A Fuzzy Model for Performance Appraisal and Promotion Ranking System: A Case Study of Nigerian Air Force

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Abstract— **Transparency in the performance appraisal and ranking of service personnel applying for promotion in any organisation is important for efficient human resource management. In this paper, an approach for the promotion screening and ranking of officers in Nigerian Air Force due for a particular rank is discussed. The approach uses fuzzy logic concepts to classify the officers for ranking decisions fairly through the various performance appraisal processes. The research established a new ranking procedure which makes it possible to rank and order the performance of the officers by aggregating the scores from each evaluator. The result from the system is to be used to appraise and promote eligible and qualified officers.**

Keywords: Fuzzy, knowledge base, human resource, metrics, Nigerian Air Force, metrics.

I. INTRODUCTION

The personnel of the Nigerian Air Force (NAF) are the most important tools it has. Without the human resource, it will not be able to accomplish its ultimate goal which is to defend Nigeria's territorial integrity by air and also combat insurgency as it is doing presently. The NAF has a well-organized human resource department known as the Directorate of Personnel Management. There has always been cases or agitation from officers and men of the NAF, who have laid complains bothering on the selection of candidates for appraisal and promotion of deserving candidates within the service.

As a result of this, some officers who thought they deserve to be selected for appraisal and subsequently promoted but were not selected end up being unsatisfied with the system and could indulge in activities unbecoming of a disciplined officer. This kind of problem and many more can be resolved with a well designed appraisal and promotion model being made an integral part of the human resources management system.

Knowledge-based economy makes it imperative for all organizations to identify and maintain talented knowledge workers. Therefore, identifying and promoting the most qualified candidates with superior human talent becomes the prime source of an organization's competitive advantage [1], [2].

When managing the human resources of an organization, appraising the performance of applicants for a particular position is a central task [3]. However, it is often difficult to assign an aggregate score for a candidate's performance when previous assessments were qualitative and originated from other organizations that have different performance evaluation criteria [4], [5].

In military organizations, transparent and fair appraisal of personnel is essential for decisions pertaining to promotions and operations [6]. For an appraisal system to be effective, organizational members must believe that their opinions are reflected in the appraisal process [7]. Such appraisal involves a number of evaluators (or decision makers) with equal authority to assess each candidate based on both qualitative and quantitative multi-performance criteria. The impacts and the relationships among the characteristics used to assign a score can sometimes be described by linguistic terms, e.g. "outstanding", ''very high'', ''poor'', ''medium'', "below average" etc. The appraisal results are then aggregated to rank order the performance of the candidates and select the finalists to be promoted [8].

Performance appraisal for promotion in the military is typically conducted for number of officers from various units/sections of the NAF in various formations across the states of the Federation. The NAF has metrics and processes for measuring performance. The value is usually between 0 – 9 for performances on the ground and in the air. Typically the combined quantitative and qualitative performance scores from the past and present records of the personnel are used in the selection and appraisal process. In order to combine such mixed performance scores, human resource department first develops evaluation criteria and establish relative weighting among them. For example, performance indices such as past position/education, awards, and organization contribution are assigned to experience, job expertise, and miscellaneous categories. Based on the metrics and relative weighting, the headquarters convenes a promotion board to conduct promotion appraisal [8]. The evaluation indices are determined and finally the officers to be promoted are selected.

The selection of evaluators and aggregation of individual evaluators' appraisal results influence the final scores of performance evaluation. Problems could occur

when there is an overly influential member in the evaluators group, or when a particular evaluator assigns evaluation results that are too high or low compared to the average scores. Some organisations avoid such problems by excluding the maximum and minimum scores from the final performance evaluation results [9].

However, this method requires many evaluators. Also, it is not clear how to remove data points when multiple evaluators ascribe identical maximum or minimum scores. Therefore, an improved approach is necessary, one that uses all performance evaluation data without removal of evaluation results [8].

In this paper, an approach that uses fuzzy logic concept for multi-criteria evaluation in the group decision making of NAF promotion exercise is presented. Fuzzy logic handles the concept of partial truth i.e. values between the two extremes. Fuzzy logic measures the ambiguity of events that have already occurred and it is implemented in several areas such as fault analysis, decision making etc [10]. Fuzzy logic provides a very valuable flexibility for reasoning, which makes it possible to take into account inaccuracies and uncertainties. One advantage of fuzzy logic is that rules are set in natural language [11]. Fuzzy logic possesses the ability to mimic the human mind to effectively employ modes of reasoning that are approximate rather than exact. With fuzzy logic it is possible to specify mapping rules in terms of words rather than numbers. Fuzzy logic provides the opportunity for modeling conditions that are inherently imprecisely defined. Fuzzy techniques in the form of approximate reasoning provide decision support and expert systems with powerful reasoning capabilities [12].

