Performance Appraisal System – Using a Multistage Fuzzy Architecture

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Abstract—**The evaluation of employee's performance is the most important and probably the most complicated task for every supervisor or manager working in any organization. Performance appraisal is intended to improve overall performance of organization by engaging and aligning each employee.**

Performance Appraisal (PA) provides a basis for identifying and correcting disparities in employee's performance. PA may also provide the basis for other personnel actions like bonus pay, training & career development, promotion & placement, recognition & rewards and disciplinary actions, its success depends primarily on the system and measures (criteria), work culture, the attitudes and involvement of participants in PA process. PA process may include various stages like planning, monitoring, development, rating and reward. In the whole process probably 'rating' is the most important and crucial steps which involves human judgment and perception which inherently leads to the vagueness in taking decision or Fuzzy decisions. This paper proposes stage-wise fuzzy reasoning model for performance rating.

Keywords: Performance Appraisal (PA), Critical Element, Rating, Fuzzy, Stage wise Fuzzy Reasoning.

I. INTRODUCTION

Performance Appraisal System's planning and development [1] involves finding critical elements which in best way can reflect employee's performance to meet organization's goal.

In order to better understand how fuzzy reasoning approach can help in designing a better PA system, a study of prevailing system of performance appraisal for workers working at various US government and state government organization like US-DOI [2] and State of Hawaii [3] was carried out. Performance categories or critical elements shown in Table 1 are considered as a minimum for worker's PA, however other elements are also added depending on job requirement and organizations need. Each element is rated on a scale of 0-5 as follows,

Unsatisfactory = 0, Minimally Successful =2, Full Successful=3, Superior=4, Exceptional=5

Traditional Non-Fuzzy Approach would evaluate overall rating of an employee as follows:
Overall Rating = Total Numerical Rating / No. of Elements

Table 1 - Traditional Non Fuzzy Approach

Critical Element	Element #	Numerical Rating
Quality of work	1	
Quantity and Timeliness of work	2	
Reliability and Initiative	3	
Relationship with others	4	
Safety and use of Equipment	5	
	Total	

Overall performance rating is then decided based on the rules shown in Table 2.

Table 2 - Overall Rating -Traditional Non Fuzzy Approach

Exceptional	4.6 ~ 5
Superior	3.6 ~ 4.59
Fully Successful	3.0 ~ 3.59
Minimally Successful	2.0 ~ 2.99
Unsatisfactory	< 2

The paper is organized as follows: Section I gives background of traditional non fuzzy approach to performance analysis. Section II explains traditional fuzzy approach and proposed stage wise fuzzy approach to performance appraisal system. Section III includes design of Stage-wise fuzzy logic model using Matlab software. Section IV shows the simulation

model and results of Fuzzy Logic model using Matlab-Simulink software. Section V and VI includes conclusion and references used in this paper, respectively.

II. FUZZY REASONING APPROACH

Traditional Fuzzy Based Approach would evaluate overall rating using all inputs (critical elements or fuzzy linguistic variables) that relates to single output (overall rating) using simple if then rules. Figure 1 shows a typical fuzzy approach block diagram.

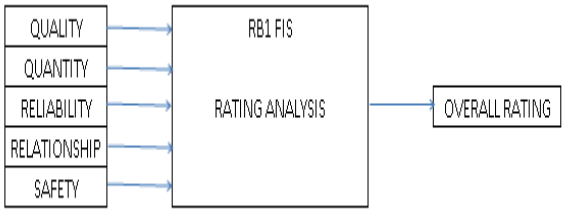

Figure 1 Traditional Fuzzy Approach

The approach in Figure 1 considers all inputs together and generates far too many rules. Also it is difficult for the expert to consider all aspects and formulates rules with proper emphasis. Sometime organizations may also weigh some factor like safety over quality and quantity or any other element. In that case the whole process will become very complex. Since each input parameter have five linguistic values (Unsatisfactory-U, Minimally Successful-MS, Full Successful-FS, Superior-S, Exceptional-E).
Hence, PA system with just five critical elements will have a maximum number of 5^5 =3125 rules.

