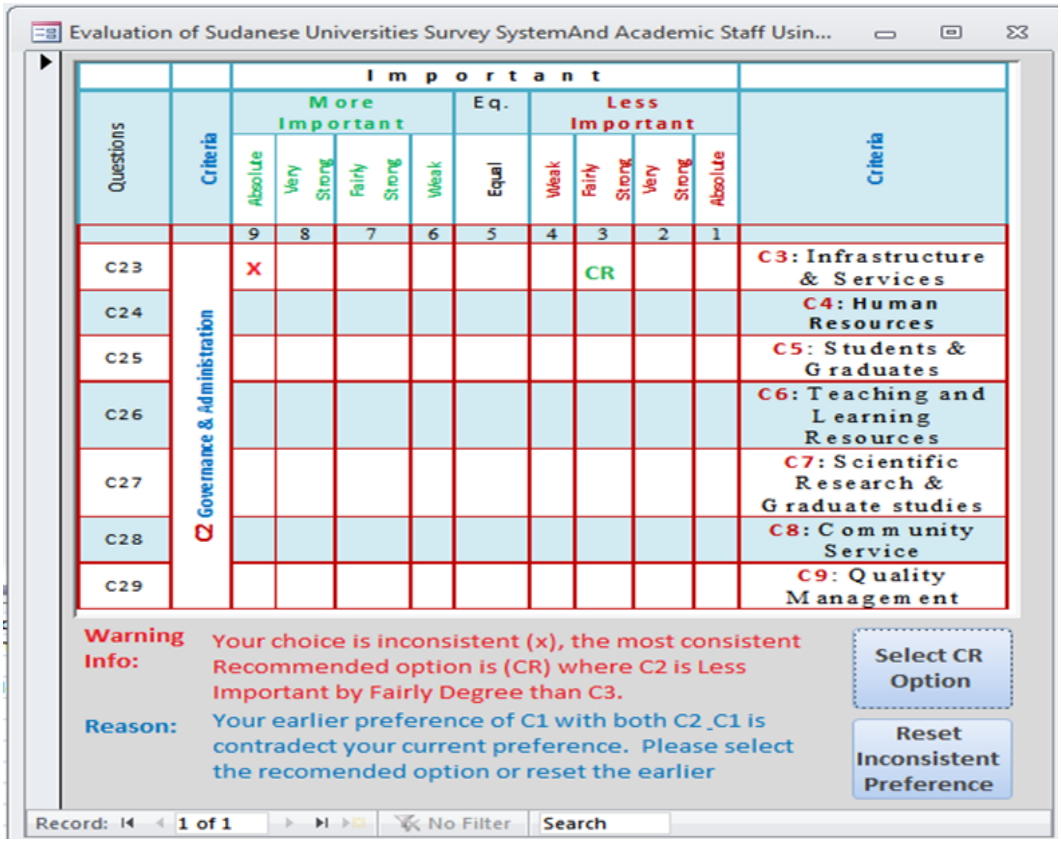


Figure 7. 4: Snapshot of the proposed consistency checking application

Criterion C2 over others criteria		Important: More Important: Absolute (9)	Very Strong (8)	Fairly Strong (7)	Weak (6)	Eql. Equal (5)	Less Important: Weak (4)	Fairly Strong (3)	Very Strong (2)	Absolute (1)	Criteria
C23	C2: Governance & Administration							RCO			C3: Infrastructure & Services
C24										RCO	C4: Human Resources
C25							RCO				C5: Students & Graduates
C26						RCO					C6: Teaching and Learning Resources
C27							RCO				C7: Scientific Research and Graduate studies
C28					RCO						C8: Community Service
C29					RCO						C9: Quality Management

Figure 7. 5: Recommended consistent option (RCO) for criterion C2 over other criteria.

Criterion C3 over others criteria		Important									Criteria
		More Important				Eql.	Less Important				
		Absolute	Very Strong	Fairly Strong	Weak	Equal	Weak	Fairly Strong	Very Strong	Absolute	
		9	8	7	6	5	4	3	2	1	
C34	C3: Infrastructure & Services							RCO			C4: Human Resources
C35					RCO						C5: Students & Graduates
C36				RCO							C6: Teaching and Learning Resources
C37					RCO						C7: Scientific Research and Graduate studies
C38			RCO								C8: Community Service
C39			RCO								C9: Quality Management

Figure 7. 6: Recommended consistent option (RCO) for criterion C3 over other criteria

Criterion C4 over others criteria		Important									Criteria
		More Important				Eql.	Less Important				
		Absolute	Very Strong	Fairly Strong	Weak	Equal	Weak	Fairly Strong	Very Strong	Absolute	
		9	8	7	6	5	4	3	2	1	
C45	C4: Human Resources		RCO								C5: Students & Graduates
C46		RCO									C6: Teaching and Learning Resources
C47			RCO								C7: Scientific Research and Graduate studies
C48		RCO									C8: Community Service
C49		RCO									C9: Quality Management

Figure 7. 7: Recommended consistent option (RCO) for criterion C4 over other criteria

Criterion C5 over others criteria		Important									Criteria
		More Important				Eql.	Less Important				
		Absolute	Very Strong	Fairly Strong	Weak	Equal	Weak	Fairly Strong	Very Strong	Absolute	
		9	8	7	6	5	4	3	2	1	
C56	C5: Students & Graduates				RCO						C6: Teaching and Learning Resources
C57						RCO					C7: Scientific Research and Graduate studies
C58			RCO								C8: Community Service
C59			RCO								C9: Quality Management

Figure 7. 8: Recommended consistent option (RCO) for criterion C5 over other criteria

Criterion C6 over others criteria		Important									Criteria
		More Important				Eql.	Less Important				
		Absolute	Very Strong	Fairly Strong	Weak	Equal	Weak	Fairly Strong	Very Strong	Absolute	
		9	8	7	6	5	4	3	2	1	
C67	C6: Teaching and Learning Resources						RCO				C7: Scientific Research and Graduate studies
C68					RCO						C8: Community Service
C69					RCO						C9: Quality Management

Figure 7. 9: Recommended consistent option (RCO) for criterion C6 over other criteria

Criterion C7 over others criteria		Important									Criteria
		More Important				Eql.	Less Important				
		Absolute	Very Strong	Fairly Strong	Weak	Equal	Weak	Fairly Strong	Very Strong	Absolute	
		9	8	7	6	5	4	3	2	1	
C78	C7: Scientific Research and Graduate studies			RCO							C8: Community Service
C79				RCO							C9: Quality Management

Figure 7. 10: Recommended consistent option (RCO) for criterion C7 over other criteria

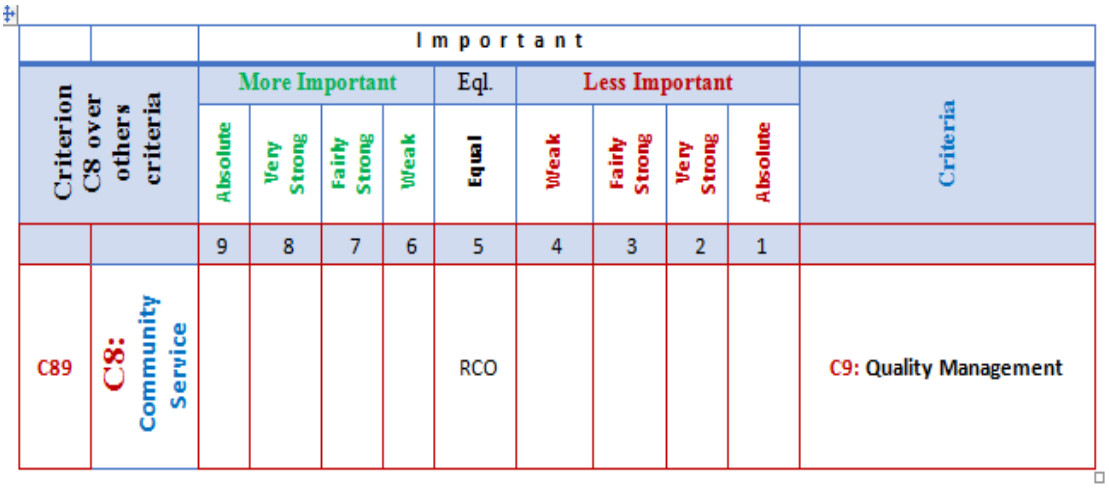


Figure 7. 11: Recommended consistent option (RCO) for criterion C8 over criteria C9

7.5 Summary

This chapter presented new proposed algorithms for online consistency checking of expert's responses in pairwise comparison survey. The scale definition and detail algorithm steps and equations were explained. An empirical example of checking consistency for Sudanese universities evaluation was presented and described. Finally, an application design, process workflow and main components were highlighted and defined.

CHAPTER VIII

8. FUZZY PREFERENCES APPROXIMATION

The fuzzy preferences approximation chapter describes the computational part of the classification model. It includes aggregation of group decisions and fuzzy preference approximation. Empirical examples are presented to evaluate the main and sub criteria.

8.1 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 & 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 & Peniwati, (1998) stated that AIJ is the most often operated using the geometry mean operation; whereas, AIP is normally perform utilizing the athematic mean operations. How to select the more precise method for aggregating?

In our case study, the more precise method is 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 algorithm (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).

$l_{ij} = (\prod_{k=1}^{K} l_{ijk})^{\frac{1}{K}}, m_{ij} = (\prod_{k=1}^{K} m_{ijk})^{\frac{1}{K}}, u_{ij} = (\prod_{k=1}^{K} u_{ijk})^{\frac{1}{K}}$ Where (l_{ij}, m_{ij} , u_{ij}) are the fuzzy evaluation of sample member's k (k = 1, 2… K) and k is total number of TFN.

For example, we take one node in the hierarchy (UC1) and aggregate six consistent individual judgments responses by calculating the geometric mean (i.e. GEOMEAN function) as shown in Figure 8.1. 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 as follows (0.54, 0.61, 0.71). (Yousif, Shaout, 2016/c)

		1	Strategic Planning			Vision			Mission			Goals and Objectives			Operation plans		
1	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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 8. 1: Aggregation of experts' responses for Universities evaluation criteria

8.2 Fuzzy Preferences Approximation

After aggregated consistent decisions in one combined results, we needed to estimate the preferences/priorities using synthetic extent analysis by (Chang, 1996). The Fuzzy synthetic extent value S_i with respect to the i^{th} 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…n and j=1, 2…m

The fuzzy preference approximation is done using the following steps:

Step 1: In the combined comparison matrix, we need to sum each raw 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 …m) values

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

Then find the inverse of the above equation

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

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.

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 $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$ is defined as

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

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:

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

Where d is the ordinate of the highest intersection point D between $\mu_{M_1}\ and\ \mu_{M_2}$.

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

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

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

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 in the hierarchy level.

8.3 Empirical Example: (Part I - Criteria Weights)

Let us take the same aggregated comparison matrix as shown in Table 8.1 and calculate the weights of the main performance evaluation criteria for Sudanese Universities.

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

$\sum_{j=1}^{m} M_{g_i}^{j} = \sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j\ =$

[(1.0000+1.4173+0.9640+.9311+1.0142+0.7300+0.7543+1.1430+0.7930) ,

(1.000+1.6406+1.1699+1.1009+1.1471+0.8535 +1.0000+1.4241+0.8880),
(1.0000+1.9065+1.4170+1.3035+ 1.3007+0.9921+1.3304+1.7744+1.0110)]
= (8.7469, 10.2241, 12.0365)

Similarly, the result of applying addition operation of TFN for

- Comparing the (UC2: Governance & Administration) criterion with other criteria:
  = (7.7539, 9.0391, 10.5834)
- Comparing (UC3: Infrastructure & Services) criterion with other criteria:
  = (8.4198, 9.6798, 11.1205)
- Comparing (UC4: Human Resources) criterion with other criteria:
  = (10.8157, 12.3518, 13.9347)
- Comparing (UC5: Students & Graduates) criterion with other criteria:
  = (8.0271, 9.2022, 10.6382)
- Comparing (UC6: Teaching and Learning Resources) criterion with other criteria:
  = (9.5631, 11.0843, 12.8765)
- Comparing (UC7: Scientific Research and Graduate Studies) criterion with other criteria:
  = (7.0598, 8.2803, 9.8448)
- Comparing (UC8: Community Service) criterion with other criteria:
  = (5.8799, 6.7714, 7.9648)
- Comparing (UC9: Quality Management) criterion with other criteria:
  = (7.0375, 8.0294, 9.2906)

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

Now, we need to calculate the fuzzy synthetic extent, which is defined as:

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

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

S_{UC1} = (8.7469, 10.2241, 12.0365) ⊗ (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) ⊗ (1/98.2894, 1/84.6626, 1/73.3041)
= (0.079, 0.107, 0.144)

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, 0.109), S_{UC9} = (0.072, 0.095, 0.127)

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

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

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

Similarly
$V(S_{UC1} \geq S_{UC3})$: $V((0.089, 0.121, 0.164) \geq (0.086, 0.114, 0.152)) = 1.000$
$V(S_{UC1} \geq S_{UC4})$: $V((0.089, 0.121, 0.164) \geq (0.110, 0.146, 0.190)) = 0.683$
$V(S_{UC1} \geq S_{UC5})$: $V((0.089, 0.121, 0.164) \geq (0.082, 0.109, 0.145)) = 1.000$
$V(S_{UC1} \geq S_{UC6})$: $V((0.089, 0.121, 0.164) \geq (0.097, 0.131, 0.176)) = 0.868$
$V(S_{UC1} \geq S_{UC7})$: $V(0.089, 0.121, 0.164) \geq (0.072, 0.098, 0.134)) = 1.000$
$V(S_{UC1} \geq S_{UC8})$: $V((0.089, 0.121, 0.164) \geq (0.060, 0.080, 0.109)) = 1.000$

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

Membership function plots of intersection of the UC1: Institutional frame work with (UC2, UC3, UC4, UC5, UC6, UC7, and UC8) are presented in **Appendix A.**

Similarly:

For UC2: Governance & Administration

$V(S_{UC2} \geq S_{UC1}) = 0.798$, $V(S_{UC2} \geq S_{UC3}) = 0.886$, $V(S_{UC2} \geq S_{UC4}) = 0.467$,
$V(S_{UC2} \geq S_{UC5}) = 0.970$, $V(S_{UC2} \geq S_{UC6}) = 0.661$, $V(S_{UC2} \geq S_{UC7}) = 1.000$,
$V(S_{UC2} \geq S_{UC8}) = 1.000$, $V(S_{UC2} \geq S_{UC9}) = 1.000$.

For UC3: Infrastructure & Services

$V(S_{UC3} \geq S_{UC1}) = 0.907$, $V(S_{UC3} \geq S_{UC2}) = 1.000$, $V(S_{UC3} \geq S_{UC4}) = 0.569$,
$V(S_{UC3} \geq S_{UC5}) = 1.000$, $V(S_{UC3} \geq S_{UC6}) = 0.766$, $V(S_{UC3} \geq S_{UC7}) = 1.000$,
$V(S_{UC3} \geq S_{UC8}) = 1.000$, $V(S_{UC3} \geq S_{UC9}) = 1.000$.

For UC4: Human Resources

$V(S_{UC4} \geq S_{UC1}) = 1.000$, $V(S_{UC4} \geq S_{UC2}) = 1.000$, $V(S_{UC4} \geq S_{UC3}) = 1.000$,
$V(S_{UC4} \geq S_{UC5}) = 1.000$, $V(S_{UC4} \geq S_{UC6}) = 1.000$, $V(S_{UC4} \geq S_{UC7}) = 1.000$,
$V(S_{UC4} \geq S_{UC8}) = 1.000$, $V(S_{UC4} \geq S_{UC9}) = 1.000$.

For UC5: Students & Graduates

$V(S_{UC5} \geq S_{UC1}) = 0.823$, $V(S_{UC5} \geq S_{UC2}) = 1.000$, $V(S_{UC5} \geq S_{UC3}) = 0.913$,
$V(S_{UC5} \geq S_{UC4}) = 0.485$, $V(S_{UC5} \geq S_{UC6}) = 0.683$, $V(S_{UC5} \geq S_{UC7}) = 1.000$,
$V(S_{UC5} \geq S_{UC8}) = 1.000$, $V(S_{UC5} \geq S_{UC9}) = 1.000$.

For UC6: Teaching and Learning Resources

$V(S_{UC6} \geq S_{UC1}) = 1.000$, $V(S_{UC6} \geq S_{UC2}) = 1.000$, $V(S_{UC6} \geq S_{UC3}) = 1.000$,
$V(S_{UC6} \geq S_{UC4}) = 0.814$, $V(S_{UC6} \geq S_{UC5}) = 1.000$, $V(S_{UC6} \geq S_{UC7}) = 1.000$,
$V(S_{UC6} \geq S_{UC8}) = 1.000$, $V(S_{UC6} \geq S_{UC9}) = 1.000$.

For UC7: Scientific Research and Graduate Studies

$V(S_{UC7} \geq S_{UC1}) = 0.664$, $V(S_{UC7} \geq S_{UC2}) = 0.861$, $V(S_{UC7} \geq S_{UC3}) = 0.746$,
$V(S_{UC7} \geq S_{UC4}) = 0.335$, $V(S_{UC7} \geq S_{UC5}) = 0.829$, $V(S_{UC7} \geq S_{UC6}) = 0.528$,
$V(S_{UC7} \geq S_{UC8}) = 1.000$, $V(S_{UC7} \geq S_{UC9}) = 1.000$.

For UC8: Community Service

$V(S_{UC8} \geq S_{UC1}) = 0.325$, $V(S_{UC8} \geq S_{UC2}) = 0.526$, $V(S_{UC8} \geq S_{UC3}) = 0.401$,
$V(S_{UC8} \geq S_{UC4}) = 0.000$, $V(S_{UC8} \geq S_{UC5}) = 0.484$, $V(S_{UC8} \geq S_{UC6}) = 0.182$,
$V(S_{UC8} \geq S_{UC7}) = 0.674$, $V(S_{UC8} \geq S_{UC9}) = 0.714$.

For UC9: Quality Management

$V(S_{UC9} \geq S_{UC1}) = 0.593$, $V(S_{UC9} \geq S_{UC2}) = 0.800$, $V(S_{UC9} \geq S_{UC3}) = 0.678$,
$V(S_{UC9} \geq S_{UC4}) = 0.246$, $V(S_{UC9} \geq S_{UC5}) = 0.765$, $V(S_{UC9} \geq S_{UC6}) = 0.449$,
$V(S_{UC9} \geq S_{UC7}) = 0.949$, $V(S_{UC9} \geq S_{UC8}) = 1.000$.