The approach makes it possible to rank the performance of officers using a multiple criteria decision system. Table 1 shows the key performance criteria for promotion in the NAF.

TABLE 1. KEY PERFORMANCE CRITERIA FOR PROMOTION SCREENING

Key Performance Criteria	**Performance Indices**
Personal Qualities	Sense of duty Loyalty Integrity Example Presence Truthfulness
Leadership	Power to inspire Power to command Discipline Attitude toward subordinate
Ability	Determination Reliability Judgement Initiative
Multi-area aptitude	Creativity Organisational contribution Management capability Achievement Job expertise Team work

II. THE FUZZY MODEL

The model is derived using fuzzy sets and fuzzy logics. Fuzzy sets and fuzzy logics are preferred because of the imprecise nature of required input data. The fuzzy logics provide convenient way to map an input space into an output space. Fuzzy set does not have crisp, clearly defined boundary. The elements of a fuzzy set are partitioned and the membership values (degree of membership) between 0 and 1 are determined. In fuzzy logic, the truth of any statement becomes a matter of degree from those documents [13]. A fuzzy set has 3 principal properties:

i. The range of values over which the set is mapped.
ii. The degree of membership axis that measures a domain value's membership in the set.
iii The surface of the fuzzy set which are the points that connect the degree of membership with the underlying domain [10].

In order to apply fuzzy analysis, there are three basic steps:

i. Fuzzification of the inputs
ii. Fuzzy inference
iii. Defuzzification of obtaining crisp output.[EECS]

For fuzzification, we need to have fuzzy set for each input. The fuzzy set contains values for linguistic variable. Once a fuzzy set is defined, for each variable there has to be calculated degree of membership for every input [14].

A fuzzy inference system defines a nonlinear mapping of the input data vector into a scalar output using fuzzy rules. The mapping process involves input/output membership functions, fuzzy operators, fuzzy if-then rules, aggregation of output sets and defuzzification [15]. A fuzzifier maps input numbers into corresponding fuzzy membership. This is required in order to activate rules that are in terms of linguistic variables. The fuzzifier takes input values and determines the degree to which they belong to each of the fuzzy set via membership function [16].

III. MODEL DERIVATION

TABLE 2. VARIABLE DESCRIPTION

Promotion parameters	**Criterion**	**Purpose**	**Measurable parameters**	**Fuzzy maximum aggregate Value expected from each evaluator (*i*)**
$Q_{j,r}$	Personal Qualities	Provides the personal qualities of the officer (*j*) for the applied rank (*r*)	Sense of duty ($Q_{j,s}$) Loyalty ($Q_{j,l}$) Integrity ($Q_{j,i}$) Example ($Q_{j,e}$) Presence ($Q_{j,p}$)	$\alpha_i = 0.3$

			Truthfulness ($Q_{j,t}$)	
$L_{j,r}$	Leadership	Represents officer's (j) leadership qualities for the applied rank (r)	Power to inspire ($L_{j,i}$) Power to command ($L_{j,c}$) Discipline ($L_{j,d}$) Attitude toward subordinate ($L_{j,s}$)	$\beta_i = 0.3$
$A_{j,r}$	Ability	Represents professional ability of officer (j) for the applied rank (r)	Determination ($A_{j,d}$) Reliability ($A_{j,r}$) Judgement ($A_{j,j}$) Initiative ($A_{j,i}$)	$\phi_i = 0.2$
$M_{j,r}$	Multi-area aptitude	Represents the general aptitude of the officer (j) for the applied rank (r)	Creativity ($M_{j,c}$) Organisational contribution ($M_{j,o}$) Management capability ($M_{j,m}$) Achievement ($M_{j,a}$) Job expertise ($M_{j,e}$) Team work ($M_{j,t}$)	$\lambda_i = 0.2$

Table 2 depicts the variable description for the promotion system.

j = represents a particular officer to be considered for appraisal

r = represents the rank an officer (j) applied for.

i = ranking/scoring of an officer (j) in each of the promotion parameters as returned by the evaluators/panelists. ($i = 1,2,3,.....,N$). Equations 1 – 4 below shows the union of the promotion parameters.