This means, implementation using Matlab – Fuzzy Tool Box is not practical and one has to write a program using high level programming language like C++ since Matlab limits the number of inputs that you show to two.

So the solution lies in Stage wise fuzzy reasoning approach described in the following section which reduces rules by dividing the whole system into various fuzzy inference stages [4, 7] which effectively evaluate an overall performance of an employee. This solution will make it possible to use Matlab since we limit each stage to two inputs.

Stage-wise Fuzzy Reasoning

If we look at the critical elements mentioned in Table 1 then we can see that elements like quality and quantity reflect employee's ability to perform 'work'. Reliability & Initiative and Relationship with others reflects employee's 'attitude', however 'safety' relates to rules and regulation requirement. With this understating, critical elements can be broadly grouped [8] as in Table 3.

Table 3 Grouping of Elements

Group	**Critical Element**
Work Related	Quality, Quantity of Work
Person's Attitude Related	Reliability, Relationship
Regulations Related	Safety

Hence performance analysis can be divided into multiple thought process.

'Quality of work' and 'Quantity of work' are used in fuzzy reasoning to determine intermediate parameter 'work' as shown in figure 2.

Similarly, 'Reliability' and 'Relationship' are used in fuzzy reasoning to determine intermediate parameter person's 'attitude' as shown in figure 2.

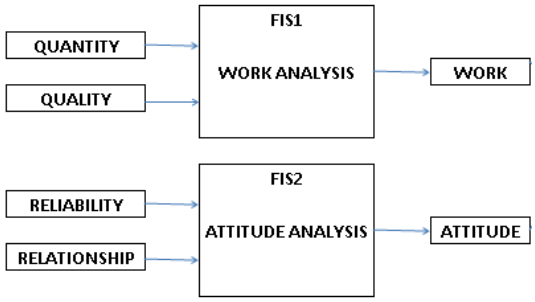

Figure 2 Stage-wise Fuzzy Approach

Both 'work and 'attitude' are combined in second stage to build work – attitude analysis which is then finally combined with regulatory requirement like 'safety' generate overall performance rating as shown in figure 3.

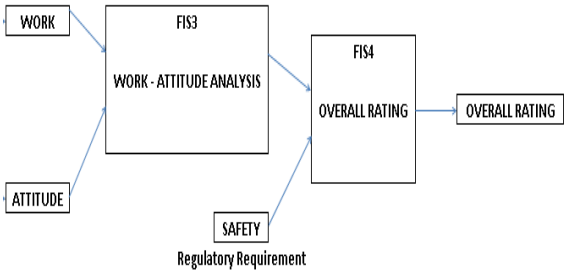

Figure 3 Stage-wise Fuzzy Approach

In this multi stage approach, management will have flexibility to give different degree of support (weight) to different performance groups (e.g. safety can have highest influence) in the appraisal rating.

III. DESIGN OF MULTI STAGE FUZZY LOGIC MODEL USING Matlab

As shown in figure 2 and figure 3, total four Fuzzy Inference Systems (FIS) namely FIS1, FIS2, FIS3 and FIS4 are crated in Matlab using Fuzzy Logic Toolbox [5].

Input/output variables and their member ship functions are defined and fuzzy control rules are created for each FIS.

Step 1: Defining Universe of Discourse and fuzzification of Critical Elements:
Each of the five identified input parameters (Critical Elements: Quality, Quantity, Reliability, Relationship, and Safety) have been given a universe of discourse (UOD) of [0 5] and have been fuzzified with five linguistic values (fuzzy sub sets: Unsatisfactory-U, Minimally Successful-MS, Full Successful-FS, Superior-S, Exceptional-E) using linear triangular membership functions [6].

Two examples of fuzzified input parameters quality and quantity are shown in figure 4.