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

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 $\boldsymbol{W_{UC}}$ = (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.

According to this example the most important criterion is the 'UC4-Human Resources' and the least important criteria are 'UC8-Community Service' and '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 Table 8.1 to Table 8.10. Also, the main criteria and sub-criteria for academic staff performance evaluation are compared in the Table 8.11 to Table 8.25.

Therefore, similarly the weight vector for sub criteria in Tables 8.2 to 8.10 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 0.325 is weight of (UC11: Strategic Planning), 0.133 is weight of (UC12: Vision), etc. correspondingly as defined in the Table1.
Similarly for the other weight vectors W_{UC2}, W_{UC3}, …, 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 Table 8.11 to Table 8.25 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 8.11:
W_{AC} = (0.300, 0.369, 0.058, 0.129, 0.031, 0.114)

Sub criteria weight (level-1): from tables 8.12 to 8.17.

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 8.18 to 8.21

W_{AC51} = (0.036, 0.156, 0.177, 0.305, 0.143, 0.182),

W_{AC52} = (0.000, 0.077, 0.081, 0.165, 0.154, 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 table 8.22 to 8.25

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).

Level of strength

The levels of strength for the criterion model are ranked as follows:

1. Main criteria weight (W_{UCi}) has the highest strength . *Where w = weight, u = alternative type, and ci = main criteria i= 1,2, ..,n)*
2. Sub criteria weight (W_{UCij}) has next highest strength. *Where w = weight, u = alternative type, and C_{ij} is sub-criteria, i = 1,2, ..,n , j=1, 2, ..., k)*
3. Individual Alternative weight with respect to specific criteria has the lowest strength.

Def1: Main criteria are the first level criteria in the decision model.

Def2: The sub-criteria is the any level other than the first level

Def3: Bottom criteria is last criteria that connect to an alternative

Def4: An alternative is the input to be processed (i.e. to be classified)

Theorem 8.1:

Any bottom criteria can be main or sub criteria, but not every main or sub criteria can be bottom criteria.

- Based on the model, the main criteria could be the only criteria in the model, then in this case the main becomes bottom criteria as well.
- Based in the model the main and sub criteria could be the only criteria in the model, which implies that the sub criteria becomes bottom criteria

Table 8. 1: 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)

Table 8. 2: 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 8. 3: 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 8. 4: 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 8. 5: 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 8. 6: 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)

Table 8. 7: 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 8. 8: 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 8. 9: 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 8. 10: 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)

Table 8. 11: 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 8. 12: Evaluation of the sub criteria of Excellence in Research (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 8. 13: 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 8. 14: 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 8. 15: 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 8. 16: 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 8. 17: 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 8. 18: 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 8. 19: 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 8. 20: 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)

Table 8. 21: Evaluation of sub criteria of (AC54) criterion

	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 8. 22: 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 8. 23: 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 8. 24: 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 8. 25: Evaluation of the sub criteria of AC64 (Comm., Collabor. & Profess.)

	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)

8.4 Summary

In this chapter, group of experts' decisions were aggregated and computational details steps for criteria/ sub-criteria weight were processed and explained using fuzzy preference approximation. Empirical examples are provided "Universities and academic staff performance evaluation" where all criteria and sub criteria weights were calculated.

CHAPTER IX

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 used the FOTOPSIS technique.

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. Sample of 15 Sudanese universities and 5 academic staff members (alternatives) were selected, evaluated and ranked.

9.1 Preliminary

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

Definition 1 (Kaufmann, 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, Gupta, 1991):

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

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

Definition 3 (Chakraborty, Yeh 2007; Chakraborty, 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

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

Where x_{ij} is the performance rating of the i-th 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.

9.2 Empirical Example: (Part II – Final Ranking)

As mentioned in the classification model in chapter 3, the final alternatives ranking process is to sort the relative distance of the alternative solutions to the ideal solution. We used the result obtained from the empirical example part I in Section 8.2 to continue and calculate the final ranking by applying the following steps (Yousif, Shaout, 2016/c):

1. Obtain the decision matrix between bottom criteria and universities/academic staff (alternatives).
2. Obtain the normalized decision matrix R, using the relationship defined in definition 3 in section 9.1. The idea behind this logic is to get fraction number between 0 & 1.
3. Compute and obtain the weighted decision matrix using the bottom criteria weight as shown in table 9.1 for universities and table 9.2 for academic staff members. The complete details of decision matrices are presented in Appendix B.
4. Compute the fuzzy positive & fuzzy negative ideal solutions (FPIS & FNIS) from the weighted decision matrix (i.e. for each bottom criterion as shown in table 9.3 for universities and table 9.4 for academic staff members.

   $\boldsymbol{I^p} = \left(i_1^p, i_2^p, \ldots\ i_j^p\ \right)$ Where I^p is the set of positive ideal solutions and i_j^p is the positive ideal solution to the j^{th} criteria at the bottom and

   $\boldsymbol{I^n} = \left(i_1^n, i_2^n, \ldots\ i_j^n\ \right)$ Where I^n is the set of negative ideal solutions and i_j^n is the positive ideal solution to the j^{th} 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 9.1.

   Let $d(i_{tj}, i_j^p)$, $d(i_{tj}, i_j^n)$ Where i_{tj} is the evaluation result of specific university/academic staff t to the j^{th} criteria at the bottom. Table 9.5 and table 9.6 show the distance result of our sample alternatives from Ideal negative & positive solutions.

   The following equations are used to obtain the distance of alternatives (Universities/academic staff) from the PIS (i.e. C_j^p) & NIS (i.e. C_j^n)

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

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

   Where the $C_j^p\ and\ C_j^n$ are the separation measure from the ideal solutions for all alternatives j=1... **41** for bottom criteria for university or j=1…**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 9.7 and table 9.8.

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

7. Classify the alternative universities and academic staff according to the above calculated values.

   Figure 9.1 and figure 9.2 are radars with markers graphs used to display values relative to a center point. The ideal solutions are in the center of graph (i.e. represented by point 0) and the other points represent the distance from negative and positive ideal solutions. The points in brown line indicate the distance from positive ideal solution and points in the blue line indicate the distance from negative ideal solution. For example in graph 9.1, the distances from negative ideal solutions for these universities (Khartoum: 0.09395, Medical Sc. & Tech: .09299, and Sudan

university of science and technology: 0.06787) are long and located near to the outer line of the graph. While the distance of the same universities from positive ideal solutions in the brown line are short (0.1191, 0.01863, 0.06788) and located near to a center point of the graph. Hence, from a quick look to points in blue line and corresponding points in brown line to the same university, you recognize the distance of university from both ideal solutions.

In table 9.7, there are 15 alternatives sample, which represents 10 public universities and 5 private universities. The ranking firstly was conducted for each group separately (i.e. public universities group & private universities group) and finally was conducted for all universities. Figure 9.3 shows graphical representation of the relative closeness to ideal Solution for both private and public universities.

Figure 9.4 and figure 9.5 are columns charts which used to compare values across universities groups in order to display the final ranking results for each university's group (private group and public group) and overall ranking for all universities. Similarly, column charts are provided to compare and display the relative closeness to ideal solution and final ranking for academic staff in figure 9.6 and figure 9.7 correspondingly.

Table 9. 1: Normalized & weighted decision matrix using bottom criteria (universities)

			1	2	3	4	5	6	7
	University / Criteria	Weights	University of Gadarif	University of al-Jazirah	Sudan University of Sc. & Tech	Omdurman Islamic University	Blue Nile University	University of Dongola	Kordofan 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)
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)
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)
…	…	…	…	…	…	…	…	…	…
41	UC92	0.028998	(0.0042, 0.0045, 0.0051)	(0.0104, 0.009, 0.0076)	(0.0104, 0.009, 0.0076)	(0.0042, 0.0045, 0.0051)	(0.0042, 0.0045, 0.0051)	(0.0042, 0.0045, 0.0051)	(0.0042, 0.0045, 0.0051)

			8	9	10	11	12	13	14	15
	Univ/ Criteria	Weights	Al Fashir University	Red Sea University	University of Khartoum	University of Sc. and Tech.	Ahfad University for Women	University of Medical Sc. & Tech.	Omdurman Ahlia University	National Ribat University
1	UC11	0.0481	(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)	(0.0034, 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)
…	…	…	…	…	…	…	…	…	…	…
41	UC92	0.028998	(0.0042, 0.0045, 0.0051)	(0.0042, 0.0045, 0.0051)	(0.0104, 0.009, 0.0076)	(0.0042, 0.0045, 0.0051)	(0.0042, 0.0045, 0.0051)	(0.0156, 0.0181, 0.0191)	(0.0023, 0.0023, 0.0022)	(0.0104, 0.009, 0.0076)

Table 9. 2 Normalized & weighted decision matrix using bottom criteria (Staff)

			1	2	3	4	5
	Criteria	Weight	Academic Staff Member 1	Academic Staff Member 2	Academic Staff Member 3	Academic Staff Member 4	Academic Staff Member 5
1	AC11	0.0765	(0.0765, 0.0765, 0.0765)	(0.1147, 0.153, 0.1913)	(0.0765, 0.0765, 0.0765)	(0.0306, 0.0383, 0.0513)	(0.0765, 0.0765, 0.0765)
2	AC12	0.1017	(0.0374, 0.0431, 0.0473)	(0.0872, 0.0862, 0.0851)	(0.0249, 0.0216, 0.0189)	(0.0249, 0.0216, 0.0189)	(0.01, 0.0108, 0.0127)
3	AC13	0.0261	(0.0055, 0.0055, 0.0061)	(0.0206, 0.0221, 0.0227)	(0.003, 0.0028, 0.0026)	(0.0055, 0.0055, 0.0061)	(0.0137, 0.0111, 0.0091)
…	…	…	…	…	…	…	…
69	AC6411	0.003306	(0.0011, 0.0012, 0.0013)	(0.0026, 0.0025, 0.0024)	(0.0011, 0.0012, 0.0013)	(0.0007, 0.0006, 0.0005)	(0.0011, 0.0012, 0.0013)

Table 9. 3 Positive & Negative ideal solutions for universities

Criteria	Negative Ideal Solution (NIS)	Positive Ideal Solution (PIS)	Criteria	Negative Ideal Solution (NIS)	Positive Ideal Solution (PIS)
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 9. 4: Positive & Negative ideal solutions for Academic staff

Criteria	Negative Ideal Solution	Positive Ideal Solution	Criteria	Negative Ideal Solution	Positive Ideal Solution
AC11	(0.0306, 0.0383, 0.0513)	(0.1147, 0.153, 0.1913)	AC541	(0.0005, 0.0005, 0.0005)	(0.0005, 0.0005, 0.0005)
AC12	(0.01, 0.0108, 0.0127)	(0.0872, 0.0862, 0.0851)	AC542	(0.0005, 0.0005, 0.0005)	(0.0005, 0.0005, 0.0005)
AC13	(0.003, 0.0028, 0.0026)	(0.0206, 0.0221, 0.0227)	AC543	(0.0004, 0.0003, 0.0003)	(0.0013, 0.0013, 0.0012)
AC14	(0.0059, 0.0051, 0.0047)	(0.04, 0.0405, 0.0402)	AC544	(0.0005, 0.0005, 0.0005)	(0.0005, 0.0005, 0.0005)
AC15	(0.0033, 0.0032, 0.0033)	(0.0518, 0.0518, 0.0518)	AC611	(0.0011, 0.0009, 0.0008)	(0.004, 0.0038, 0.0036)
AC21	(0.0173, 0.0156, 0.0142)	(0.0606, 0.0624, 0.0637)	AC612	(0.0017, 0.0019, 0.002)	(0.0041, 0.0038, 0.0036)
AC22	(0.03, 0.0265, 0.0234)	(0.0449, 0.053, 0.0585)	AC613	(0.0022, 0.0025, 0.0027)	(0.0052, 0.005, 0.0048)
AC23	(0.0076, 0.007, 0.0067)	(0.0521, 0.056, 0.0576)	AC614	(0.0018, 0.0015, 0.0013)	(0.0062, 0.0061, 0.006)
AC24	(0.0238, 0.0258, 0.0272)	(0.0555, 0.0517, 0.0489)	AC621	(0.0004, 0.0004, 0.0005)	(0.0009, 0.0008, 0.0008)
AC25	(0.0056, 0.0056, 0.0056)	(0.0056, 0.0056, 0.0056)	AC622	(0.0009, 0.0011, 0.0011)	(0.0021, 0.0021, 0.0021)
AC26	(0.0096, 0.0083, 0.0076)	(0.0657, 0.0666, 0.0659)	AC623	(0.001, 0.0011, 0.0012)	(0.0023, 0.0022, 0.0022)
AC31	(0.0048, 0.0048, 0.0048)	(0.0048, 0.0048, 0.0048)	AC624	(0.0007, 0.0006, 0.0005)	(0.0025, 0.0024, 0.0024)
AC32	(0.0024, 0.0022, 0.0019)	(0.0037, 0.0043, 0.0048)	AC625	(0.0011, 0.0008, 0.0007)	(0.0016, 0.0016, 0.0017)
AC33	(0.0084, 0.0073, 0.0064)	(0.0293, 0.0292, 0.029)	AC626	(0.0022, 0.0022, 0.0022)	(0.0022, 0.0022, 0.0022)
AC34	(0.0006, 0.0007, 0.0008)	(0.0056, 0.0057, 0.0057)	AC627	(0.0017, 0.0017, 0.0017)	(0.0017, 0.0017, 0.0017)
AC41	(0.0003, 0.0003, 0.0003)	(0.0003, 0.0003, 0.0003)	AC628	(0.002, 0.002, 0.002)	(0.002, 0.002, 0.002)
AC42	(0.014, 0.014, 0.014)	(0.014, 0.014, 0.014)	AC631	(0.0001, 0.0001, 0.0001)	(0.0001, 0.0001, 0.0001)
AC43	(0.0168, 0.0168, 0.0168)	(0.0168, 0.0168, 0.0168)	AC632	(0.0011, 0.0011, 0.0011)	(0.0011, 0.0011, 0.0011)
AC44	(0.0217, 0.0179, 0.0151)	(0.0326, 0.0359, 0.0378)	AC633	(0.0005, 0.0005, 0.0006)	(0.0012, 0.0011, 0.001)
AC511	(0.0002, 0.0002, 0.0001)	(0.0003, 0.0003, 0.0004)	AC634	(0.0012, 0.0012, 0.0012)	(0.0012, 0.0012, 0.0012)
AC512	(0.0005, 0.0004, 0.0004)	(0.0017, 0.0016, 0.0016)	AC635	(0.0027, 0.0029, 0.0031)	(0.0062, 0.0058, 0.0055)
AC513	(0.0005, 0.0004, 0.0004)	(0.0018, 0.0018, 0.0017)	AC636	(0.0037, 0.0037, 0.0037)	(0.0037, 0.0037, 0.0037)
AC514	(0.0008, 0.0007, 0.0006)	(0.0027, 0.0026, 0.0026)	AC637	(0.0022, 0.0022, 0.0022)	(0.0022, 0.0022, 0.0022)
AC515	(0.0009, 0.0009, 0.0009)	(0.0009, 0.0009, 0.0009)	AC641	(0.0004, 0.0004, 0.0003)	(0.0014, 0.0014, 0.0014)

AC516	(0.0011, 0.0011, 0.0011)	(0.0011, 0.0011, 0.0011)	AC642	(0.0003, 0.0002, 0.0002)	(0.0009, 0.0009, 0.0009)
AC521	(0, 0, 0)	(0, 0, 0)	AC643	(0.0002, 0.0002, 0.0002)	(0.0008, 0.0008, 0.0008)
AC522	(0.0004, 0.0004, 0.0004)	(0.0004, 0.0004, 0.0004)	AC644	(0.0006, 0.0007, 0.0007)	(0.0013, 0.0013, 0.0013)
AC523	(0.0004, 0.0004, 0.0004)	(0.0004, 0.0004, 0.0004)	AC645	(0.0001, 0.0001, 0.0001)	(0.0005, 0.0005, 0.0005)
AC524	(0.0005, 0.0006, 0.0006)	(0.0012, 0.0012, 0.0011)	AC646	(0.0006, 0.0005, 0.0004)	(0.0022, 0.0021, 0.002)
AC525	(0.0008, 0.0008, 0.0008)	(0.0008, 0.0008, 0.0008)	AC647	(0.0009, 0.0009, 0.0009)	(0.0009, 0.0009, 0.0009)
AC526	(0.0007, 0.0006, 0.0005)	(0.0024, 0.0023, 0.0022)	AC648	(0.0008, 0.001, 0.0011)	(0.0019, 0.0019, 0.0019)
AC527	(0.0007, 0.0008, 0.0008)	(0.0015, 0.0015, 0.0015)	AC649	(0.0009, 0.0008, 0.0006)	(0.0032, 0.003, 0.0029)
AC531	(0.0001, 0.0001, 0.0001)	(0.0003, 0.0003, 0.0003)	AC6410	(0.0009, 0.001, 0.0011)	(0.0021, 0.0021, 0.0021)
AC532	(0.0002, 0.0002, 0.0002)	(0.0002, 0.0002, 0.0002)	AC6411	(0.0007, 0.0006, 0.0005)	(0.0026, 0.0025, 0.0024)
AC533	(0.0001, 0.0001, 0.0002)	(0.0003, 0.0003, 0.0003)			

Table 9. 5: Distance from FNIS and FPIS for universities (separation measures)

