Performance Evaluation – Methods and Techniques Survey

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Abstract— **Performance evaluation (PE) is key factor in improving the quality of work input, inspires staffs make them more engaged. PE also introduces a foundation for upgrades and increments in the development of an organization and employee succession plans. Performance appraisal system varies according to the nature of the work and designation within an organization. This paper presents a comprehensive survey of classical performance methods such as ranking method and graphic rating scale as well as modern methods such as 360 degree appraisal and Management by Objectives (MBO). The survey also provides a comprehensive review of various fuzzy hybrid Multi Criteria Decision Making (MCDM) techniques such as Fuzzy Technique for Order Preference by Similarity to Ideal Solution (TOPSIS & FTOPSIS), Fuzzy Analytic Hierarchy Process (AHP & FAHP), Multistage and Cascade fuzzy Technique, Hybrid Neuro-Fuzzy (NF) technique and Type-2 fuzzy technique. Furthermore, this paper introduces a new proposal for Performance Evaluation of Sudanese Universities and Academic staff using fuzzy logic.**

Keywords: Fuzzy, TOPSIS, FAHP, MCDM, Performance Evaluation, Appraisal Methods

I. Introduction

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

Generally, performance appraisal aims to recognize current skills' status of their work force. 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' contribution to an organization depends on the evaluation of his/her rating. It is essential to have accurate unbiased appraisal assessment in order to measure the employees' contribution to organization objectives. Employers/managers 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 performance level. Since these factors mostly are uncertain and vague in nature a fuzzy performance appraisal method is more appropriate.

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 MBO and assessment Centers. The survey also reviews and classifies some evaluation techniques used in multi criteria environment.

The rest of this paper is organized as follows: Section II reviews both performance appraisal methods: traditional and modern method. Section III explains and classifies the fuzzy related performance appraisal techniques including the MCDM techniques. A new proposal for Performance Evaluation of Sudanese Universities and Academic staff Using Fuzzy logic is introduced in Section IV. Other performance evaluation methods and Conclusion are provided in Sections V & VI.

II. Performance Appraisal Methods

Performance Appraisal can be generally categorized into two groups: Traditional (Past oriented) methods and Modern (future oriented) methods [1]. Other researchers [4] have classified the existent methods to three groups; absolute standards, relative standards and objectives. The performance appraisal methods are:

A. 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

Superior ranks his employee based on merit from best to worst [2]. 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 [3]. According to [2], 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 [2], 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 attempt to concentrate on behavior [4]. Some of the evaluation criterion are as follows: overall impression of performance, existing capabilities & qualifications, previous performance, and suggestions by others.

B. 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 [5]. Weihrich [6] 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 [7].

g) Humans Resource Accounting (HRA)

In this method, the performance is judged in terms of cost and contribution of the employees. Johnson [8] incorporate 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 [9].

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 [4]. 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 [10]. 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 1 shows the summary of performance appraisal methods with pros and cons for each method.

Table 1: Appraisal performance Methods Summary

SR	***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. ✓ Flexible methodology. ✓ Assists in promotion decisions and diagnosing employee development needs. ✓ Allow multiple traits measurement.	× Costly and difficult to manage. × Needs a large staff and a great deal of time. × Limited number of 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.

C. The comparison of Performance Appraisal Methods

As shown in table 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 [60] 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 (a: Ranking Method, b: graphic rating scales method, etc.).

Table 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 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: rij = xij / max (xi), or **Cost:** rij = min (xi) / xij

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

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

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

$$\boldsymbol{wj} = (n - rj + 1) \; / \; \sum_{k=1}^{n} (n - rk + 1)$$

Where wj is the normalized weight for the jth criterion, n is the number of criterion under consideration and rj is the rank position of criterion.

Table 3**:** Rank, weight and wj 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

Then use each criteria weight in table 3 with the above normalized matrix to rank the appraisal method as shown in the table 4. In this example MBO is on the top of the list, then followed by 360 Degree, etc.

Table 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

III. Fuzzy Related Appraisal Techniques

There are many fuzzy related appraisal techniques in literature. In this section we will present them.

A. AHP & FAHP

a. Analytic Hierarchy Process (AHP) Technique

Analytic hierarchy process (AHP) is a quantitative technique for ranking decision alternatives using multiple criteria [11]. 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 [23]; 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 [12, 16].