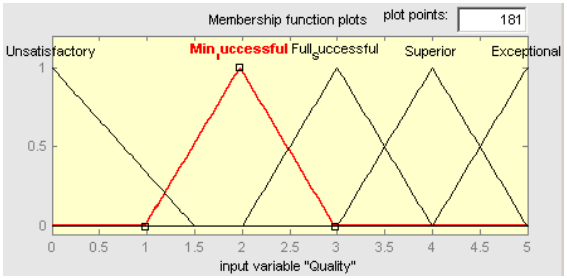

Figure 4.a Fuzzified input parameter - Quality

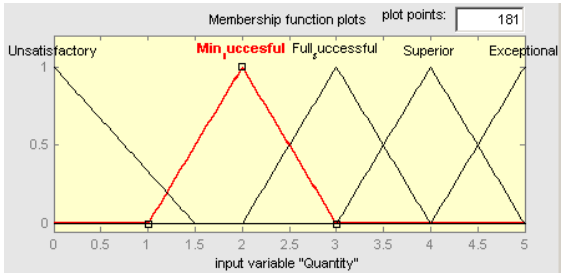

Figure 4.b Fuzzified input parameter – Quantity

Step 2: Defining fuzzy control rules: Fuzzy control rules are defined as follows:

Fuzzy controller FIS1 (Refer to figure 2)
Quality and Quantity are the fuzzy input variables and 'Work' is the fuzzy output variable. Fuzzy linguistic values of the input and output variables are set at {U, MS, FS, S, E}. Table 4 shows the fuzzy control rules. The rules are defined based on personal experience and organization's strategy.

Table 4 Fuzzy control rules for FIS1

Work		Quantity of Work				
		U	MS	FS	S	E
Quality of Work	U	$U_{1.0}$	$U_{1.0}$	$U_{1.0}$	$U_{1.0}$	$U_{1.0}$
	MS	$U_{1.0}$	$MS_{0.5}$	$MS_{0.6}$	$MS_{0.8}$	$MS_{1.0}$
	FS	$U_{1.0}$	$MS_{0.6}$	$FS_{0.5}$	$FS_{0.8}$	$S_{1.0}$
	S	$U_{1.0}$	$MS_{0.8}$	$S_{0.8}$	$S_{1.0}$	$E_{0.8}$
	E	$U_{1.0}$	$MS_{1.0}$	$S_{1.0}$	$E_{0.8}$	$E_{1.0}$

As seen from the table above, there are total eighteen rules and each rule is given different Degree of Support (DOS) to clearly identify importance of each rule in rating analysis [7] e.g if the rating for 'Quality of work' is 'unsatisfied' than irrespective of rating for 'Quantity of work', overall rating for 'work is 'unsatisfactory' and has highest priority. A surface viewer for FIS1 is shown in figure5.

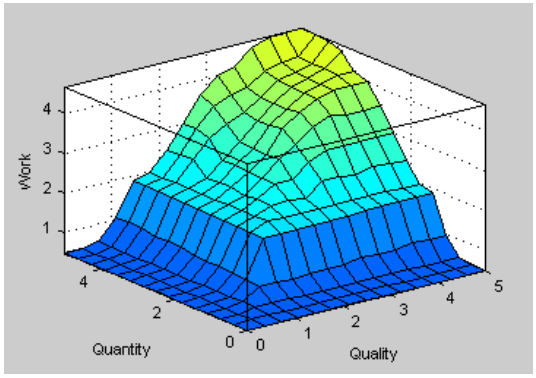

Figure 5 Surface Viewer for FIS1

Fuzzy controller FIS2 (Refer figure 2)
Relationship and Reliability are the fuzzy input variables and 'Attitude' is the fuzzy output variable. Fuzzy linguistic values of input and output variables are set at {U, MS, FS, S, E}. Table 5 shows fuzzy control rules, the rules are defined based on personal experience and organization's strategy.