SN	**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

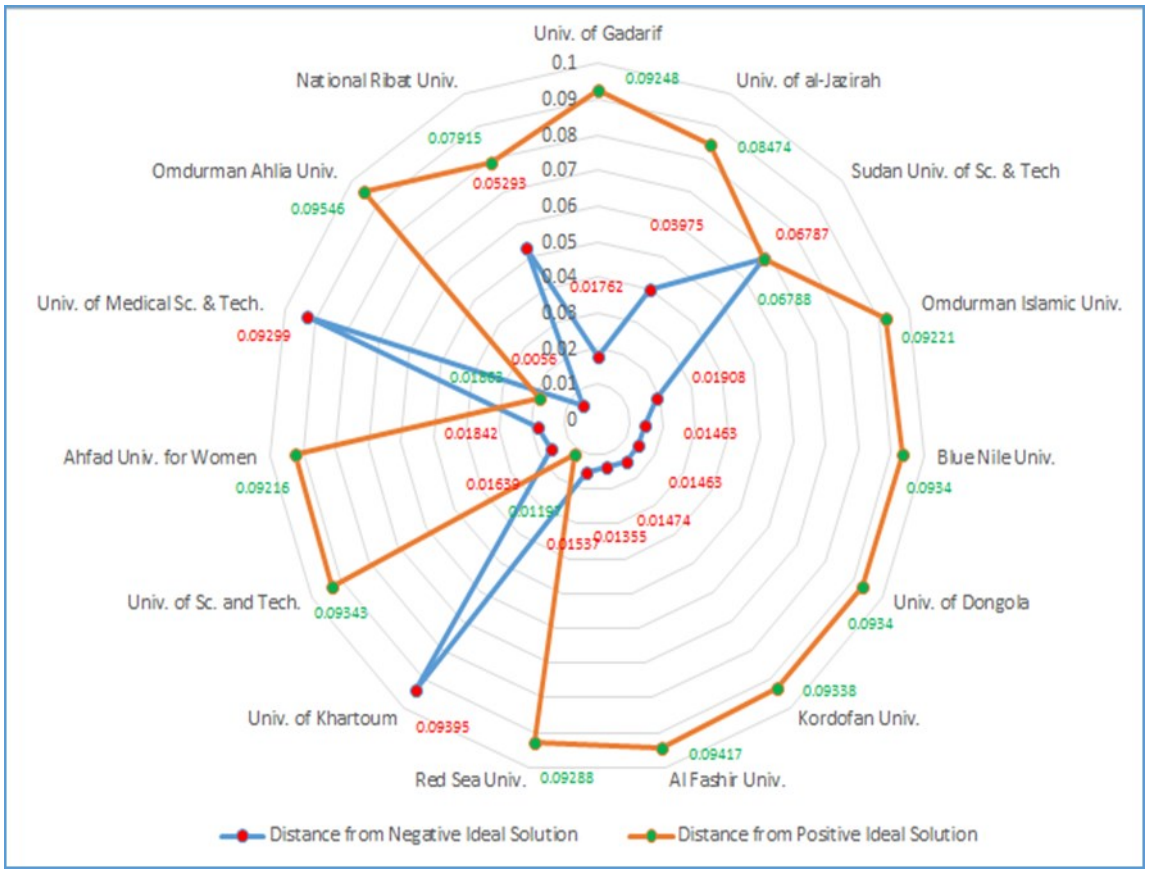


Figure 9. 1: Chart shows the distance of universities from NIS and PIS

Table 9. 6: Distance from FNIS and FPIS for Academic staff (separation measures)

SN	**Alternatives (Universities)**	**Distance from Negative Ideal Solution**	**Distance from Positive Ideal Solution**
1	Academic staff member 1	0.054626463	0.149494517
2	Academic staff member 2	0.187562834	0.000796357
3	Academic staff member 3	0.041233367	0.158978264
4	Academic staff member 4	0.01177982	0.183251488
5	Academic staff member 5	0.045212377	0.161128674

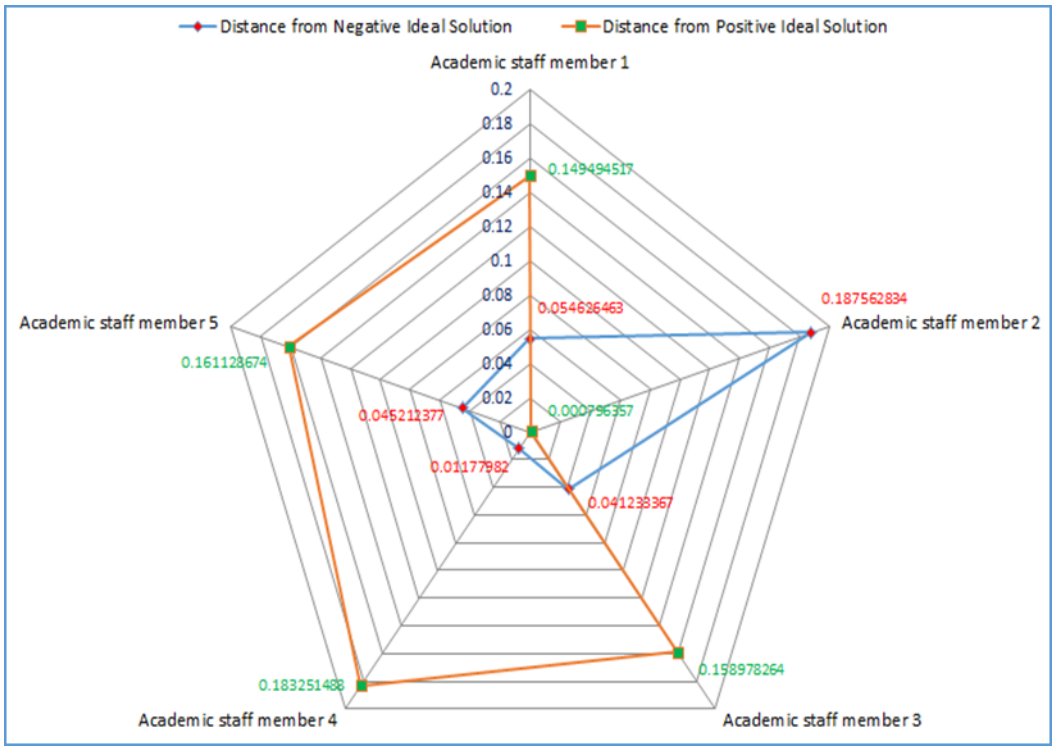


Figure 9. 2: Chart shows the distance of Academic Staff from NIS and PIS

Table 9. 7: The final ranking results for private, public, and all universities

SN.	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

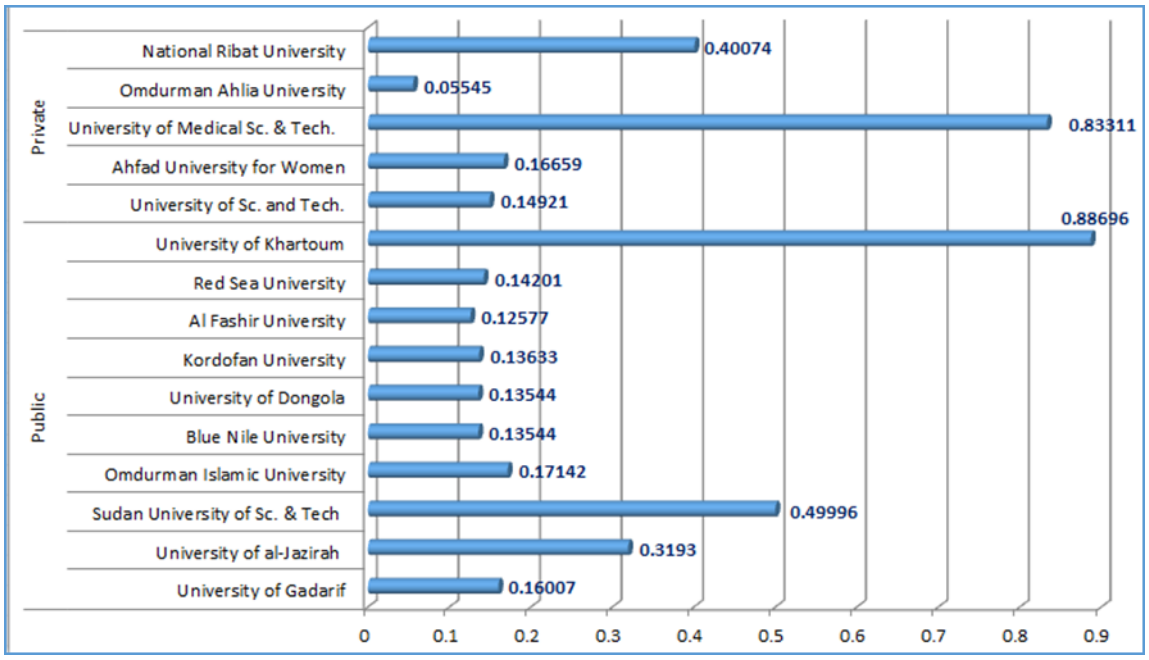


Figure 9. 3 Relative Closeness to ideal Solution

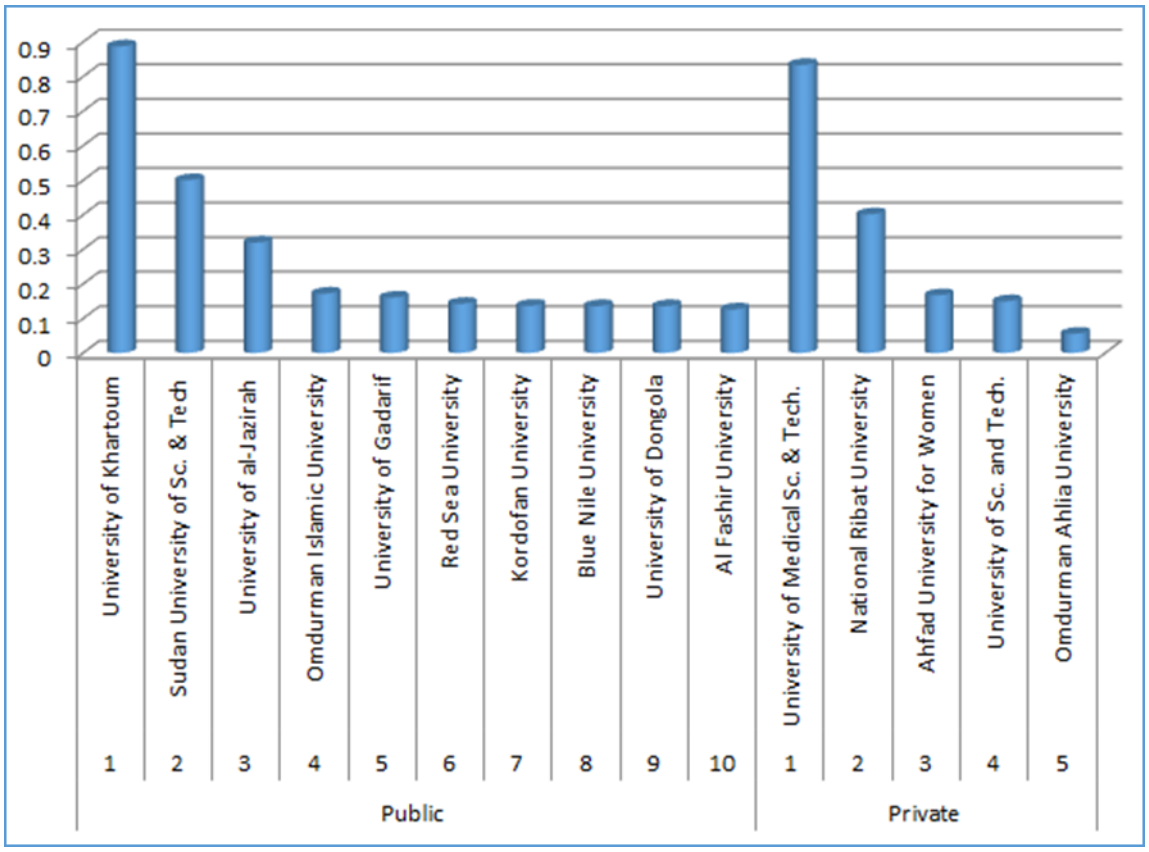


Figure 9. 4 Graph for final ranking results for each universities group (private & public)

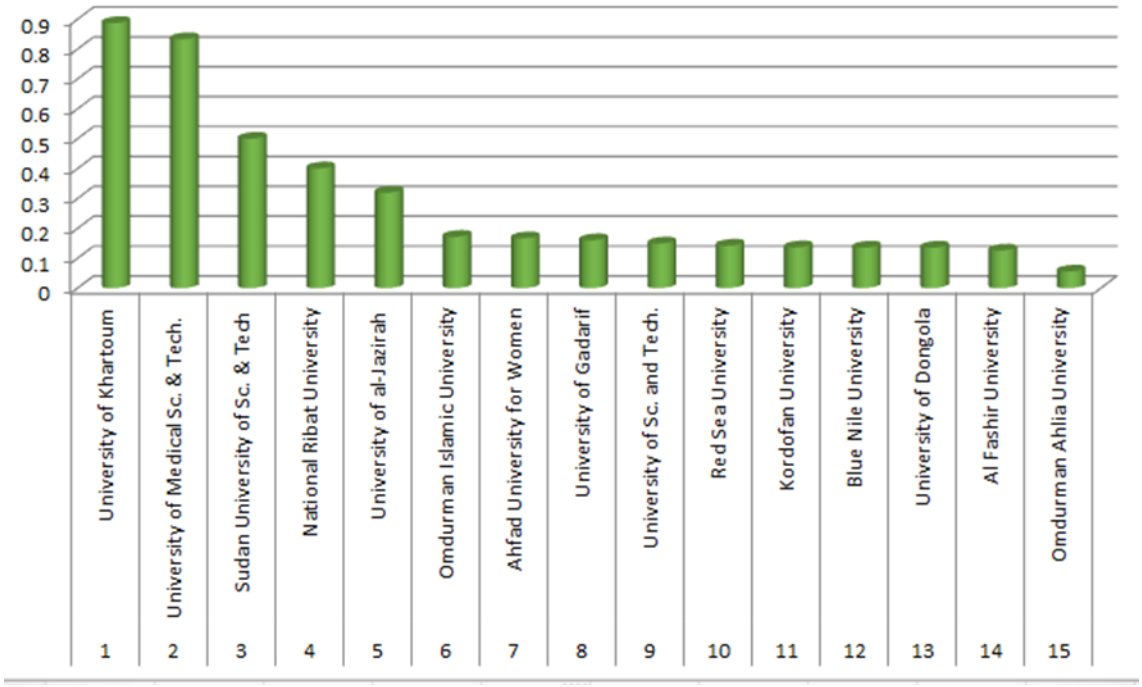


Figure 9. 5 Graph of final ranking results for all universities (private & public)

Table 9. 8: The final ranking results for Academic staff

SN.	Alternatives	Relative Closeness to ideal Solution	Ranking
1	Academic staff member 1	0.267618072	2
2	Academic staff member 2	0.995772137	1
3	Academic staff member 3	0.205948908	4
4	Academic staff member 4	0.060399638	5
5	Academic staff member 5	0.219114794	3

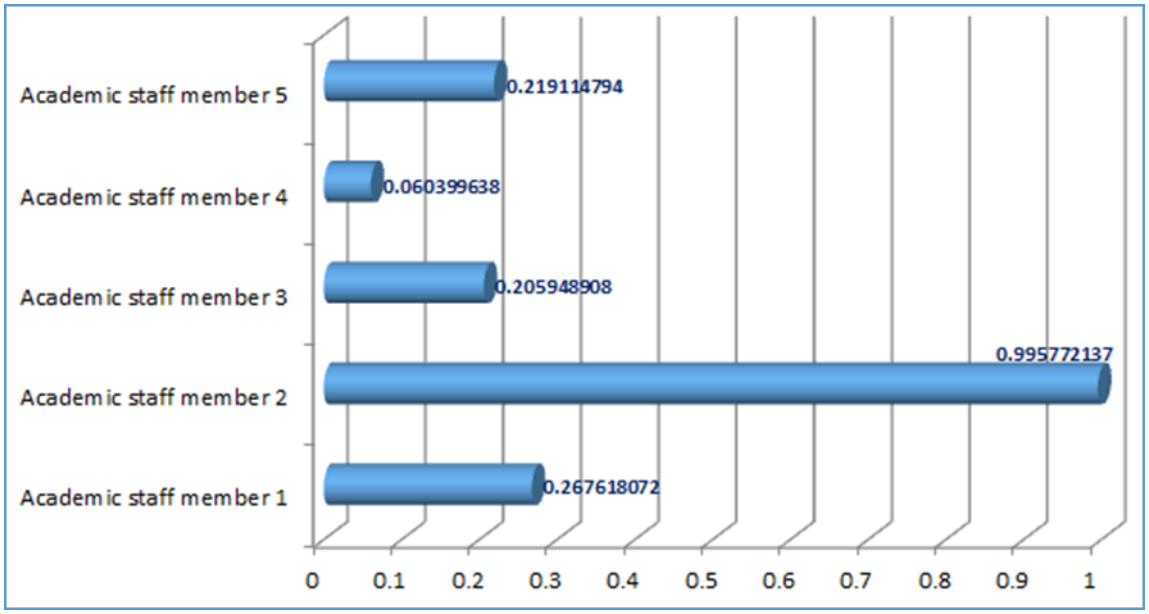


Figure 9. 6 Graph shows the Relative Closeness of Academic staff to ideal Solution

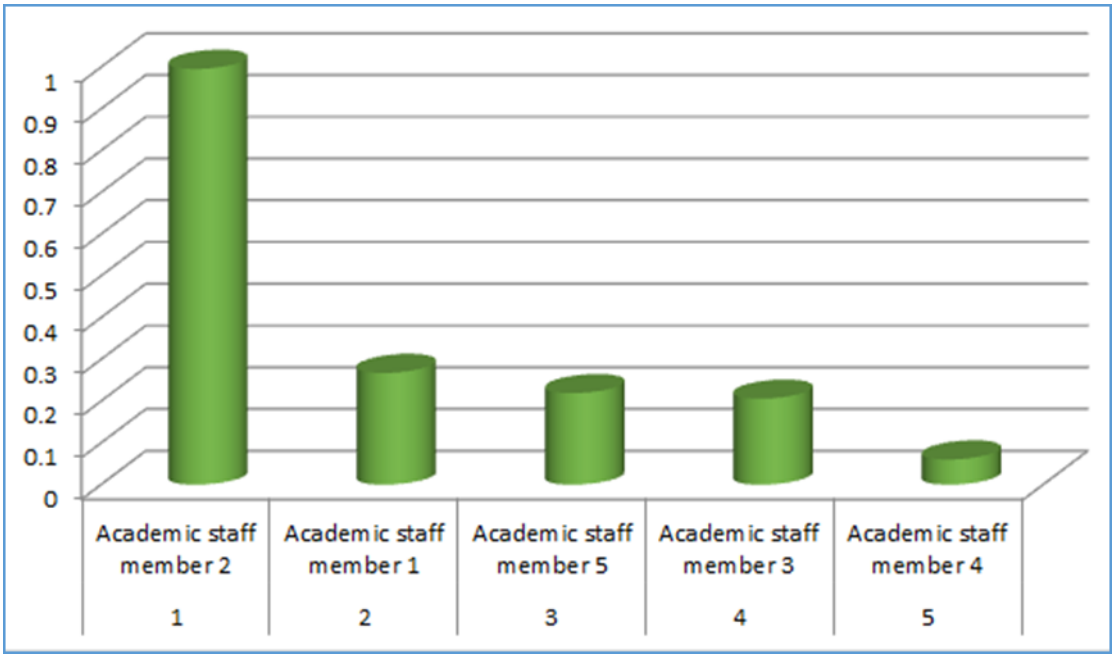


Figure 9. 7 Graph of final ranking results for Academic Staff Members

9.3 Summary

This chapter provided the final ranking process for universities and academic staff based on criteria weights which were calculated in the chapter 8. An empirical example was provided where comparison matrix was designed between alternatives and bottom criteria, positive and negative ideal solutions were obtained and separation measures and relative closeness to ideal solution were calculated. Many charts were presented such as distance from NIS & PIS, final ranking result for private/public/all universities and relative closeness to ideal solution.