The Saaty [12] help introducing AHP. The principles are reviewed giving overall background information on the measurement type utilized, its properties and application. Saaty [12] 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 [13, 14, and 15]. The AHP is utilized with two types of measurement which are relative and absolute [12]. The paired comparisons in both measurements are performed to derive priorities for criteria with respect to the goal. Figure 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 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.

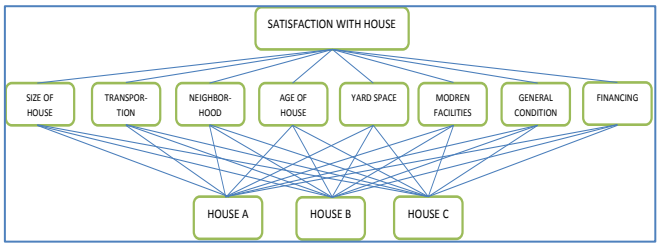

Figure 1: Decomposition of the problem into a hierarchy

The 2nd Step is the gathering of pair-wise comparison judgments using the scale as shown in the table 5 and the matrix pair-wise comparison as shown in table 6. Instead of naming the criteria, table 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 1. Hence, there will be eight decision matrices as shown in table 7 (i.e. 8 elements in 2nd level and 3 houses to be compared).

Table 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 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 8.

Table 7: Comparison matrices and local priorities

Size of house	A	B	C	Priority vector
A	1	6	8	0.754
B	1/6	1	4	0.181
C	1/8	1/4	1	0.065

Yard Space	A	B	C	Priority vector
A	1	5	4	0.674
B	1/5	1	1/3	0.101
C	1/4	3	1	0.226

Transportation	A	B	C	Priority vector
A	1	7	1/5	0.233
B	1/7	1	1/8	0.005
C	5	8	1	0.713

Modern facilities	A	B	C	Priority vector
A	1	8	6	0.747
B	1/8	1	1/5	0.060
C	1/6	5	1	0.193

Neighborhood	A	B	C	Priority vector
A	1	8	6	0.745
B	1/8	1	1/4	0.065
C	1/6	4	1	0.181

General Condition	A	B	C	Priority vector
A	1	1/2	1/2	0.200
B	2	1	1	0.400
C	2	1	1	0.400

Age of house	A	B	C	Priority vector
A	1	1	1	0.333
B	1	1	1	0.333
C	1	1	1	0.333

Financing	A	B	C	Priority vector
A	1	1/7	1/5	0.072
B	7	1	3	0.650
C	5	1/3	1	0.278

Table 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 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 [12].

Table 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 [16, 17] 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) **[**21**].**
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 [20].
There are various FAHP techniques which are proposed by several authors. The earliest effort in FAHP appeared in [18]**.** 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. The [19] 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 [22] 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. The FAHP technique uses triangular fuzzy functions with their parameters as shown in table 10. The AHP inability to deal with the impression and subjective-ness 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. Table 11 and 12 demonstrate the relevant pair-wise matrix related to weights for factors and one of the sub-factors respectively.

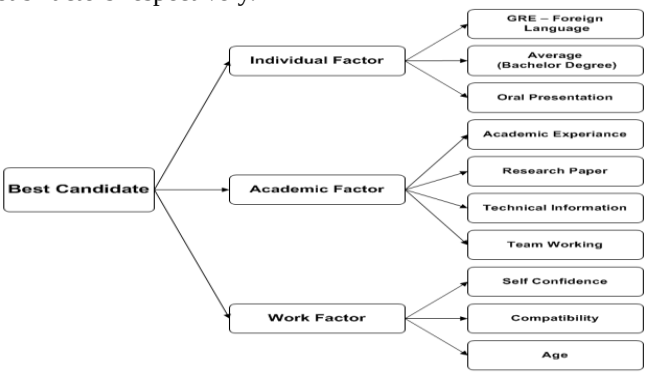

Figure 2: Hierarchy for staff selection problem

Table 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 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 12: Pair-wise comparison matrix and fuzzy weights for the work factor 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 [19, 44, 45, 46, 47, 48, 49, 50] 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 13 shows the comparison summary points between AHP and FAHP.

Table 13: AHP vs. FAHP summary

	Classical AHP	Fuzzy AHP
1	If information / evaluations are certain, then classical method should be selected.	If the 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 where the decision is continues.
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.