$$Q_{j,r} = \sum(Q_{j,s} + Q_{j,l} + Q_{j,i} + Q_{j,e} + Q_{j,p} + Q_{j,t}) \ldots\ldots. (1)$$

$$L_{j,r} = \sum(L_{j,i} + L_{j,c} + L_{j,d} + L_{j,s}) \ldots\ldots (2)$$

$$A_{j,r} = \sum(A_{j,d} + A_{j,r} + A_{j,j} + A_{j,i}) \ldots. (3)$$

$$M_{j,r} = \sum(M_{j,c} + M_{j,o} + M_{j,m} + M_{j,a} + M_{j,e} + M_{j,t} \ldots\ldots\ldots (4)$$

$\alpha_i(Q_{j,r})$ = is the fuzzy function that returns the weight of an officer (j)'s Personal Qualities awarded by one of the evaluators (i)

$\beta_i(L_{j,r})$ = is the fuzzy function that returns the weight of an officer (j)'s Leadership Qualities awarded by one of the evaluators (i)

$\emptyset_i(A_{j,r})$ = is the fuzzy function that returns the weight of an officer (j)'s Ability awarded by one of the evaluators (i)

$\lambda_i(M_{j,r})$ = is the fuzzy function that returns the weight of an officer (j)'s Multi-area aptitude awarded by one of the evaluators (i)

The fuzzy functions $\alpha_i(Q_{j,r})$, $\beta_i(L_{j,r})$, $\emptyset_i(A_{j,r})$ and $\lambda_i(M_{j,r})$ are obtained by applying fuzzy rules using fuzzy inference methods.

The Performance Appraisal and Promotion Ranking System (PAPRS) Model is:

$$P_{j,r} = (\sum_{i=1}^{N} \alpha_i(S_{j,r}) + \sum_{i=1}^{N} \beta_i(A_{j,r}) + \sum_{i=1}^{N} \phi_i(G_{j,r}) + \sum_{i=1}^{N} \lambda_i(I_{j,r})) / N \ldots\ldots (5)$$

Then, $P = \{P_{j,r}\}$ is the universal set containing performance of all officers applying for promotion

Let x = fuzzy set of performances from officers selected/recommended for promotion.

The membership function $\mu_x(P_{j,r})$ gives the degree of membership of an officer j's performance ($P_{j,r}$) in the set of selected/recommended for promotion x : $0 \leq \mu_x(P_{j,r}) \leq 1$

Thus, using the characteristics or discrimination function, For any given set x, this function assigns a value $\mu_x(P_{j,r})$ to every $(P_{j,r}) \in P$

$$\mu_x(P_{j,r}) = \begin{cases} 1 & f\ (P_{j,r}) \in \text{x (Highly Qualified)} \\ \geq 0.5 & f\ (P_{j,r}) \in \text{x (Qualified)} \ldots. (6) \\ < 0.5 & f\ (P_{j,r})\ \notin \text{x (Not Qualified)} \end{cases}$$

The function maps elements of the universal set to the set containing 0 and 1.

That is, $\mu_x : P \rightarrow \{0, 1\}$

1 means full membership (Highly Qualified), 0.5 and above means graded membership (qualified) and 0 means no membership (Not Qualified)

The fuzzy inference method applies approximate reasoning method. Fuzzy inference takes inputs, applies fuzzy rules and produce outputs. Fuzzy rules deal with fuzzy values e.g highly qualified, qualified, not qualified etc., these fuzzy concepts are usually represented by their membership functions. A membership function shows the extent to which a value from a domain is included in a fuzzy concept [17], [18].

For the Performance Appraisal and Promotion Ranking System (PAPRS), by applying fuzzy inference method based on fuzzy logic, an officer (j) and his chance of qualifying for promotion in a given rank (r) can be determined. A fuzzy rule defines the degree of the officer's suitability for promotion in a given rank (r) depending on the nature of the personal qualities, leadership qualities, ability and general aptitude he has.

IV. THE PAPRS FUZZY RULES

A. For the Personal Qualities

Rule: IF the weight/grade of an officer (for a particular rank) in the promotion parameter
'Personal Qualities' is at least two-third of the total weight for that parameter
THEN the chance of qualifying for promotion in that rank (*r*) is high.

B. For the Leadership

Rule: IF the weight/grade of an officer (for a particular rank) in the promotion parameter
'Leadership' is at least two-third of the total weight for that parameter
THEN the chance of qualifying for promotion in that rank (*r*) is high.

C. For the Ability

Rule: IF the weight/grade of an officer (for a particular rank) in the promotion parameter
'Ability' is at least half of the total weight for that parameter
THEN the chance of qualifying for promotion in that rank (*r*) is high.