CHAPTER X

10. MODEL TESTING, DISCUSSION & CONCLUSION

10.1 Model Testing

Currently, there is no official/unofficial organization concerned 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 collages for all Sudanese universities based on the number of applicants and number of available seats in specific year. Differences in these rates for the same college in different universities may give idea about universities classification. As an example, you may find huge different in the minimum rate of admission for the medicine colleges between Khartoum university and to medicine college in Blue Nile university.

We compared our model result with result of admission rates published by (GAADEV) for the previous two years (2014/2015 & 2015/2016). We considered the results of 10 public universities for the following colleges: Medicine, Economics, Engineering, Education and Computer Science. Then, the overall average was calculated to rank these universities. The comparison output of those 10 universities is satisfactory and acceptable as shown in table 10.1.

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 10.1. A graphical view of comparison between the model ranking result and 2014/2015 & 2015/2016 admission ranking results is shown in figure 10.1. The blue line represents the model result while the brown and grey lines represent the admission results for 2014/2015 and 2015/2016 correspondingly.

The admission rates reported by the GAADEV is just an indicator and not real classifications process because it is not based on known criteria. It depends only on the applicants' interest. Hence our classification model which is based on agreed criteria and proved computational theory is more accurate and efficient in estimating the performance evaluation and classification.

Definition

Def1: Admission Requirement is the minimum requirement for admission, which is function of Applicants' interest (AI) and Seats availability (SA), AR=f(AI, SA).

Def2: Ranking Weight is final weight for an alternative based on alterative evaluation (AV) and criteria weight (C), that is RW = AV x C

Def3: Alternative evaluation is the weight which given to the an alternative based on the criteria weigh

Theorem 10.1:

In Admission Requirement Classification, the admission requirement (AR) is directly proportional with applicants' interest (AI) and inversely proportional with seats availability (SA). While in Criteria Base Classification, the ranking weight (RW) is directly propositional with alternative evaluation (AV) value based on specific criteria weight (C).

Proof: Based on the definition AR increases if SA is fixed and AI is high and AR deceases if SA is fixed and AI is low. Also based on the definition of RW, it does increase if AV is high

Table 10. 1: Comparison Result (2014/2015 vs 2015/2016 vs Proposed Model)

1. Medicine	% Rate (2014/2015)	% Rate (2015/2016)	Rank (2014/2015)	Rank (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)	% Rate (2015/2016)	Rank (2014/2015)	Rank (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)	% Rate (2015/2016)	Rank (2014/2015)	Rank (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)	% Rate (2015/2016)	Rank (2014/2015)	Rank (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)	% Rate (2015/2016)	Rank (2014/2015)	Rank (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

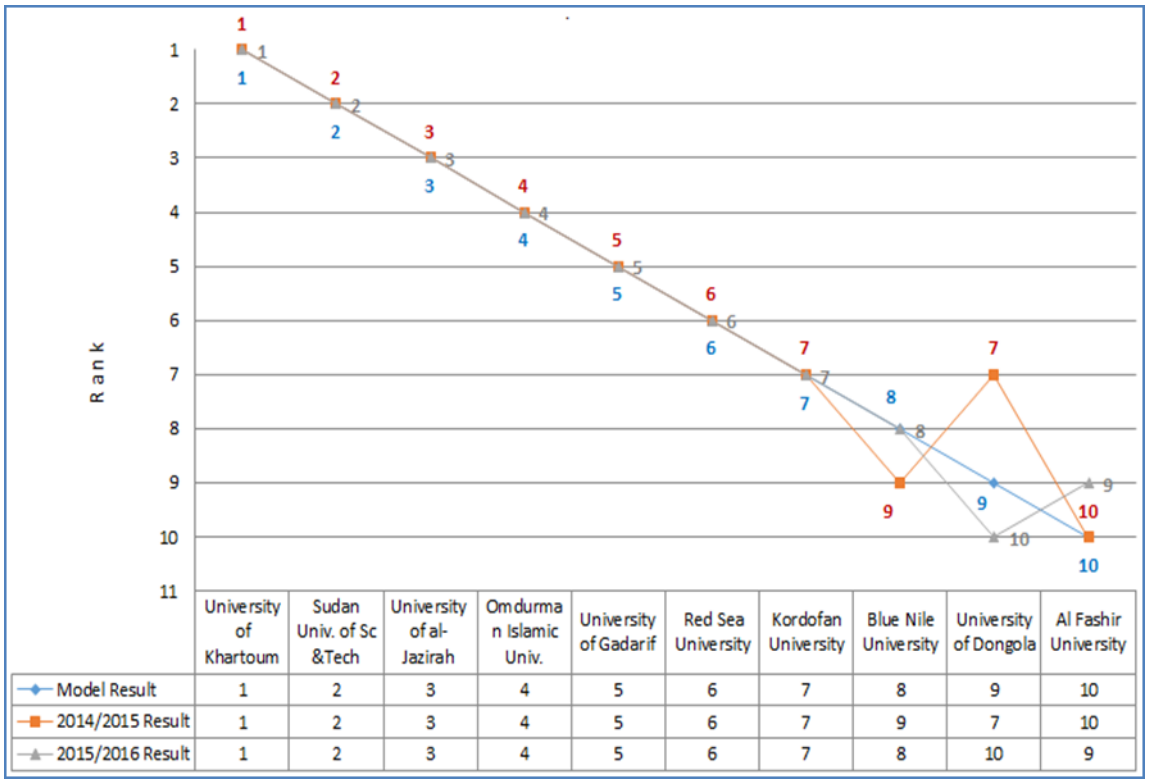


Figure 10. 1 Comparison graphical view (2014/2015 vs 2015/2016 vs Proposed Model)

Currently there is no completed model dedicated for ranking Sudanese universities based on the performance evaluation. Therefore, we compare the complexity of our proposed model and the existing current model (Admission rates model: by GAADEV) used with respect to purpose, evaluation criteria used, consistency, cost and efficiency as shown in the table.

Table 10. 2: Exiting current model (GAADEV) vs the proposed Model

SR	Comparison Criteria	Admission classification rates (by GAADEV)	Proposed Model
1	Objective/Purpose	It is used for admission selection purpose only.	It is mainly designed to measure the performance of the Sudanese universities and academic staff using fuzzy logic
2	Evaluation Criteria	There are no performance evaluation criteria. The admission rates are based on the total number of available seats and related applicants' requests.	Set of tested and evaluated performance criteria with specific weightage are defined and used by the proposed model.

3	Consistency/dependability	It depends on the applicants/students requests. Admission rates may change due to change in applicants' requests or/and available seats.	It depends on agreed criteria and actual information about the institutes gathered and evaluated by experts
4	Cost	Since the classification rates don't depend on specific agreed performance criteria, hence the outcome is not cost-effective irrespective of the located cost	The cost depends on the model implementation approach (i.e. number of evaluators/experts that will be selected to evaluate the criteria and institutes, implementation tool, etc.). Generally, the model output could be cost effective.
5	Efficiency & Accuracy	It is designed to determine the minimum admission rate according to available seats and number of request. Hence it is not efficient and accurate for measuring and ranking universities based on performance.	It is more accurate and efficient in reflecting the actual universities performance. It is based on specific performance criteria.

10.2 Discussion, Recommendation & Conclusion

Pairwise comparisons judgments process for criteria is corner-stone of the performance evaluation process. Therefore, experts/population' definition and selection are critical for the final ranking result. Administrative and management as well as academic experience are required in expert's profile to accurately evaluate the degree of importance among those academic and administrative criteria. Evaluation of criteria may vary from one country to another depending on the regulations, culture, financial capabilities, etc.

We observed there are huge differences between bottom criteria as shown in figure 10.2 & figure 10.3. Some of these criteria are so critical to overall ranking process due to their high weightage comparing with others criteria such as Faculty Members criterion

in universities evaluation (UC42: 0.159929) and Quality of Research in academic staff evaluation (AC12: 0.1017) while others have zero or small weightages such as Graduates criterion (UC53: zero), Management of Community Service criterion (UC81: zero), Community Service Programs criterion (UC82: zero), and External/Foreign Relations (UC26: 0.0033828) for universities evaluation, and Students Motivation criterion (AC521: zero), and Classroom Environment criterion (AC631: 0.0001995) for academic staff evaluation.

Similarly, figure 10.3 compares the most and least weightages within the main criteria: Human Resource criterion (UC4: 0.217) and Community service criterion (UC8: zero) for university evaluation and similarly Teaching quality criterion (AC2: 0.369) and Student Feedback (AC5: 0.031) for academic staff evaluation.

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). Figure 9.1 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).

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. In this study, detail analysis through If-Scenario tool is designed to analyze the result based on emphasizing on some criteria. As example for If-scenarios, the weight of 'Institutional Frame Work' criterion was swapped with 'Human Resources' criterion, which automatically affect on bottom criteria weight, alternatives distances from negative & positive ideal solutions and final ranking result. The detail scenarios analysis and steps are presented in **Appendix C**.

One of the challenges faced was the consistency of criteria pairwise comparison for both university and academic staff. Although online survey may not be the best choice for our appraisers in this study, but it will be very helpful in minimizing the number of

inconsistent result by embedding a warning and information instructions during pairwise comparisons process.

There are departments of Quality & Assurance in Sudanese public universities, which were initiated recently by Ministry of higher Education and Scientific Research. In spite of the current status of these departments, but it holds a promising idea to host and provide info for these kinds of researches.

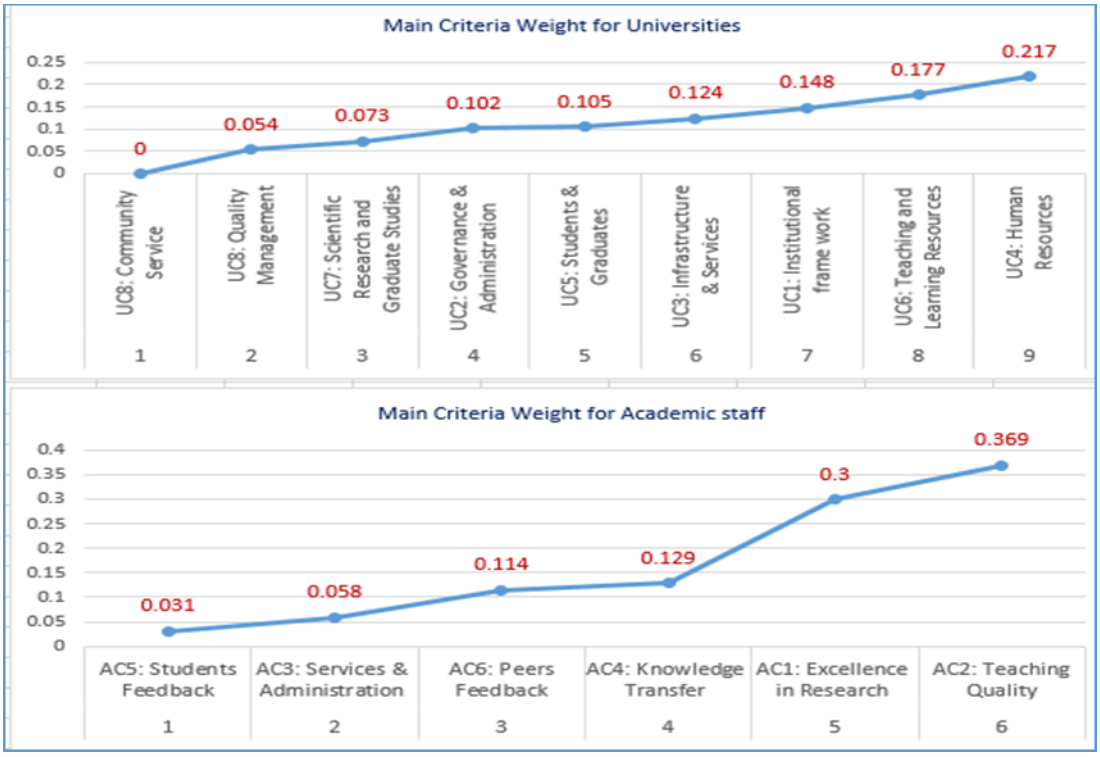


Figure 10. 2: Charts compare the main criteria weight for universities & academic staff

The challenges and benefits of implementing the proposed evaluation model requires collaborated administrative efforts from both institutes and ministry of higher education in Sudan, we recommend the following:

- Paying attention to periodic performance evaluation process of higher education institutes and faculty members and associate the result with incentives and promotions
- Involve all related parties in evaluation process including the academic staff member such as the dean, department head, students, peers and appraisee (360 degree)

- Periodic reassessment for performance criteria weights by specialized experts according to the ministry of higher education plans and related institution objectives using the proposed Evaluation Model.
- Awareness of the evaluation criteria and evaluation process for both appraisers and appraises.

The research provided in this dissertation emphasized the need and worth for performance evaluation system of Sudanese universities and academic staff using fuzzy logic. The focus was on designing and realizing a model which can determine and evaluate suitable criteria, get consistent experts responses, and compute performance evaluation.

In this dissertation, we presented the suitable quantitative and qualitative criteria for performance evaluation of Sudanese universities and academic staff. Two types of survey were conducted pairwise comparison survey to evaluate the criteria and evaluation survey forms to evaluate the universities & academic staff. Consistency checking was performed for every expert participated in the pairwise comparison. New consistency algorithm is introduced. Two combined techniques were used to build the evaluation model: Fuzzy analytic hierarchy process is utilized to provide the criteria weighted and Fuzzy Technique for Order of Preference by Similarity to Ideal Solution is utilized to compute the final ranking. Comparison was conducted to test the proposed model result with the previous ranking. The previous ranking was derived from Sudanese admission result for years 2014/2015 & 2015/2016 (GAADEV result).

10.3 Future Work

This dissertation opens up an area of opportunities where the future researchers can deliver more powerful, user friendly software that can analyze all the possible performance factors for universities, academic staff or any others kind of alternatives using the proposed model and include these design components:

- Setting parameters.
- Criteria Evaluation Process (Pairwise comparison),
- Alternatives Evaluation Process,
- Ranking Process.
- Analyzing Component (if-scenarios)

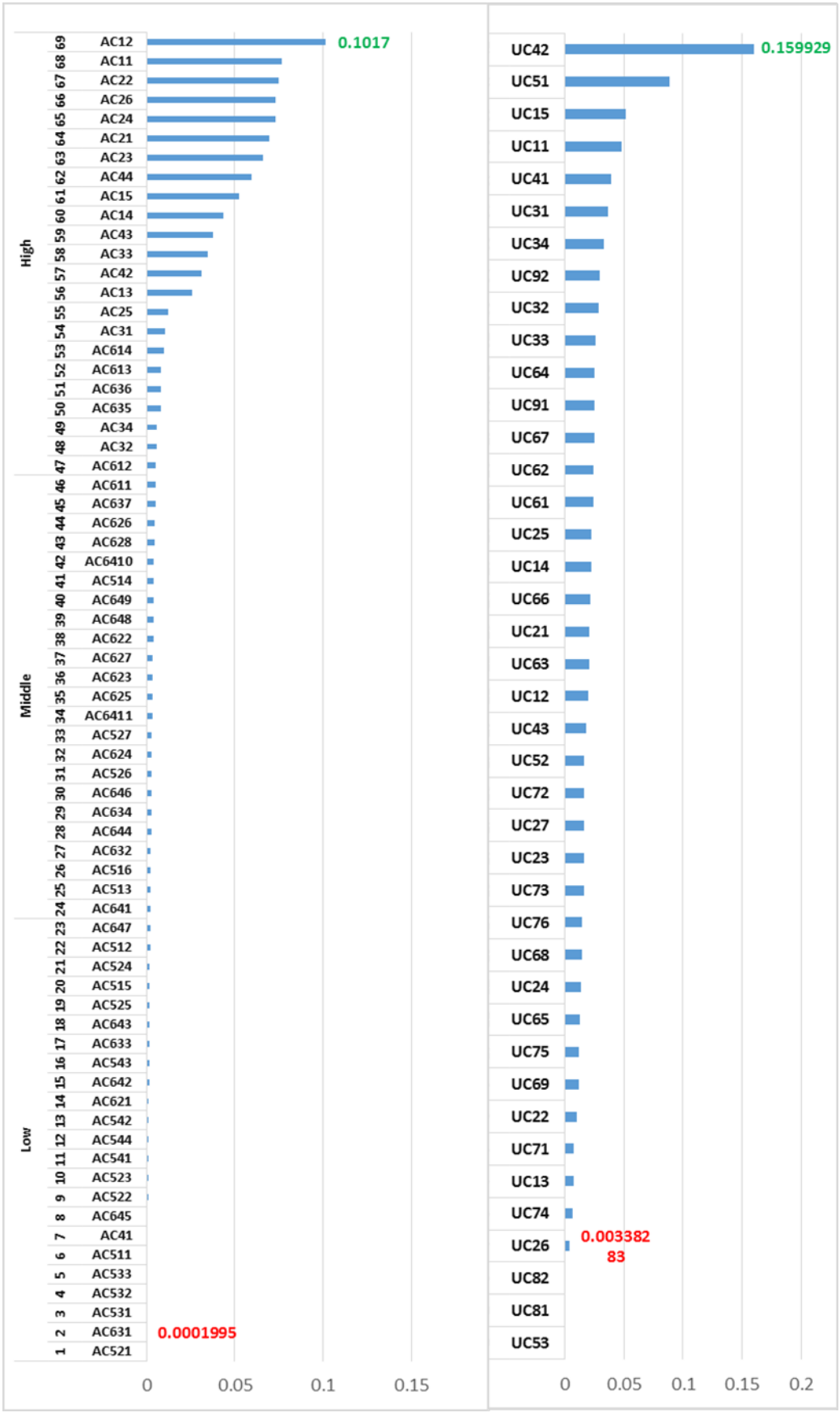


Figure 10. 3: Charts compare bottom criteria weight for universities & academic staff