B. *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 [24]. It was firstly initiated by Hwang and Yoon [25, 26]. 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 [25, 27]. In addition to assert the distance of selection alternative to positive and negative ideal solution, TOPSIS also presents ideal and non-ideal solutions [28]. 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 [25]. 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 [29].

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 [30, 31]. This technique is mainly suitable for solving the group decision-making problem under fuzzy circumstances. The fuzzy TOPSIS technique has the following steps [25]: 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 vertex method.
Fuzzy TOPSIS method is used in different fields in the literature. Ghosh [32] applied fuzzy AHP and TOPSIS to evaluate faculty performance in engineering education. The first ten students 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 [33]. 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 14 and figure 3).

Table 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	

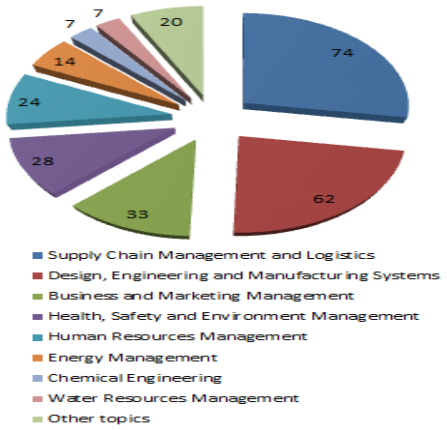

Figure 3: Graphically distribution of TOPSIS papers by application areas

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 [34]. 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.

C. Multistage Fuzzy & Cascaded Fuzzy Technique

The multistage fuzzy logic inference has been proposed [35, 36, 37, 38, and 39] 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 [29, 30]. 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 $[8^7 = 2097152]$ 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 $[6 * 8^2 = 384]$. A systematic approach for designing a multistage fuzzy logic controller (MFLC) for large scale nonlinear systems was proposed in [35]. 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 [40]. 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.

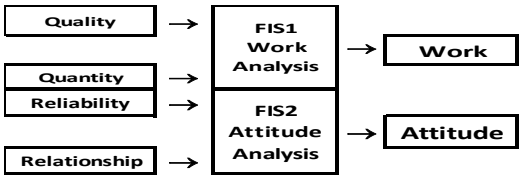

Figure 4. 2-Stage-wise Fuzzy Approach

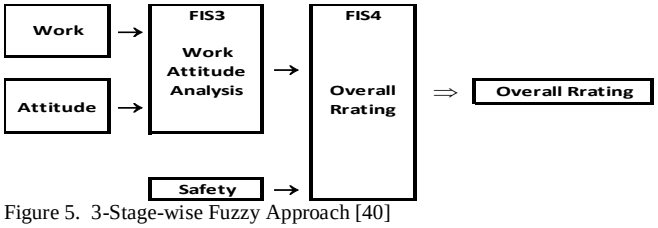

Figure 5. 3-Stage-wise Fuzzy Approach [40]

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 [41]. A cascaded fuzzy inference system (FIS) [42] 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 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".

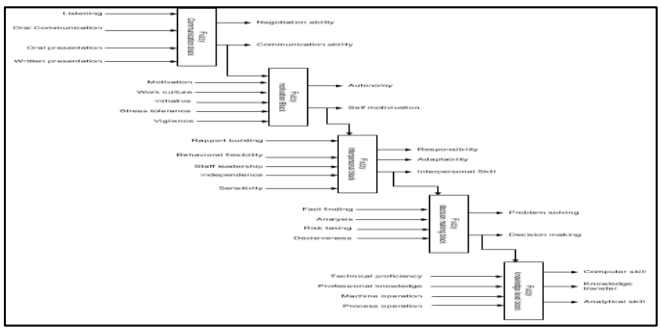

Figure 6: The structure of the proposed Cascaded Fuzzy Inference System [41]

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. [43] proposes a new cascaded Mamdani FIS and its performance is assessed with the assistance of prediction of Indian River water quality index (WQI).

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 [51]. Let U= {u1, u2, u3 ... un) be a set of objects for assessment. Let F = {f1, f2, f3… fm} be the set of basic factors in the evaluation process, and let E = {e1, e2... en} 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 [52] 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 [52].

A performance appraisal system has been developed using performance appraisal criteria from Information and communication based company in Malaysia [53]. 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.