D. For the Aptitude

Rule: IF the weight/grade of an officer (for a particular rank) in the promotion parameter
Multi-area Aptitude' is at least half of the total weight for that parameter THEN the chance of qualifying for promotion in that rank (r) is high.

The process of combining output fuzzy sets into a single set is called aggregation, a process that unifies the output of all the rules. Aggregation takes all fuzzy sets that represent the output for each rules and combines them into a single fuzzy set that is used as input into the defuzzification process [19]. The final step is defuzzification used to obtain crisp output from numbers obtained during fuzzy inference [14]. This step allows to switch from the fuzzy set resulting from aggregation of results to a single decision [11]. The input to the defuzzification process is a fuzzy set, the aggregate output fuzzy set, and the output of the defuzzification process is a single number [16].

V. THE PAPRS DE-FUZZIFICATION PROCESS

An officer (*j*) for promotion is then classified to be qualified or not qualified for promotion based on the value of his or her performances ($P_{j,r}$). Then those officers with performance values ($P_{j,r}$) between 0.5 and 1, will automatically be included in the list of 'Recommended for Promotion' which is then sent to the appropriate authority for ratification and promotion.

Figure 1 is the system model diagram for the PAPRS. The PAPRS is a four (4) input, one (1) output, three (3) rule system as shown in Figure 1. The inputs are crisp (non-fuzzy) value limited to a specific range. All rules are evaluated in parallel using fuzzy reasoning. The results of the rules are combined and distilled (defuzzified). Finally, the result is a crisp value.

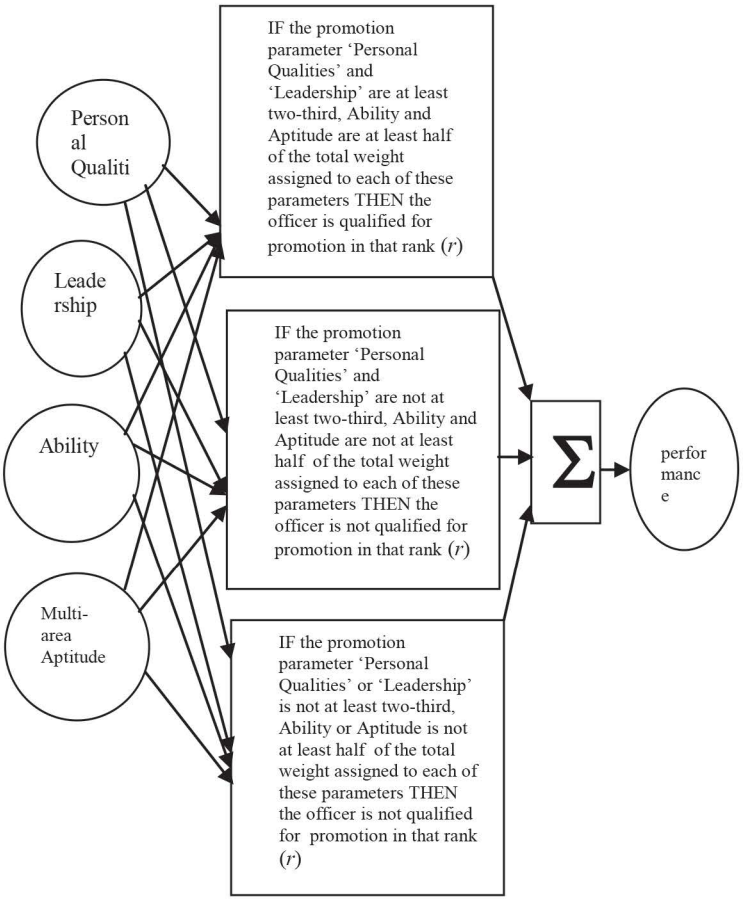

Fig. 1. System model diagram

VI. PAPRS OVERALL SYSTEM DESIGN

Figure 2 depicts the overall system structure. The system receives as inputs from the users (grades or scores from evaluators/assessors) – an officer's scoring in the four promotion parameters (personal qualities, leadership, ability and multi area aptitude) and evaluates the data gathered by matching it with the requirements for promotion and finally generates result or take decision on whether the officer is qualified for promotion or not.