REFERENCE

- Aggarwal A, Thakur G. (2013). *Techniques of Performance Appraisal-A Review*. International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-2, Issue-3.
- Ajith A. (2001). *Neuro Fuzzy Systems: State-of-the-art Modeling Techniques*. 6th International Work-Conference on Artificial and Natural Neural Networks, IWANN 2001 Granada, Spain, June 13–15, 2001 Proceedings, Part 1.
- AKKOÇ A, Vatansever K. (2013). *Fuzzy Performance Evaluation with AHP and Topsis Methods: Evidence from Turkish Banking Sector after the Global Financial Crisis*. Eurasian Journal of Business and Economics, 6 (11), 53-74.
- Aruldoss M, Lakshmi T, Venkatesan V. (2013). *A Survey on Multi Criteria Decision Making Methods and Its Applications*. American Journal of Information Systems, Vol. 1, No. 1, 31-43.
- Aþkýn Ö, Güzin Ö. (2007). *Comparison of AHP and Fuzzy AHP for the multi-criteria Decision Making Processes with the Linguistic Evaluation*. Istanbul Ticaret Üniversitesi Fen Bilimleri Dergisi Yýl: 6 Sayý: 11Bahar /1 s. 65-85.
- Ayağ, Z. (2005). *A Fuzzy AHP-based Simulation Approach to Concept Evaluation in a NPD Environment.* IIE Transactions, Vol. 37, pp. 827-842.
- Barua A, Mudunuri L, Kosheleva O. (2014). *Why Trapezoidal and Triangular Membership Functions Work So Well*: Towards a Theoretical Explanation. Journal of Uncertain Systems, Vol.8
- Behzadian M, Otaghsara S, Yazdani M, Ignatius J. (2012). *A state-of the-art survey of TOPSIS applications.* Expert Systems with Applications 39 13051–13069.
- Bhosale, G., Kulkarni, R. (2013). *Role of Fuzzy Techniques in Performance Appraisal of Teaching Staff*. International Journal of Latest Trends in Engineering and Technology (IJLTET), ISSN: 2278-621X, Special Issue - IDEAS.
- Boender, C. G, De Graan, J. G., and Lootsma, F. A. (1989). *Multicriteria Decision Analysis with Fuzzy Pairwise Comparisons*. Fuzzy Sets and Systems, 29, 133-14.
- Bottani, E, Rizzi, A. (2006). *A Fuzzy TOPSIS Methodology to Support Outsourcing of Logistics Services*. Supply Chain Management: An International Journal, 11/4: 294-308.
- Bracken D., Timmreck C., Church A. (2001). *Handbook of Multisource Feedback*. First Edition, Jossey Bass Inc.
- Buckley, J. J. (1985a). *Ranking Alternatives Using Fuzzy Members*. Fuzzy Sets and Systems. 15, 21-31.
- Buckley, J. J. (1985b). *Fuzzy Hierarchical Analysis. Fuzzy Sets and Systems*. 17, 233-247.
- Byham WC. (1986). *The Assessment Center Method and Methodology: New Applications and Methodologies*. Development Dimensions International.
- Çelen, A. (2014). Comparative Analysis of Normalization Procedures in TOPSIS Method: With an Application to Turkish Deposit Banking Market. *Informatica, 24*(2), 185-208. doi:10.15388/informatica.2014.10
- Cengiz K., Baþar Ö. (2013). *Personnel selection using type-2 fuzzy AHP method*. The Business & Management Review, Volume 4 Number 1.
- Chakraborty, S., & Yeh, C. (2009). A simulation comparison of normalization procedures for TOPSIS. *2009 International Conference on Computers & Industrial Engineering*. doi:10.1109/iccie.2009.5223811

- Chakraborty, S., Yeh, C. (2007). A simulation based Comparative Study of Normalization Procedures in Multi attribute Decision Making. In: Proceedings of the 6th WSEAS International Conference on Artificial Intelligence, Knowledge Engineering and Data Bases, Corfu Island, Greece
- Chang DY. (1996). *Application of extent analysis method on fuzzy AHP*. European Journal of Operation Research 95 649–655.
- Chang, C., Wu, C., & Lin, H. (2009). Applying fuzzy hierarchy multiple attributes to construct an expert decision making process. *Expert Systems with Applications, 36*(4), 7363-7368. doi:10.1016/j.eswa.2008.09.026
- Chen C. (2000). *Extensions of the TOPSİS for Group Decision Making Under Fuzzy Environment.* Fuzzy Sets and Systems, 114: 1-9.
- Cheng C, Yang K, Hwang C. (1999). *Evaluating attack helicopters by AHP based on linguistic variable weight*. European Journal of Operational Research, Vol. 116, pp. 423-435.
- Chung F, Duan Ji. (2000). *On Multistage Fuzzy Neural Network Modeling*. IEEE Trans. Fuzzy Systems 8 (2) (2000) 125–142.
- Coccia M. (2008). *Measuring scientific performance of public research units for strategic change*. Journal of Informatics, 183–94.
- Costa C, Oliveira M. (2012). *A multi Criteria Decision Analysis Model for Faculty Evaluation*. Omega: 40 424–436.
- Davies, M. A. (1994). A Multi-criteria Decision Model Application for Managing Group Decisions. *The Journal of the Operational Research Society, 45*(1), 47. doi:10.2307/2583950
- Elmore H. (2008). *Toward objectivity in faculty evaluation. Academe*; 94: 38–40.
- Elverfeldt A.V. (2005). *Performance Appraisal-how to improve its effectiveness*. Enschede: University of Twenty.
- Etzkowitz H. (2003). *Research groups as 'quasi-firms': the invention of the entrepreneurial university*. Research Policy; 32:109–21
- Evaluation and Accreditation Commission (EVAC). (2012). *Guide of the National Standards for Quality assurance in HE*. Ministry of Higher Education and scientific Research, Sudan, Khartoum
- Fitz-Gibbon C.T. (1990). *Performance Indicators,* Publisher: Multilingual Matters Ltd, Pub., pp.1.
- Forman, E. & Peniwati K. (1998). *Aggregation individual judgment and priorities with the Analytic Hierarchy Process*. *European Journal of Operational Research,* 108 (1998) 165 - 169.
- Gary D. (2011). *Human Resource Management*. Tenth Edition, Prentice Hall.
- Ghosh D. (2011). *Analytic Hierarchy Process & TOPSIS Method to Evaluate Faculty Performance in Engineering Education*. UNIASCIT, Vol 1 (2), 63-70.
- GMeenakshi, (2012). *Multi source feedback based performance appraisal system using Fuzzy logic decision support system*. International Journal on Soft Computing (IJSC) Vol.3, No.1.
- Gungor Z, Serhadloglub G, Kesen S. (2009). *A fuzzy AHP approach to personnel selection problem*. Applied Soft Computing 9 641–646.
- Higgins, J.C. (1989). *Performance measurement in universities.* European Journal of Operational Research, 38(3), 358-368

- Hongxing L. (1990). *Multifactorial functions in fuzzy sets theory*. Fuzzy Sets and Systems. Volume 35, Issue 1, 69-84, 9 March.
- Huber MT, (2002). *Faculty evaluation and the development of academic careers*. New Directions for Institutional Research, 114:73–83.
- Hwang C, Yoon K. (1981). *Multiple Attribute Decision Making: Methods and Applications*. New York: Springer-Verlag.
- Jafari M, Bourouni A, Amiri R. (2009). *A New Framework for Selection of the Best Performance Appraisal Method.* European Journal of Social Sciences – Volume 7, Number 3.
- Johanson U, Eklov G, Holempren M, Martensson M. (1998). *Human Resource Costing and Accounting versus the Balanced Scorecard: A Literature Survey of Experience with the concepts*. Paris: OECD, Paris.
- Kabir G, Hasin M. (2012). *Comparative Analysis of TOPSIS and Fuzzy TOPSIS for the Evaluation of Travel Website Service Quality*. International Journal for Quality research, Vol. 6, No. 3.
- Kaufmann, A., & Gupta, M. M. (1991). *Introduction to fuzzy arithmetic: Theory and applications*. New York, NY: Van Nostrand Reinhold.
- Kulak, O., and Kahraman, C. (2005). *Fuzzy Multi-Criterion Selection Among Transportation Companies Using Axiomatic Design and Analytic Hierarchy Process*, Information Sciences, 170, 191-210.
- Laarhoven P, Pedrycz W. (1983). *A fuzzy extension of Saaty's priority theory*. Fuzzy Sets and Systems 11 (3) 229–241.
- Laarhoven, P. J. M., and Pedrycz, W. (1983). A Fuzzy Extension of Saaty's Priority Theory. Fuzzy Sets and Systems, 11, 229-241.
- Lootsma, F. (1997). *Fuzzy Logic for Planning and Decision-Making*. Kluwer Academic Publishers, Dordrecht.
- Mahapatra S. Nanda S., Panigrahy B. (2011). *A Cascaded Fuzzy Inference System for Indian River water quality prediction*. Advances in Engineering Software. Volume 42, Issue 10, Pages 787–796.
- Mahar, JA. (2009). *The Use of 360-Degree Feedback Compared to Traditional Evaluative Feedback for the Professional Growth of Teachers*. Seton Hall University Dissertations and Theses (ETDs). Paper 1700.
- Manal S., Choudhury J., Chaudhuri S. (2012). *In Search of Suitable Fuzzy Membership Function in Prediction of Time Series Data*. IJCSI International Journal of Computer Science Issues. Vol. 9, Issue 3, No 3
- Ministry of Higher Education & Scientific Research Sudan. (2016). http://www.mohe.gov.sd/index.php Accessed on 17.03.2016.
- Mitaim S. (1996). *What is the best shape for a fuzzy set in function approximation? Fuzzy Systems*. Vol.2. Pages: 1237– 1243.
- Mondy R. (2008). *Human Resource Management*. Tenth Edition. Pearson Education. Prentice Hall.
- Neogi A, Mondal A, and Mandal S. (2011). *A Cascaded Fuzzy Inference System for University Non-Teaching Staff Performance Appraisal*. Journal of Information Processing Systems, Vol.7, No.4, 595.
- Nisha M., Priti S. (2013). *Modeling Performance Appraisal using Soft Computing Techniques: Designing Neuro-Fuzzy Application*. International Conference on Intelligent Systems and Signal Processing (ISSP).
- Pedrycz W. (1994). *Why triangular membership functions. Fuzzy set and Systems*. Volume 64, Issue 1, Pages 21-30

- Raju G, Zhou J, Kisner R. (1991). *Hierarchical fuzzy control*, International Journal of Control 54 (5) 1201–1216.
- Raju G, Zhou J. (1993). *Adaptive hierarchical fuzzy control*. IEEE Trans. Systems Man Cybernet. 23 (4) 973–980.
- Ramirez E, Mayorga R. (2007). *A cascaded fuzzy inference system for dynamic online portals customization*. International Journal of Intelligent Technology, Vol.2, No. 1, 2007, pp.7-20.
- Ribeiro R. (1996). *Fuzzy Multiple Criterion Decision Making: A Review and New Preference Elicitation Techniques*. Fuzzy Sets and Systems, 78, 155-181.
- Rouyendegh B, Erkan T. (2012). *Selection of Academic Staff using the Fuzzy Analytic Hierarchy Process (FAHP)*. : ISSN 1330-3651, UDC/UDK 658.310.8-057.4:65.012.123.
- Russell R., Taylor B. (2003). *Operations Management 4th edition. Upper Saddle River*. New Jersey: Prentice Hall.
- Saaty TL. (1977). *Scaling method for priorities in hierarchical structures*. Journal of mathematical Psychology 15/3 234-281.
- Saaty TL. (1980). *Multi-criteria Decision Making: The Analytic Hierarchy Process*. 1988; Revised and published by the author. New York: Original version published by McGraw-Hill.
- Saaty TL. (1986). *Decision Making for Leaders: The Analytic Hierarchy Process for Decisions in complex World*, RWS. Pittsburgh, PA Publications.
- Saaty TL. (1990). *How to make decisions: The Analytical Hierarchy Process*. European Journal of Operation Research, Vol. 48 9-26.
- Saaty, T. L. (1995). *Decision making for leaders: The analytic hierarchy process for decisions in a complex world*. Pittsburgh, PA: RWS Publications.
- Saeed N, Mansoor K, Reza M, Jafar S. (2012). *Comparison of AHP and FAHP for Selecting Yard Gantry Cranes in Marine Container Terminals*. Journal of the Persian Gulf (Marine Science)/Vol. 3/No. 7/59-70.
- Shaout A., and M. Al-Shammari. (1998). *Fuzzy Logic Modeling for Performance Appraisal Systems*. The journal of Expert Systems with Applications, Volume 14, No. 3, pp. 323-328.
- Shaout, A., and M. Al-Shammari, (1998). *Fuzzy Modeling for Performance Appraisal Systems*. The proceedings of the International Association of Science and Technology for Development (IASTED) conference, March 30 - April 2 , Irbid, Jordan.
- Shaout A, Trivedi J. (2013). *Performance Appraisal System – Using a Multistage Fuzzy Architecture.* International Journal of Computer and Information Technology (ISSN: 2279 – 0764) Volume 02– Issue 0.
- Shaout A, Yousif MK. (2014/a). *Employee Performance Appraisal System Using Fuzzy Logic.* International Journal of Computer Science & Information Technology (IJCSIT) Vol 6, No 4.
- Shaout A, Yousif MK. (2014/b). *Performance Evaluation - methods and Techniques Survey*. International Journal of Computer and Information Technology (IJCIT) Vol 03, No 05 (ISSN: 2279-0764).
- Tolga, E., Demircan, M. L., & Kahraman, C. (2005). *Operating system selection using fuzzy replacement analysis and analytic hierarchy process*. *International Journal of Production Economics, 97*(1), 89-117. doi:10.1016/j.ijpe.2004.07.001
- Vahidnia MH, Alesheika, AA, Alimohammadi. (2009). *Hospital site selection using AHP and its derivatives.* Journal of Environmental Management, 90, pp. 3048-3056.

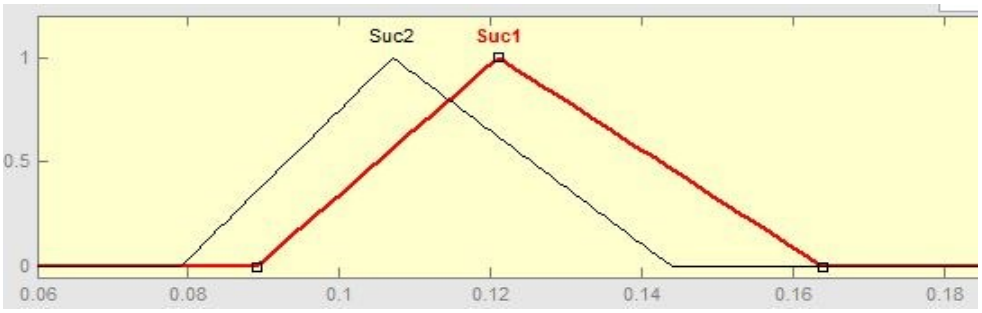
- Wang J, Cheng C, Cheng, Huang K. (2009). *Fuzzy Hierarchical TOPSIS for Supplier Selection*. Applied Soft Computing 9 (1), 377-386.
- Weihrich H. (2000). *A new approach to MBO Updating a time honored technique*.
- Wu B. (2005). *The philosophy and practice of Management by Objectives*. Troy State University.
- Yalcin N, Bayrakdaroglu A, Kahraman C. (2009). *Fuzzy Performance Evaluation in Turkish Banking Sector using Analytic Hierarchy Process and TOPSIS*. Expert Systems with Applications. 36, 11699–11709.
- Yang T, Hung C.C. (2007). *Multiple-attribute decision making methods for plant layout design problem.* Robotics and Computer-Integrated Manufacturing, 23(1), 126-137.
- Yee. C. C, Chen Y.Y. (2010). *Performance Appraisal System using Multifactorial Evaluation Model*. International Journal of Human and Social Sciences 5:12.
- Yeh Z, Chen H. (1998). *A Novel Approach for Multi-stage Inference Fuzzy Control*. IEEE Trans. Systems Man Cybernet. 28 (6)935–946.
- Yeh Z, Li K. (2004). *A systematic Approach for Designing Multistage Fuzzy Control Systems*. Fuzzy Sets and Systems 143 (2004) 251–273.
- Yousif MK., Shaout A (2016/a). *Fuzzy Logic Model Design for Performance Evaluation of Sudanese Universities & Academic Staff.* The International Arab Conference on Quality Assurance in Higher Education. Khartoum. Sudan University of Science & Technology
- Yousif MK., Shaout A (2016/b). *Fuzzy Consistency Algorithm of Performance Evaluation of Sudanese Universities.* The International Arab Conference on Quality Assurance in Higher Education. Khartoum. Sudan University of Science & Technology
- Yousif MK., Shaout A (2016/c). *Fuzzy Logic Computational Model for Performance Evaluation of Sudanese Universities and Academic Staff*. Submitted to the Journal of King Saud University - Computer and Information Sciences
- Zadeh L A. (1965). *Fuzzy Sets*. Information and Control. Vol.8, no.3, pp.:338-353.
- Zadeh, L.A. (1975). *The concept of a Linguistic variable and its application to approximate reasoning*. Inform. Sci., 8 199–249.
- عماد ابوالرب؛ عيسى قدادة؛ محمودالوادى، رعد الطائى . (2010) . *ضمان الجودة فى مؤسسات التعليم العالى*
- وزارة التعليم العالى والبحث العلمى (2016). دليل المنافسة للقبول لمؤسسات التعليم العالى