E. 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 [54]. 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 them-selves 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 [55]. A neuro-fuzzy technique for performance evaluation that eliminates any emotional components that may have a negative effect on unbiased assessment was proposed in [55]. 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.

F. 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] [56]. 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 [57]. A multi-criteria personnel selection based on type-2 fuzzy AHP technique was proposed in [58]. This technique was used

to select the best candidate from among three candidates who apply for a position in a manufacturing firm.

Table 15 shows the summary list of all fuzzy techniques related to performance appraisal with summary benefits description for each technique.

Table 12: Related Fuzzy Techniques Summary

SR	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.	[12, and 22]
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.	[32]
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.	[40 and 41]
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.	[53]
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.	[55]
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.	[58]

IV. Performance Evaluation of Sudanese Universities & Academic Staff Using Fuzzy logic

a. Introduction & Problem Statement

During the past few years there have been considerable increases in Sudanese educational institutes. There are more than 100 private & public universities and colleges in Sudan today (31 governmental universities, 11 non-governmental universities, and 60 private colleges) [59]. Most of these universities have several faculties such as medicine,

engineering, science, art, etc. This rapid increase has not been accompanied with enough scientific evaluation research and appropriate information that can help and guide the applicants in finding a best faculty from these universities. The evaluation research will also allow the various levels of management in Sudan (faculties, universities, and the ministry of higher education) to execute gab analysis process and establish future development plan for the country.
Due to a combination of qualitative and quantitative multi-criteria, human impression and lack of information, there is a need for a mathematical and perception computation to evaluate the academic staff performance and rank Sudanese universities. This evaluation will lead to proper action such as upgrades, promotion and individual development for academic staff as well as to provide the Higher Education Ministry with proper information for future planning.

b. Objective

The main objective of this proposal is to serve the following categories: (Students/applicants/Applicants' Parents, Faculty & university management and Ministry of Higher Education)

a. To identify the performance measurement indicators for evaluating the best academic staffs, faculties and Sudanese academic institutions.
b. To design and develop an appropriate Fuzzy performance evaluation model with possibly new theorems and fuzzy data structures which can handles 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.
c. To implement and test the proposal system
d. The evaluation result serves the Sudanese communities as follows:

- To find an accurate source of processed information that guides and helps applicants' & students' parents to choose the best university for their future study in a specific field.
- Ranking and evaluation system to help the Ministry of Higher Education to be aware of the faculties' level and standard and to maintain future plan.
- Ranking and appraisal system for teachers/professors that help university/faculty management to upgrade, promote and fill the gaps in their academic staff.

c. Methodology

A combination of multiple techniques including the fuzzy Analytic Hierarchy Analysis will be adapted to develop multisystem multi-criteria model. The overall concept of the analytic hierarchy process is shown in figure 7.

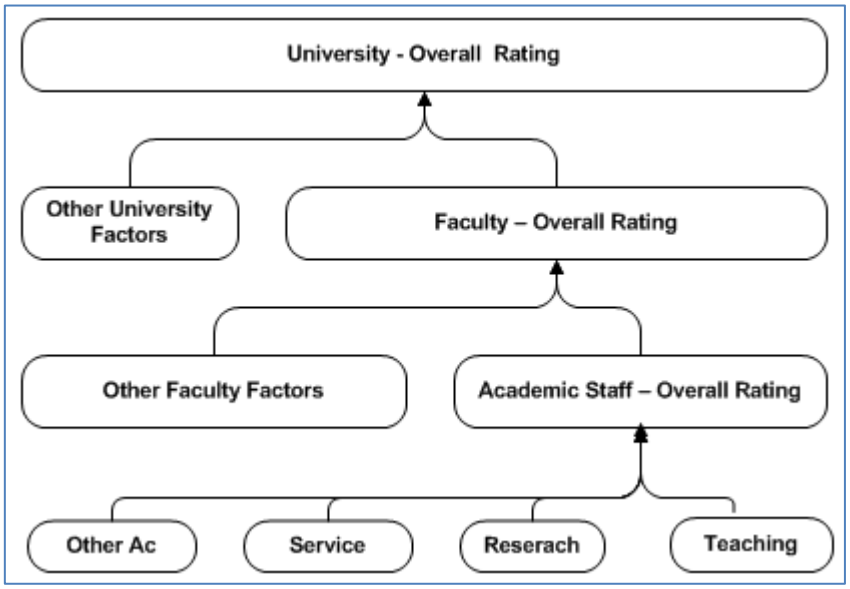

Figure 7: General structure for the proposal of PE of Sudanese Universities & academic staff