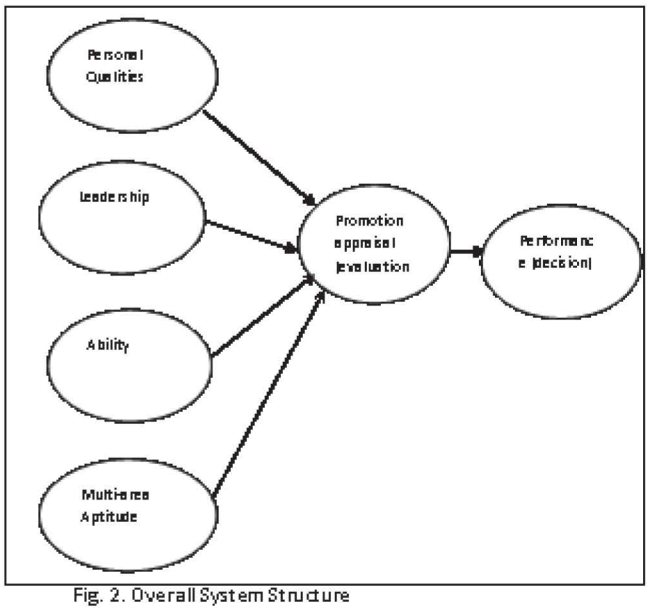

Fig. 2. Overall System Structure

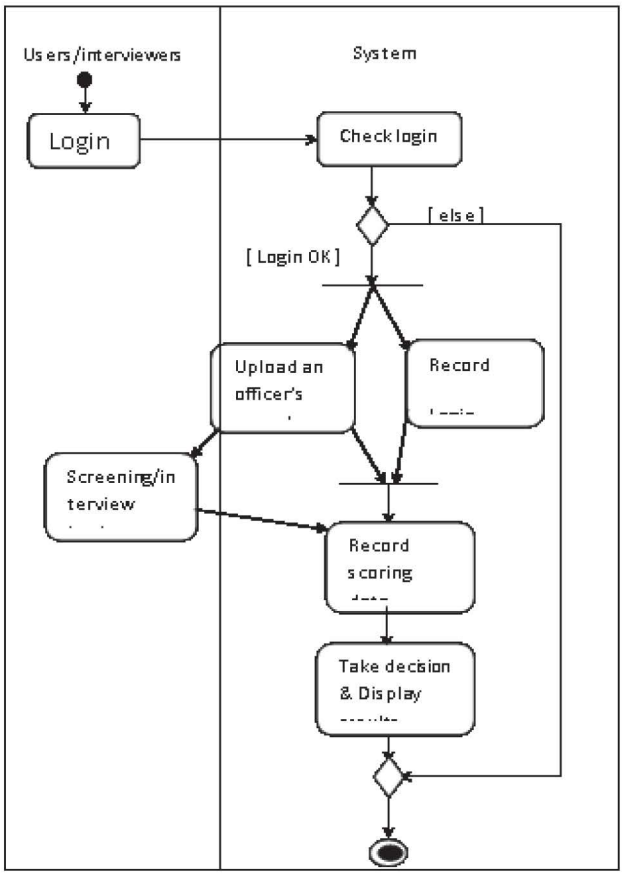

Fig. 3.Activity diagram of the PAPRS [20]

VII. PAPRS ACTIVITY DIAGRAM

Figure 3 is the activity diagram of the PAPRS. Activity diagram depicts the activity and the event that causes the object to be in the particular state [11]. It describes the workflow behaviour of a system.

The sequence of activities within the PAPRS is clearly illustrated in the UML activity diagram shown in Figure 3. The activity diagram shows the workflow from the start to the finished point detailing the many parts that exist in the progression of events contained in the system.

III. PAPRS IMPLEMENTATION TECHNOLOGY

The technological approach for the development of the PAPRS is an integration of web technology, database technology and programming technology, using open source solution (Apache, MySQL and PHP) running on Windows or Linux operating system. The technological tools are chosen because of their enormous advantages over other platforms as attested, that open source programs are better because [21]:

- They are free
- They are cross-platform and 'technology neutral'
- They must not restrict other software
- They embrace diversity

V. THE PAPRS

The PAPRS is a proposed web-enabled system currently being developed using all the technological tools above, by carefully following well design structures. It consists of four modules – system Admin, User Admin, database unit and reports. It is hoped that the system will be adopted by the NAF after the system testing stage.

VI.CONCLUSION

This research indeed has successfully proposed a customized PAPRS model for the Nigerian Air Force. The fuzzy system model obtained using fuzzy logic as specified in the PAPRS diagram is currently being developed using the open source solution (Linux, Apache, PHP, MySQL) and can also run on windows platform.

Further research on PAPRS should focus on expanding the model to accommodate similar processes for other law enforcement agencies within the country.

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