APPENDICES

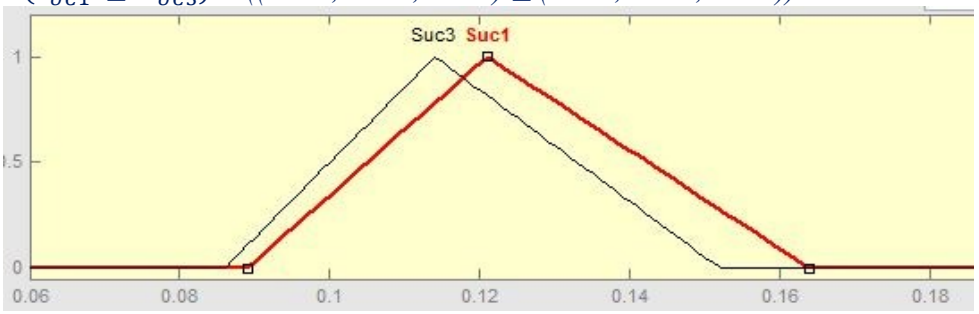
Appendix A: Membership Function Plots

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

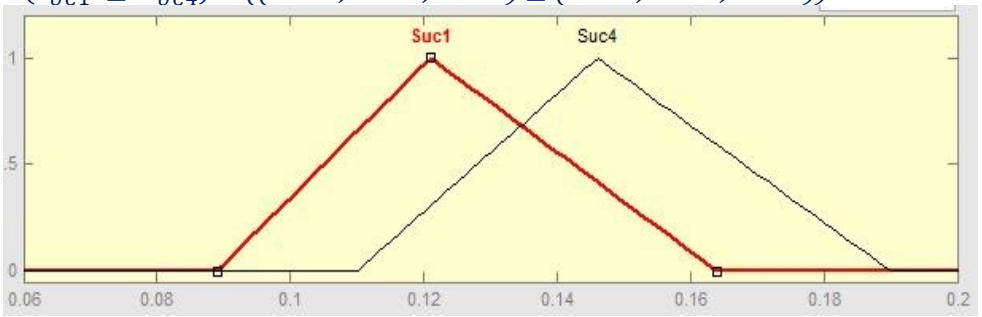
- $(S_{UC1} \geq S_{UC2})$: $V((0.089, 0.121, 0.164) \geq (0.079, 0.107, 0.144)) = 1.000$



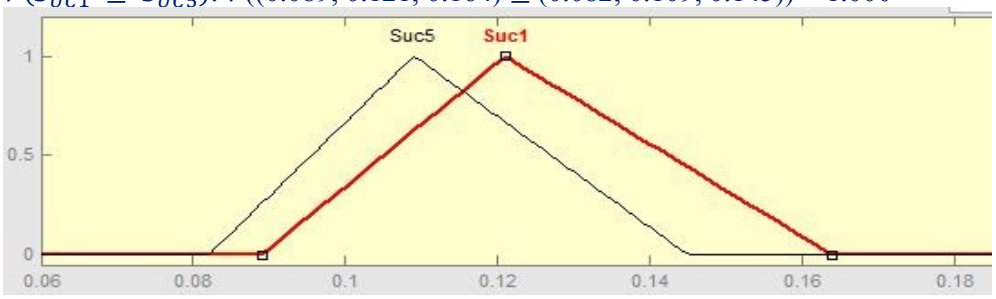
- $V(S_{UC1} \geq S_{UC3})$: $V((0.089, 0.121, 0.164) \geq (0.086, 0.114, 0.152)) = 1.000$



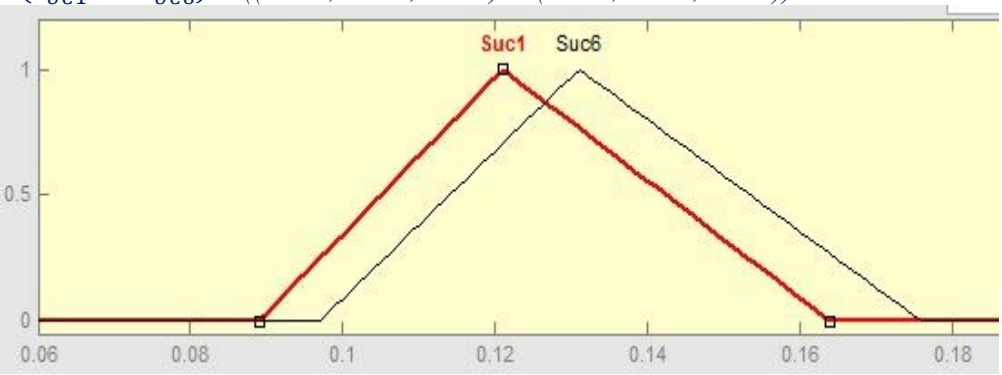
- $V(S_{UC1} \geq S_{UC4})$: $V((0.089, 0.121, 0.164) \geq (0.110, 0.146, 0.190)) = 0.683$



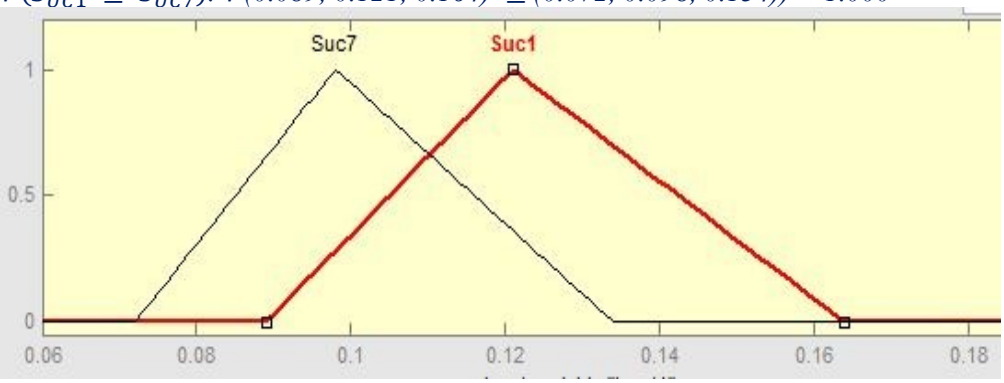
- $V(S_{UC1} \geq S_{UC5})$: $V((0.089, 0.121, 0.164) \geq (0.082, 0.109, 0.145)) = 1.000$



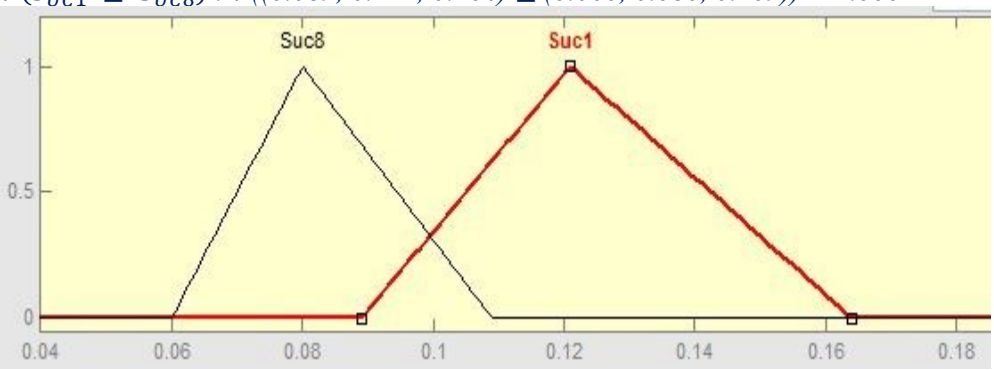
- $V(S_{UC1} \geq S_{UC6})$: *V((0.089, 0.121, 0.164) ≥ (0.097, 0.131, 0.176)) = 0.868*



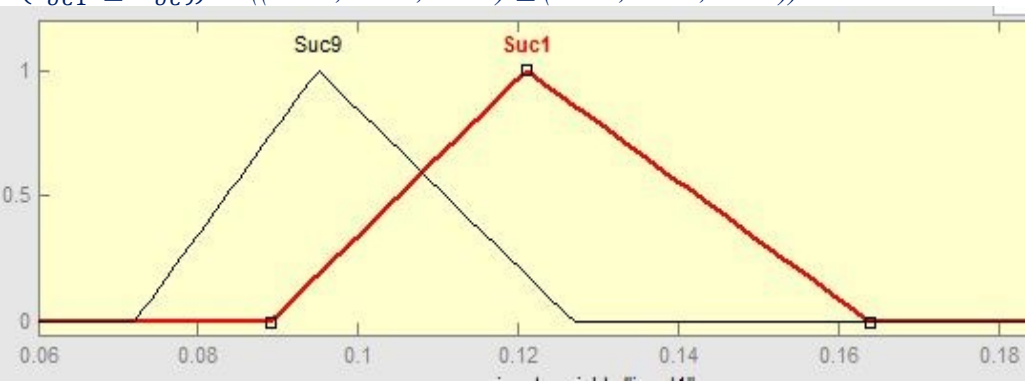
- $V(S_{UC1} \geq S_{UC7})$: *V(0.089, 0.121, 0.164) ≥ (0.072, 0.098, 0.134)) = 1.000*



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



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



Appendix B: Decision Matrices Between the Bottom Criteria and Alternatives

This appendix presents the complete details of normalized and weighted decision matrices using bottom criteria for universities and academic staff as explained in section 9.2.

Table B-1: Normalized & weighted decision matrix using bottom criteria (universities)

			1	2	3	4	5	6	7
	University / Criteria	Weights	University of Gadarif	University of al-Jazirah	Sudan University of Sc. & Tech	Omdurman Islamic University	Blue Nile University	University of Dongola	Kordofan 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)
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)
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)
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)
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)
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)
7	UC22	0.00999746	(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)
8	UC23	0.01606526	(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)
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)
10	UC25	0.02240361	(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)
11	UC26	0.00338283	(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)
12	UC27	0.01608853	(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)
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)
14	UC32	0.028644	(0.0057, 0.0046, 0.0038)	(0.0086, 0.0092, 0.0095)	(0.0086, 0.0092, 0.0095)	(0.0086, 0.0092, 0.0095)	(0.0057, 0.0046, 0.0038)	(0.0057, 0.0046, 0.0038)	(0.0057, 0.0046, 0.0038)

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)
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)
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)
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)
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)
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)
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)
22	UC53	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)
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)
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)
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)
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)
28	UC66	0.02124	(0.0035, 0.0041, 0.0048)	(0.0088, 0.0082, 0.0071)	(0.0088, 0.0082, 0.0071)	(0.0035, 0.0041, 0.0048)	(0.0035, 0.0041, 0.0048)	(0.0035, 0.0041, 0.0048)	(0.0035, 0.0041, 0.0048)
29	UC67	0.02478	(0.0063, 0.0054, 0.0046)	(0.0063, 0.0054, 0.0046)	(0.0095, 0.0108, 0.0116)	(0.0063, 0.0054, 0.0046)	(0.0025, 0.0027, 0.0031)	(0.0025, 0.0027, 0.0031)	(0.0025, 0.0027, 0.0031)
30	UC68	0.013983	(0.0017, 0.0017, 0.0019)	(0.0043, 0.0034, 0.0028)	(0.0065, 0.0069, 0.007)	(0.0017, 0.0017, 0.0019)	(0.0017, 0.0017, 0.0019)	(0.0017, 0.0017, 0.0019)	(0.0017, 0.0017, 0.0019)
31	UC69	0.011328	(0.0025, 0.0022, 0.0019)	(0.0038, 0.0044, 0.0047)	(0.0038, 0.0044, 0.0047)	(0.0025, 0.0022, 0.0019)	(0.0025, 0.0022, 0.0019)	(0.0025, 0.0022, 0.0019)	(0.0025, 0.0022, 0.0019)
32	UC71	0.007665	(0.0017, 0.0015, 0.0013)	(0.0026, 0.003, 0.0032)	(0.0026, 0.003, 0.0032)	(0.0017, 0.0015, 0.0013)	(0.0017, 0.0015, 0.0013)	(0.0017, 0.0015, 0.0013)	(0.0017, 0.0015, 0.0013)
33	UC72	0.016352	(0.0029, 0.0034, 0.0041)	(0.0072, 0.0068, 0.0061)	(0.0072, 0.0068, 0.0061)	(0.0029, 0.0034, 0.0041)	(0.0016, 0.0017, 0.0018)	(0.0016, 0.0017, 0.0018)	(0.0016, 0.0017, 0.0018)
34	UC73	0.015987	(0.0027, 0.0031, 0.0036)	(0.0067, 0.0062, 0.0053)	(0.0067, 0.0062, 0.0053)	(0.0027, 0.0031, 0.0036)	(0.0027, 0.0031, 0.0036)	(0.0027, 0.0031, 0.0036)	(0.0027, 0.0031, 0.0036)
35	UC74	0.006716	(0.0015, 0.0013, 0.0011)	(0.0023, 0.0026, 0.0028)	(0.0023, 0.0026, 0.0028)	(0.0015, 0.0013, 0.0011)	(0.0015, 0.0013, 0.0011)	(0.0015, 0.0013, 0.0011)	(0.0015, 0.0013, 0.0011)

36	UC75	0.011753	(0.0027, 0.0023, 0.002)	(0.0041, 0.0047, 0.005)	(0.0041, 0.0047, 0.005)	(0.0011, 0.0012, 0.0013)	(0.0027, 0.0023, 0.002)	(0.0027, 0.0023, 0.002)	(0.0027, 0.0023, 0.002)
37	UC76	0.0146	(0.0038, 0.0032, 0.0028)	(0.0057, 0.0065, 0.0069)	(0.0038, 0.0032, 0.0028)	(0.0038, 0.0032, 0.0028)	(0.0015, 0.0016, 0.0018)	(0.0015, 0.0016, 0.0018)	(0.0015, 0.0016, 0.0018)
38	UC81	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)
40	UC91	0.025002	(0.0038, 0.004, 0.0045)	(0.0095, 0.0081, 0.0067)	(0.0095, 0.0081, 0.0067)	(0.0038, 0.004, 0.0045)	(0.0038, 0.004, 0.0045)	(0.0038, 0.004, 0.0045)	(0.0038, 0.004, 0.0045)
41	UC92	0.028998	(0.0042, 0.0045, 0.0051)	(0.0104, 0.009, 0.0076)	(0.0104, 0.009, 0.0076)	(0.0042, 0.0045, 0.0051)	(0.0042, 0.0045, 0.0051)	(0.0042, 0.0045, 0.0051)	(0.0042, 0.0045, 0.0051)

			8	9	10	11	12	13	14	15
	Univ/ Criteria	**Weights**	**Al Fashir University**	**Red Sea University**	**University of Khartoum**	**University of Sc. and Tech.**	**Ahfad University for Women**	**University of Medical Sc. & Tech.**	**Omdurman Ahlia University**	**National Ribat University**
1	UC11	0.0481	(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)	(0.0034, 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)
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)
5	UC15	0.05106	(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)
7	UC22	0.00999746	(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	0.01606526	(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)	(0.0029, 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	0.02240361	(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	0.00338283	(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	0.01608853	(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)	(0.0065, 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, 0.0038)	(0.0057, 0.0046, 0.0038)	(0.0086, 0.0092, 0.0095)	(0.0086, 0.0092, 0.0095)	(0.0086, 0.0092, 0.0095)	(0.0086, 0.0092, 0.0095)	(0.0057, 0.0046, 0.0038)	(0.0086, 0.0092, 0.0095)
15	UC33	0.026164	(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)	(0.007, 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)	(0.0173, 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)	(0.0267, 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)	(0.0039, 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)	(0.0155, 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)	(0.0029, 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)
23	UC61	0.023718	(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)	(0.005, 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)	(0.0034, 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)	(0.0044, 0.0034, 0.0027)	(0.0067, 0.0067, 0.0067)

27	UC65	0.012213	(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, 0.0048)	(0.0035, 0.0041, 0.0048)	(0.0088, 0.0082, 0.0071)	(0.0035, 0.0041, 0.0048)	(0.0035, 0.0041, 0.0048)	(0.0088, 0.0082, 0.0071)	(0.0035, 0.0041, 0.0048)	(0.0035, 0.0041, 0.0048)
29	UC67	0.02478	(0.0025, 0.0027, 0.0031)	(0.0063, 0.0054, 0.0046)	(0.0095, 0.0108, 0.0116)	(0.0063, 0.0054, 0.0046)	(0.0063, 0.0054, 0.0046)	(0.0095, 0.0108, 0.0116)	(0.0063, 0.0054, 0.0046)	(0.0063, 0.0054, 0.0046)
30	UC68	0.013983	(0.0017, 0.0017, 0.0019)	(0.0017, 0.0017, 0.0019)	(0.0065, 0.0069, 0.007)	(0.0043, 0.0034, 0.0028)	(0.0017, 0.0017, 0.0019)	(0.0065, 0.0069, 0.007)	(0.0017, 0.0017, 0.0019)	(0.0017, 0.0017, 0.0019)
31	UC69	0.011328	(0.0025, 0.0022, 0.0019)	(0.0025, 0.0022, 0.0019)	(0.0038, 0.0044, 0.0047)	(0.0025, 0.0022, 0.0019)	(0.0025, 0.0022, 0.0019)	(0.0038, 0.0044, 0.0047)	(0.0025, 0.0022, 0.0019)	(0.0025, 0.0022, 0.0019)
32	UC71	0.007665	(0.0017, 0.0015, 0.0013)	(0.0017, 0.0015, 0.0013)	(0.0026, 0.003, 0.0032)	(0.0017, 0.0015, 0.0013)	(0.0017, 0.0015, 0.0013)	(0.0026, 0.003, 0.0032)	(0.0017, 0.0015, 0.0013)	(0.0017, 0.0015, 0.0013)
33	UC72	0.016352	(0.0016, 0.0017, 0.0018)	(0.0029, 0.0034, 0.0041)	(0.0072, 0.0068, 0.0061)	(0.0029, 0.0034, 0.0041)	(0.0029, 0.0034, 0.0041)	(0.0072, 0.0068, 0.0061)	(0.0016, 0.0017, 0.0018)	(0.0029, 0.0034, 0.0041)
34	UC73	0.015987	(0.0027, 0.0031, 0.0036)	(0.0027, 0.0031, 0.0036)	(0.0067, 0.0062, 0.0053)	(0.0027, 0.0031, 0.0036)	(0.0027, 0.0031, 0.0036)	(0.0067, 0.0062, 0.0053)	(0.0027, 0.0031, 0.0036)	(0.0027, 0.0031, 0.0036)
35	UC74	0.006716	(0.0015, 0.0013, 0.0011)	(0.0015, 0.0013, 0.0011)	(0.0023, 0.0026, 0.0028)	(0.0015, 0.0013, 0.0011)	(0.0015, 0.0013, 0.0011)	(0.0023, 0.0026, 0.0028)	(0.0006, 0.0007, 0.0008)	(0.0015, 0.0013, 0.0011)
36	UC75	0.011753	(0.0027, 0.0023, 0.002)	(0.0027, 0.0023, 0.002)	(0.0041, 0.0047, 0.005)	(0.0027, 0.0023, 0.002)	(0.0027, 0.0023, 0.002)	(0.0041, 0.0047, 0.005)	(0.0011, 0.0012, 0.0013)	(0.0027, 0.0023, 0.002)
37	UC76	0.0146	(0.0015, 0.0016, 0.0018)	(0.0038, 0.0032, 0.0028)	(0.0057, 0.0065, 0.0069)	(0.0038, 0.0032, 0.0028)	(0.0038, 0.0032, 0.0028)	(0.0057, 0.0065, 0.0069)	(0.0015, 0.0016, 0.0018)	(0.0038, 0.0032, 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)
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)
40	UC91	0.025002	(0.0038, 0.004, 0.0045)	(0.0038, 0.004, 0.0045)	(0.0095, 0.0081, 0.0067)	(0.0038, 0.004, 0.0045)	(0.0038, 0.004, 0.0045)	(0.0143, 0.0162, 0.0168)	(0.0021, 0.002, 0.002)	(0.0038, 0.004, 0.0045)
41	UC92	0.028998	(0.0042, 0.0045, 0.0051)	(0.0042, 0.0045, 0.0051)	(0.0104, 0.009, 0.0076)	(0.0042, 0.0045, 0.0051)	(0.0042, 0.0045, 0.0051)	(0.0156, 0.0181, 0.0191)	(0.0023, 0.0023, 0.0022)	(0.0104, 0.009, 0.0076)