The hierarchical structure of evaluating Sudanese universities and academic staff will be constructed based on four layers: faculties, academic staff, info-structure and administration. The FAHP method will be used for weighting the criteria and the total evaluation performance ordering preference will be conducted using the FTOPSIS technique. FOPSIS technique based on the concept that selected alternative is the shortest geometric distance to positive ideal solution (SDPIS) and the longest geometric distance to negative ideal solution (LDNIS).

Interviews and questioner methods will be used to gather the required data.
It is mostly used in different areas of multi criteria group decision making due to the following:

- It is built on the view that it offers the best suitable result as the SDPIS or LDNIS.
- It is simple, understandable and empirical

d. High level Action Plan

The high level action plan consists of the following main steps: determining the evaluation criteria, design and develop a suitable fuzzy evaluation model, determine the actual evaluation data for ten universities and implement and test the proposal system. These steps are explained in figure 8.

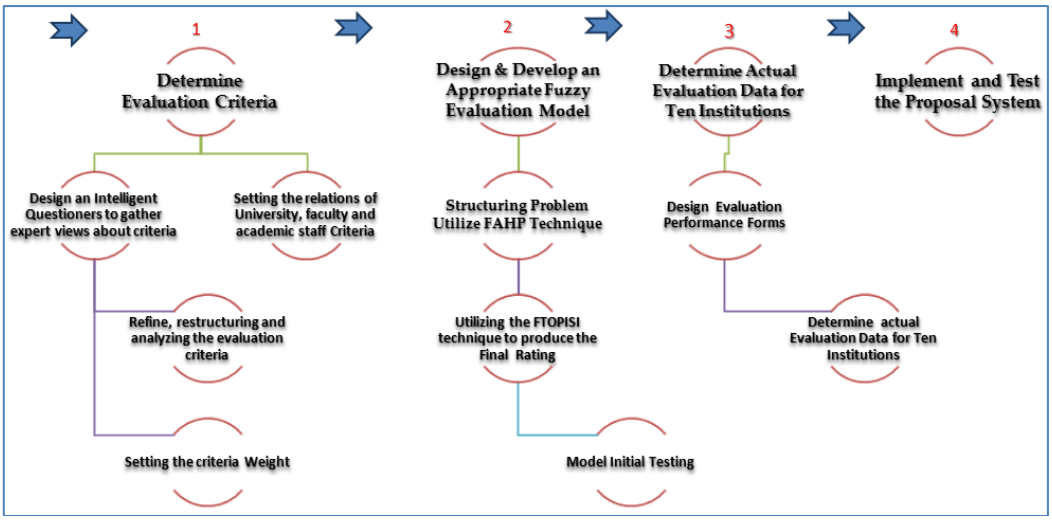

Figure 8: High Action Implementation plan.

V. Other Performance Evaluation Methods

Several methods such as 270 degree, 180 degree, 90 degree, balanced score card (BSC), mixed standard scale, forced distribution method, mixed standard scale, electronic performance monitoring, confidential reports etc. are also used for performance appraisal but were no discussed in this survey.

VI. Conclusion

We conclude that there are several methods that were utilized for performance appraisal. It is very hard to state which method is better to use than others since it depend on the type and size of business. Every method has its own pros and cons. This survey has covered and classified many multi criteria decision making (MCDM) techniques such as TOPSIS, FTOPSIS, AHP and FAHP. Fuzzy multi criteria decision techniques were used in performance evaluation and many other applications such as banking, and safety assessment. Other techniques were used for performance appraisal such as multistage fuzzy, cascaded fuzzy, Neuro-Fuzzy (NF) and Type-2 fuzzy evaluation. Each one of these techniques has its own scope of performance, thus the right technique has to be selected based on the application at hand. Due to the advantages and disadvantages that each technique might have, most corporations would merge and match different techniques for their own performance appraisal system that can meet their organizational requirements.
In this paper a new proposal for performance evaluation of Sudanese universities and academic staff using fuzzy logic was also introduced.

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