Table B-2: Normalized & weighted decision matrix using bottom criteria (Staff)

			1	2	3	4	5
	Criteria	Weight	Academic Staff Member 1	Academic Staff Member 2	Academic Staff Member 3	Academic Staff Member 4	Academic Staff Member 5
1	AC11	0.0765	(0.0765, 0.0765, 0.0765)	(0.1147, 0.153, 0.1913)	(0.0765, 0.0765, 0.0765)	(0.0306, 0.0383, 0.0513)	(0.0765, 0.0765, 0.0765)
2	AC12	0.1017	(0.0374, 0.0431, 0.0473)	(0.0872, 0.0862, 0.0851)	(0.0249, 0.0216, 0.0189)	(0.0249, 0.0216, 0.0189)	(0.01, 0.0108, 0.0127)
3	AC13	0.0261	(0.0055, 0.0055, 0.0061)	(0.0206, 0.0221, 0.0227)	(0.003, 0.0028, 0.0026)	(0.0055, 0.0055, 0.0061)	(0.0137, 0.0111, 0.0091)
4	AC14	0.0435	(0.0107, 0.0101, 0.0108)	(0.04, 0.0405, 0.0402)	(0.0107, 0.0101, 0.0108)	(0.0059, 0.0051, 0.0047)	(0.0059, 0.0051, 0.0047)
5	AC15	0.0522	(0.0033, 0.0032, 0.0033)	(0.0518, 0.0518, 0.0518)	(0.0033, 0.0032, 0.0033)	(0.0033, 0.0032, 0.0033)	(0.0033, 0.0032, 0.0033)
6	AC21	0.069741	(0.0173, 0.0156, 0.0142)	(0.0606, 0.0624, 0.0637)	(0.0173, 0.0156, 0.0142)	(0.0173, 0.0156, 0.0142)	(0.0173, 0.0156, 0.0142)
7	AC22	0.074907	(0.03, 0.0265, 0.0234)	(0.0449, 0.053, 0.0585)	(0.03, 0.0265, 0.0234)	(0.03, 0.0265, 0.0234)	(0.03, 0.0265, 0.0234)
8	AC23	0.066051	(0.0139, 0.014, 0.0154)	(0.0521, 0.056, 0.0576)	(0.0139, 0.014, 0.0154)	(0.0076, 0.007, 0.0067)	(0.0347, 0.028, 0.023)
9	AC24	0.073062	(0.0238, 0.0258, 0.0272)	(0.0555, 0.0517, 0.0489)	(0.0238, 0.0258, 0.0272)	(0.0238, 0.0258, 0.0272)	(0.0238, 0.0258, 0.0272)
10	AC25	0.012546	(0.0056, 0.0056, 0.0056)	(0.0056, 0.0056, 0.0056)	(0.0056, 0.0056, 0.0056)	(0.0056, 0.0056, 0.0056)	(0.0056, 0.0056, 0.0056)
11	AC26	0.073062	(0.0175, 0.0167, 0.0177)	(0.0657, 0.0666, 0.0659)	(0.0175, 0.0167, 0.0177)	(0.0096, 0.0083, 0.0076)	(0.0175, 0.0167, 0.0177)
12	AC31	0.010788	(0.0048, 0.0048, 0.0048)	(0.0048, 0.0048, 0.0048)	(0.0048, 0.0048, 0.0048)	(0.0048, 0.0048, 0.0048)	(0.0048, 0.0048, 0.0048)
13	AC32	0.00609	(0.0024, 0.0022, 0.0019)	(0.0037, 0.0043, 0.0048)	(0.0024, 0.0022, 0.0019)	(0.0024, 0.0022, 0.0019)	(0.0024, 0.0022, 0.0019)
14	AC33	0.035032	(0.0126, 0.0146, 0.0161)	(0.0293, 0.0292, 0.029)	(0.0084, 0.0073, 0.0064)	(0.0084, 0.0073, 0.0064)	(0.0084, 0.0073, 0.0064)
15	AC34	0.00609	(0.0016, 0.0014, 0.0013)	(0.0056, 0.0057, 0.0057)	(0.0016, 0.0014, 0.0013)	(0.0006, 0.0007, 0.0008)	(0.0006, 0.0007, 0.0008)
16	AC41	0.000774	(0.0003, 0.0003, 0.0003)	(0.0003, 0.0003, 0.0003)	(0.0003, 0.0003, 0.0003)	(0.0003, 0.0003, 0.0003)	(0.0003, 0.0003, 0.0003)
17	AC42	0.031218	(0.014, 0.014, 0.014)	(0.014, 0.014, 0.014)	(0.014, 0.014, 0.014)	(0.014, 0.014, 0.014)	(0.014, 0.014, 0.014)
18	AC43	0.037539	(0.0168, 0.0168, 0.0168)	(0.0168, 0.0168, 0.0168)	(0.0168, 0.0168, 0.0168)	(0.0168, 0.0168, 0.0168)	(0.0168, 0.0168, 0.0168)
19	AC44	0.059469	(0.0326, 0.0359, 0.0378)	(0.0326, 0.0359, 0.0378)	(0.0217, 0.0179, 0.0151)	(0.0217, 0.0179, 0.0151)	(0.0217, 0.0179, 0.0151)
20	AC511	0.0004799	(0.0002, 0.0002, 0.0001)	(0.0003, 0.0003, 0.0004)	(0.0002, 0.0002, 0.0001)	(0.0002, 0.0002, 0.0001)	(0.0002, 0.0002, 0.0001)
21	AC512	0.0020795	(0.0007, 0.0008, 0.0009)	(0.0017, 0.0016, 0.0016)	(0.0005, 0.0004, 0.0004)	(0.0007, 0.0008, 0.0009)	(0.0005, 0.0004, 0.0004)
22	AC513	0.0023594	(0.0008, 0.0009, 0.0009)	(0.0018, 0.0018, 0.0017)	(0.0008, 0.0009, 0.0009)	(0.0008, 0.0009, 0.0009)	(0.0005, 0.0004, 0.0004)
23	AC514	0.0040657	(0.0027, 0.0026, 0.0026)	(0.0027, 0.0026, 0.0026)	(0.0011, 0.0013, 0.0015)	(0.0008, 0.0007, 0.0006)	(0.0008, 0.0007, 0.0006)

24	AC515	0.0019062	(0.0009, 0.0009, 0.0009)	(0.0009, 0.0009, 0.0009)	(0.0009, 0.0009, 0.0009)	(0.0009, 0.0009, 0.0009)	(0.0009, 0.0009, 0.0009)
25	AC516	0.0024261	(0.0011, 0.0011, 0.0011)	(0.0011, 0.0011, 0.0011)	(0.0011, 0.0011, 0.0011)	(0.0011, 0.0011, 0.0011)	(0.0011, 0.0011, 0.0011)
26	AC521	0	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)
27	AC522	0.0008904	(0.0004, 0.0004, 0.0004)	(0.0004, 0.0004, 0.0004)	(0.0004, 0.0004, 0.0004)	(0.0004, 0.0004, 0.0004)	(0.0004, 0.0004, 0.0004)
28	AC523	0.0009366	(0.0004, 0.0004, 0.0004)	(0.0004, 0.0004, 0.0004)	(0.0004, 0.0004, 0.0004)	(0.0004, 0.0004, 0.0004)	(0.0004, 0.0004, 0.0004)
29	AC524	0.0019079	(0.0005, 0.0006, 0.0006)	(0.0012, 0.0012, 0.0011)	(0.0012, 0.0012, 0.0011)	(0.0005, 0.0006, 0.0006)	(0.0005, 0.0006, 0.0006)
30	AC525	0.0017807	(0.0008, 0.0008, 0.0008)	(0.0008, 0.0008, 0.0008)	(0.0008, 0.0008, 0.0008)	(0.0008, 0.0008, 0.0008)	(0.0008, 0.0008, 0.0008)
31	AC526	0.002937	(0.001, 0.0012, 0.0012)	(0.0024, 0.0023, 0.0022)	(0.0007, 0.0006, 0.0005)	(0.001, 0.0012, 0.0012)	(0.0007, 0.0006, 0.0005)
32	AC527	0.003122	(0.0015, 0.0015, 0.0015)	(0.0015, 0.0015, 0.0015)	(0.0007, 0.0008, 0.0008)	(0.0015, 0.0015, 0.0015)	(0.0015, 0.0015, 0.0015)
33	AC531	0.0004129	(0.0003, 0.0003, 0.0003)	(0.0003, 0.0003, 0.0003)	(0.0001, 0.0001, 0.0001)	(0.0001, 0.0001, 0.0001)	(0.0001, 0.0001, 0.0001)
34	AC532	0.0004129	(0.0002, 0.0002, 0.0002)	(0.0002, 0.0002, 0.0002)	(0.0002, 0.0002, 0.0002)	(0.0002, 0.0002, 0.0002)	(0.0002, 0.0002, 0.0002)
35	AC533	0.0004129	(0.0001, 0.0001, 0.0002)	(0.0003, 0.0003, 0.0003)	(0.0001, 0.0001, 0.0002)	(0.0001, 0.0001, 0.0002)	(0.0001, 0.0001, 0.0002)
36	AC541	0.0010513	(0.0005, 0.0005, 0.0005)	(0.0005, 0.0005, 0.0005)	(0.0005, 0.0005, 0.0005)	(0.0005, 0.0005, 0.0005)	(0.0005, 0.0005, 0.0005)
37	AC542	0.0012119	(0.0005, 0.0005, 0.0005)	(0.0005, 0.0005, 0.0005)	(0.0005, 0.0005, 0.0005)	(0.0005, 0.0005, 0.0005)	(0.0005, 0.0005, 0.0005)
38	AC543	0.001499	(0.0005, 0.0006, 0.0007)	(0.0013, 0.0013, 0.0012)	(0.0004, 0.0003, 0.0003)	(0.0004, 0.0003, 0.0003)	(0.0004, 0.0003, 0.0003)
39	AC544	0.0011048	(0.0005, 0.0005, 0.0005)	(0.0005, 0.0005, 0.0005)	(0.0005, 0.0005, 0.0005)	(0.0005, 0.0005, 0.0005)	(0.0005, 0.0005, 0.0005)
40	AC611	0.0051015	(0.0017, 0.0019, 0.002)	(0.004, 0.0038, 0.0036)	(0.0011, 0.0009, 0.0008)	(0.0017, 0.0019, 0.002)	(0.0017, 0.0019, 0.002)
41	AC612	0.005358	(0.0017, 0.0019, 0.002)	(0.0041, 0.0038, 0.0036)	(0.0017, 0.0019, 0.002)	(0.0017, 0.0019, 0.002)	(0.0017, 0.0019, 0.002)
42	AC613	0.0082935	(0.0052, 0.005, 0.0048)	(0.0052, 0.005, 0.0048)	(0.0022, 0.0025, 0.0027)	(0.0022, 0.0025, 0.0027)	(0.0022, 0.0025, 0.0027)
43	AC614	0.0097755	(0.0062, 0.0061, 0.006)	(0.0062, 0.0061, 0.006)	(0.0027, 0.0031, 0.0033)	(0.0018, 0.0015, 0.0013)	(0.0027, 0.0031, 0.0033)
44	AC621	0.0013965	(0.0009, 0.0008, 0.0008)	(0.0009, 0.0008, 0.0008)	(0.0004, 0.0004, 0.0005)	(0.0004, 0.0004, 0.0005)	(0.0004, 0.0004, 0.0005)
45	AC622	0.003933	(0.0021, 0.0021, 0.0021)	(0.0021, 0.0021, 0.0021)	(0.0009, 0.0011, 0.0011)	(0.0021, 0.0021, 0.0021)	(0.0009, 0.0011, 0.0011)
46	AC623	0.003705	(0.0023, 0.0022, 0.0022)	(0.0023, 0.0022, 0.0022)	(0.001, 0.0011, 0.0012)	(0.001, 0.0011, 0.0012)	(0.001, 0.0011, 0.0012)
47	AC624	0.0031065	(0.0011, 0.0012, 0.0013)	(0.0025, 0.0024, 0.0024)	(0.0011, 0.0012, 0.0013)	(0.0007, 0.0006, 0.0005)	(0.0007, 0.0006, 0.0005)
48	AC625	0.0033915	(0.0011, 0.0008, 0.0007)	(0.0016, 0.0016, 0.0017)	(0.0016, 0.0016, 0.0017)	(0.0016, 0.0016, 0.0017)	(0.0016, 0.0016, 0.0017)
49	AC626	0.0048165	(0.0022, 0.0022, 0.0022)	(0.0022, 0.0022, 0.0022)	(0.0022, 0.0022, 0.0022)	(0.0022, 0.0022, 0.0022)	(0.0022, 0.0022, 0.0022)

50	AC627	0.003762	(0.0017, 0.0017, 0.0017)	(0.0017, 0.0017, 0.0017)	(0.0017, 0.0017, 0.0017)	(0.0017, 0.0017, 0.0017)	(0.0017, 0.0017, 0.0017)
51	AC628	0.004389	(0.002, 0.002, 0.002)	(0.002, 0.002, 0.002)	(0.002, 0.002, 0.002)	(0.002, 0.002, 0.002)	(0.002, 0.002, 0.002)
52	AC631	0.0001995	(0.0001, 0.0001, 0.0001)	(0.0001, 0.0001, 0.0001)	(0.0001, 0.0001, 0.0001)	(0.0001, 0.0001, 0.0001)	(0.0001, 0.0001, 0.0001)
53	AC632	0.0025365	(0.0011, 0.0011, 0.0011)	(0.0011, 0.0011, 0.0011)	(0.0011, 0.0011, 0.0011)	(0.0011, 0.0011, 0.0011)	(0.0011, 0.0011, 0.0011)
54	AC633	0.001539	(0.0005, 0.0005, 0.0006)	(0.0005, 0.0005, 0.0006)	(0.0012, 0.0011, 0.001)	(0.0005, 0.0005, 0.0006)	(0.0005, 0.0005, 0.0006)
55	AC634	0.0027645	(0.0012, 0.0012, 0.0012)	(0.0012, 0.0012, 0.0012)	(0.0012, 0.0012, 0.0012)	(0.0012, 0.0012, 0.0012)	(0.0012, 0.0012, 0.0012)
56	AC635	0.008208	(0.0027, 0.0029, 0.0031)	(0.0062, 0.0058, 0.0055)	(0.0027, 0.0029, 0.0031)	(0.0027, 0.0029, 0.0031)	(0.0027, 0.0029, 0.0031)
57	AC636	0.008208	(0.0037, 0.0037, 0.0037)	(0.0037, 0.0037, 0.0037)	(0.0037, 0.0037, 0.0037)	(0.0037, 0.0037, 0.0037)	(0.0037, 0.0037, 0.0037)
58	AC637	0.005016	(0.0022, 0.0022, 0.0022)	(0.0022, 0.0022, 0.0022)	(0.0022, 0.0022, 0.0022)	(0.0022, 0.0022, 0.0022)	(0.0022, 0.0022, 0.0022)
59	AC641	0.0022515	(0.0006, 0.0007, 0.0008)	(0.0014, 0.0014, 0.0014)	(0.0014, 0.0014, 0.0014)	(0.0004, 0.0004, 0.0003)	(0.0006, 0.0007, 0.0008)
60	AC642	0.0014535	(0.0009, 0.0009, 0.0009)	(0.0009, 0.0009, 0.0009)	(0.0004, 0.0005, 0.0005)	(0.0003, 0.0002, 0.0002)	(0.0004, 0.0005, 0.0005)
61	AC643	0.001596	(0.0008, 0.0008, 0.0008)	(0.0008, 0.0008, 0.0008)	(0.0008, 0.0008, 0.0008)	(0.0002, 0.0002, 0.0002)	(0.0008, 0.0008, 0.0008)
62	AC644	0.0027075	(0.0013, 0.0013, 0.0013)	(0.0013, 0.0013, 0.0013)	(0.0013, 0.0013, 0.0013)	(0.0006, 0.0007, 0.0007)	(0.0013, 0.0013, 0.0013)
63	AC645	0.000798	(0.0005, 0.0005, 0.0005)	(0.0005, 0.0005, 0.0005)	(0.0001, 0.0001, 0.0001)	(0.0001, 0.0001, 0.0001)	(0.0002, 0.0003, 0.0003)
64	AC646	0.0028215	(0.0009, 0.001, 0.0011)	(0.0022, 0.0021, 0.002)	(0.0009, 0.001, 0.0011)	(0.0006, 0.0005, 0.0004)	(0.0009, 0.001, 0.0011)
65	AC647	0.002109	(0.0009, 0.0009, 0.0009)	(0.0009, 0.0009, 0.0009)	(0.0009, 0.0009, 0.0009)	(0.0009, 0.0009, 0.0009)	(0.0009, 0.0009, 0.0009)
66	AC648	0.003933	(0.0019, 0.0019, 0.0019)	(0.0019, 0.0019, 0.0019)	(0.0019, 0.0019, 0.0019)	(0.0008, 0.001, 0.0011)	(0.0019, 0.0019, 0.0019)
67	AC649	0.004047	(0.0014, 0.0015, 0.0016)	(0.0032, 0.003, 0.0029)	(0.0014, 0.0015, 0.0016)	(0.0009, 0.0008, 0.0006)	(0.0014, 0.0015, 0.0016)
68	AC6410	0.004275	(0.0021, 0.0021, 0.0021)	(0.0021, 0.0021, 0.0021)	(0.0021, 0.0021, 0.0021)	(0.0009, 0.001, 0.0011)	(0.0021, 0.0021, 0.0021)
69	AC6411	0.003306	(0.0011, 0.0012, 0.0013)	(0.0026, 0.0025, 0.0024)	(0.0011, 0.0012, 0.0013)	(0.0007, 0.0006, 0.0005)	(0.0011, 0.0012, 0.0013)

Appendix C: If-Scenario Test

The If-Scenario tool provides detail 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 in 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.

Table C-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

Step2: The following analysis graphs and table will be automatically updated and presented. The differences between the actual study and if-scenario case can be observed in the following graphs & table:

- Main criteria weight vs. If-Scenario case - (Figure C-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 C-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 C-2)
- Actual alternatives distance from Negative Ideal Solution (NIS) Vs. If-Scenario alternatives distance from Negative Ideal Solution (NIS) - (Figure C-3)
- Actual alternatives distance from Positive Ideal Solution (NIS) Vs. If-Scenario alternatives distance from Positive Ideal Solution (NIS) - (Figure C-4)
- Actual Final Ranking vs. If-scenario Final (Figure C-5 & Figure C-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 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).

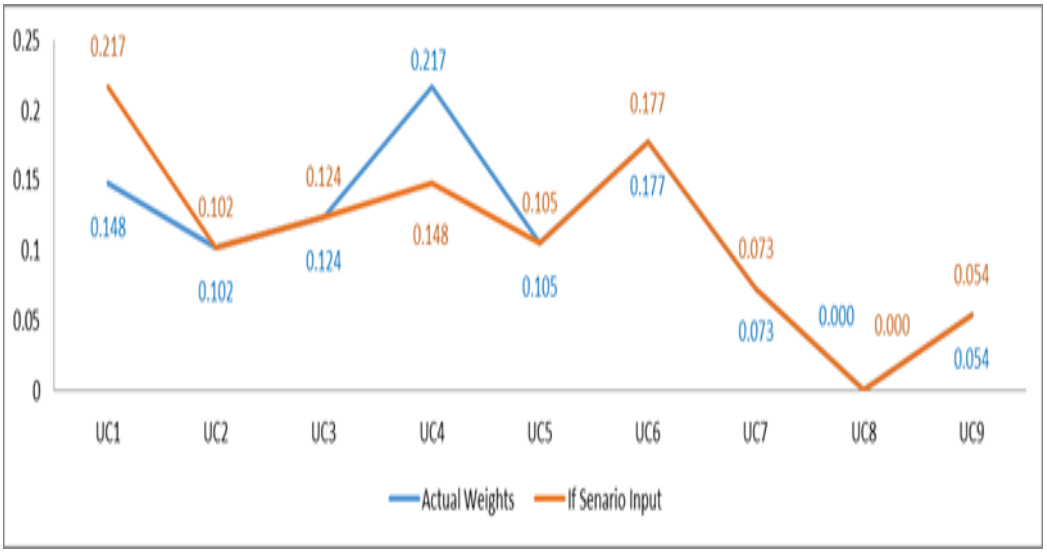


Figure C-1: Main criteria Wight vs. If-Scenario

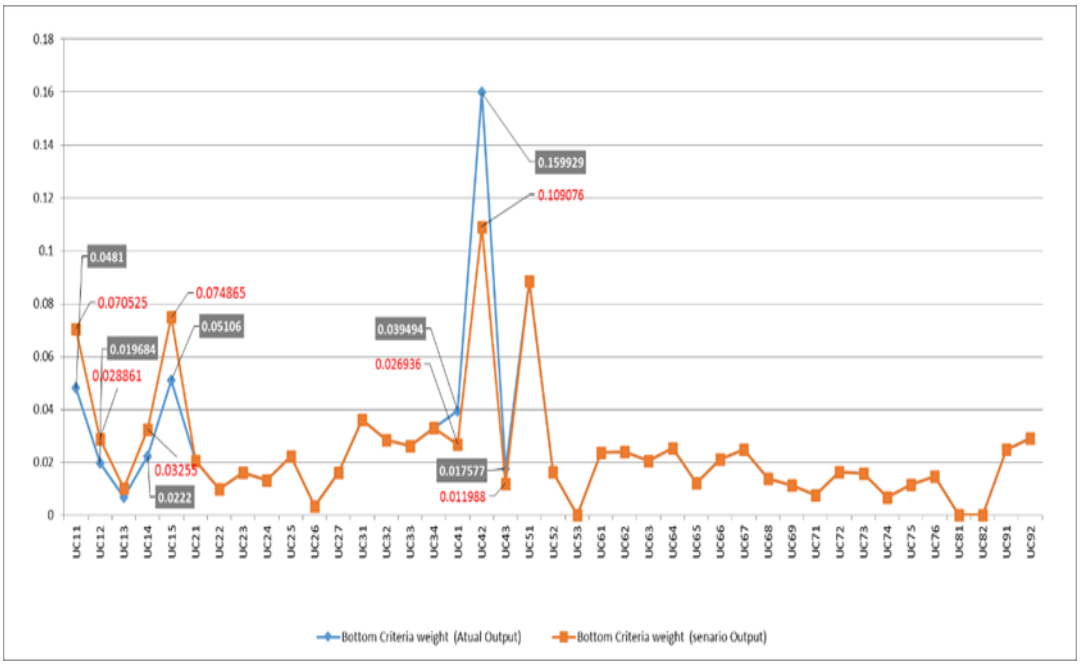


Figure C-2: Actual bottom Criteria Wight vs. If-Scenario

Table C-2: Automatic calculation of the new Bottom Criteria

Main Criteria	Bottom Criteria Code	Sub-Criteria Weights	Main CriteriaWeights	Bottom Criteria weight (Atual Output)	Bottom Criteria weight (senario 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

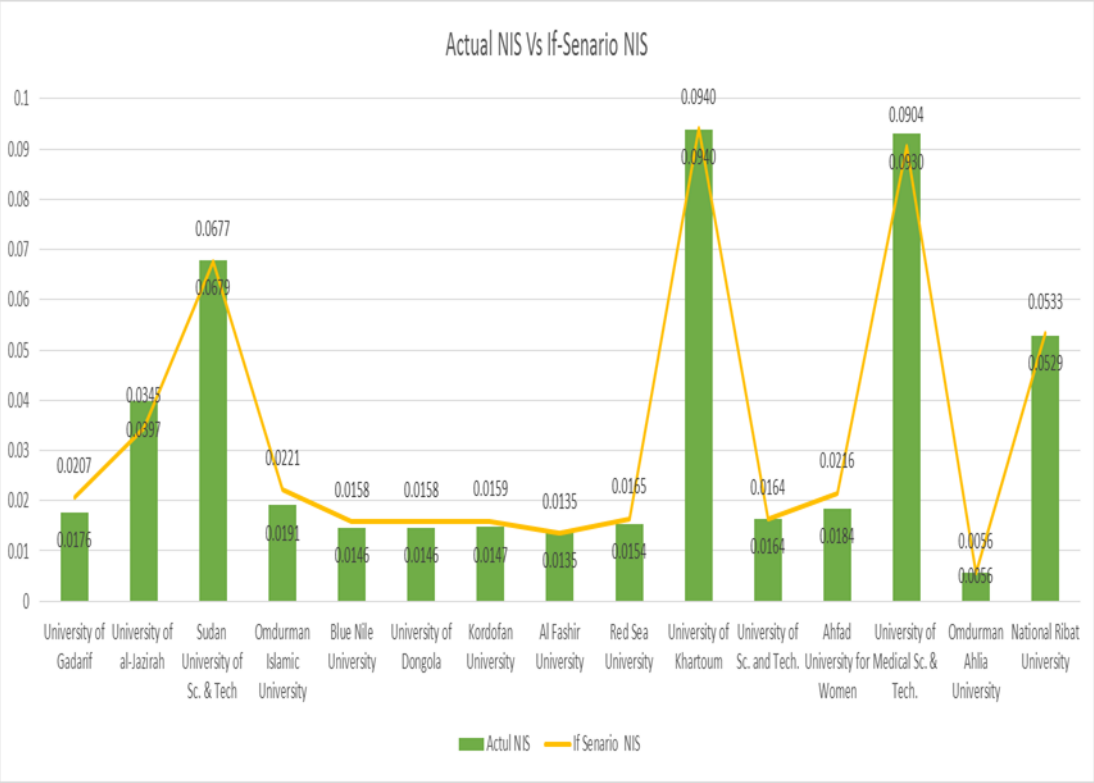


Figure C-3: Actual Alternatives distances from NIS vs. If-scenario distances from NIS

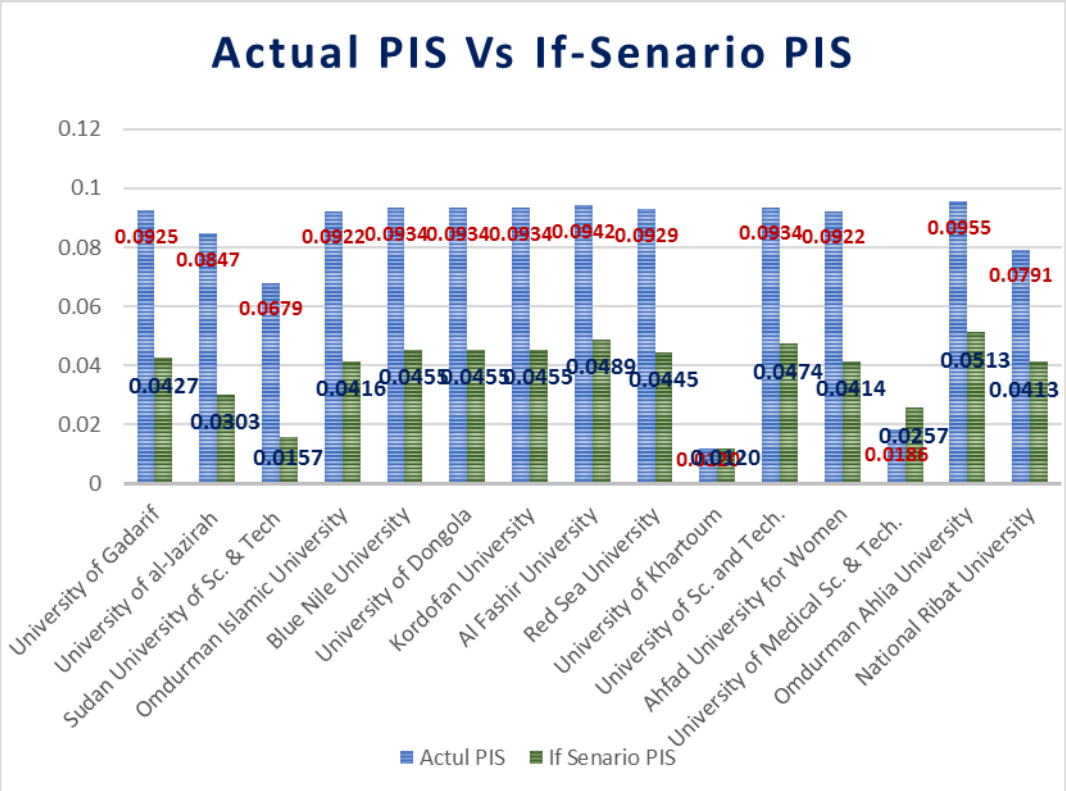


Figure C-4: Actual Alternatives distances from PIS vs. If-scenario distances from PIS

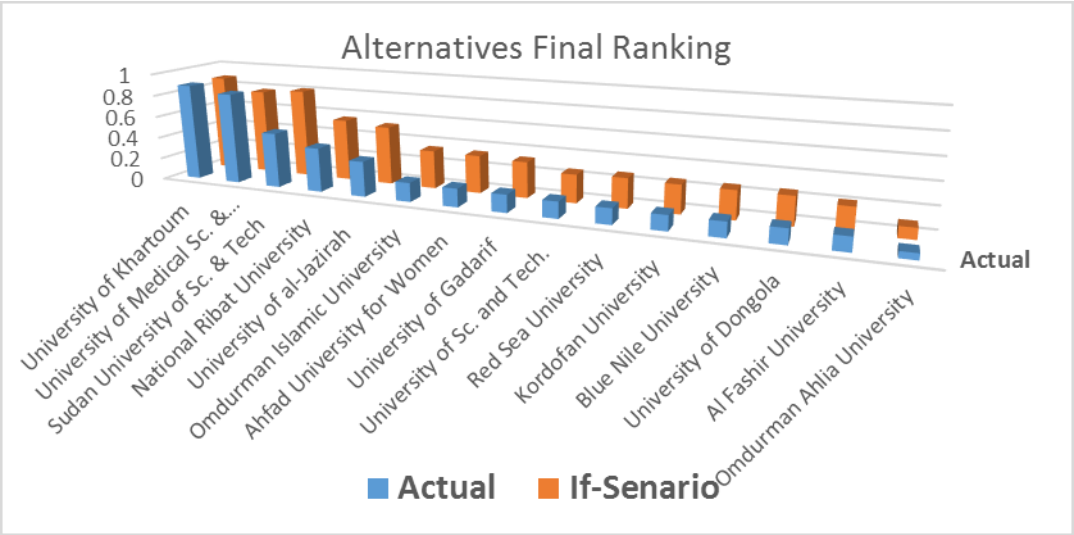


Figure C-5: Actual Final Ranking vs. If-scenario Final Ranking

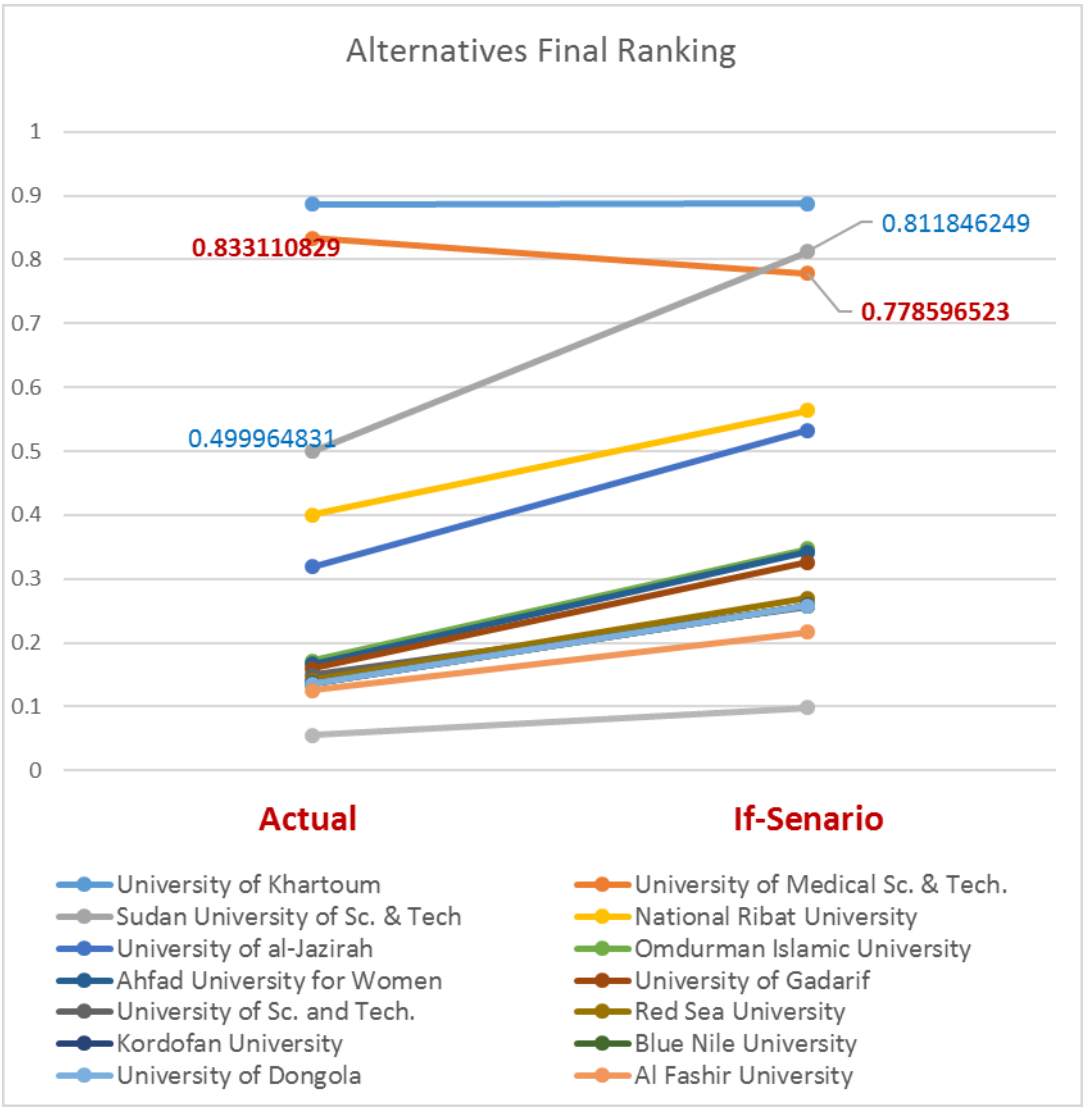


Figure C-6: Actual Final Ranking vs. If-scenario Final

(Univ. of Medical is swapped with Sudan Univ.of Sc.)

LIST OF PUBLICATIONS

- Shaout A, Yousif MK. (2014a). *Employee Performance Appraisal System Using Fuzzy Logic.* International Journal of Computer Science & Information Technology (IJCSIT) Vol 6, No 4.
- Shaout A, Yousif MK. (2014b). *Performance Evaluation - methods and Techniques Survey*. International Journal of Computer and Information Technology (IJCIT) Vol 03, No 05 (ISSN: 2279-0764).
- Yousif MK., Shaout A (2016/a). *Fuzzy Logic Model Design for Performance Evaluation of Sudanese Universities & Academic Staff.* The International Arab Conference on Quality Assurance in Higher Education. Khartoum. Sudan University of Science & Technology
- Yousif MK., Shaout A (2016/b). *Fuzzy Consistency Algorithm of Performance Evaluation of Sudanese Universities.* The International Arab Conference on Quality Assurance in Higher Education. Khartoum. Sudan University of Science & Technology
- Yousif MK., Shaout A (2016/c). *Fuzzy Logic Computational Model for Performance Evaluation of Sudanese Universities and Academic Staff.* The Journal of King Saud University - Computer and Information Sciences