Table 5 Fuzzy control rules for FIS2

Attitude		Reliability				
		U	MS	FS	S	E
Relationship	U	$U_{1.0}$	$MS_{0.2}$	$MS_{1.0}$	$FS_{0.8}$	$FS_{1.0}$
	MS	$U_{1.0}$	$MS_{0.4}$	$FS_{0.8}$	$S_{0.6}$	$S_{0.8}$
	FS	$U_{1.0}$	$MS_{0.6}$	$FS_{1.0}$	$S_{0.8}$	$S_{1.0}$
	S	$U_{1.0}$	$MS_{0.8}$	$S_{0.8}$	$S_{1.0}$	$E_{0.8}$
	E	$U_{1.0}$	$MS_{1.0}$	$S_{1.0}$	$E_{0.8}$	$E_{1.0}$

Each rule is given different DOS [7] to clearly identify importance of each rule in rating analysis e.g if 'Reliability' is 'unsatisfied' than irrespective of rating for 'Relationship', overall rating for 'Attitude' is unsatisfactory. A surface viewer for FIS2 is shown in figure 6.

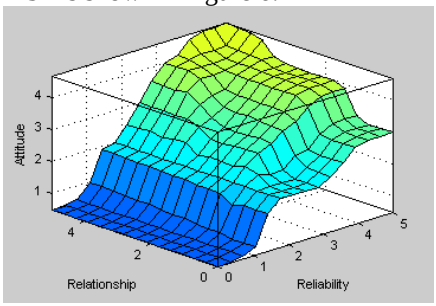

Figure 6 Surface Viewer for FIS2

Fuzzy controller FIS3 (Refer figure 3)
This is an intermediate stage fuzzy controller, output variables 'Work' and 'Attitude' of FIS1 and FIS2 respectively are taken as an input variables and 'Work Attitude' is an output variable. Fuzzy linguistic values of input and output variables are set at {U, MS, FS, S, E}. Table 6 shows fuzzy control rules, again the rules are defined based on personal experience and organization's strategy.

Table 6 Fuzzy control rules for FIS3

Work - Attitude		Work				
		U	MS	FS	S	E
Attitude	U	$U_{1.0}$	$U_{1.0}$	$MS_{1.0}$	$FS_{0.8}$	$FS_{1.0}$
	MS	$U_{1.0}$	$MS_{0.4}$	$FS_{0.5}$	$FS_{1.0}$	$S_{1.0}$
	FS	$U_{1.0}$	$MS_{0.6}$	$FS_{0.6}$	$S_{0.6}$	$E_{0.6}$
	S	$U_{1.0}$	$MS_{0.8}$	$FS_{0.8}$	$S_{0.8}$	$E_{0.8}$
	E	$U_{1.0}$	$MS_{1.0}$	$FS_{1.0}$	$S_{1.0}$	$E_{1.0}$

Different DOS [7] is used to identify importance of rules. A surface viewer for FIS3 is shown in figure 7.

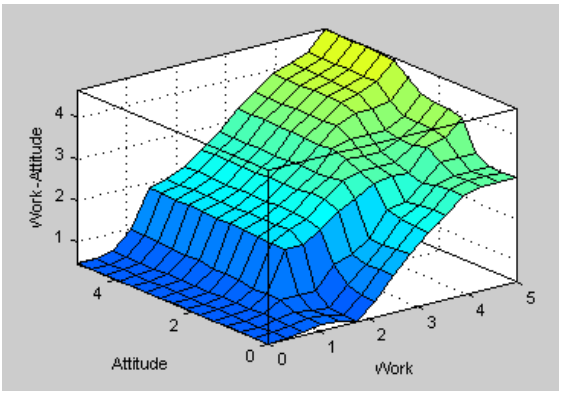

Figure 7 Surface Viewer for FIS3

Fuzzy controller FIS4 (Refer figure 3)
This is the final stage fuzzy controller. An output variable 'Work-Attitude' of FIS3 and an independent variable 'Safety' are taken as an input variables and 'Overall rating' of employee's performance is an output variable. Table 7 shows fuzzy control rules. Again the rules are defined based on personal experience and organization's strategy.

Table 7 Fuzzy control rules for FIS4

Overall Rating		Work - Attitude				
		U	MS	FS	S	E
Safety	U	$U_{1.0}$	$U_{1.0}$	$U_{1.0}$	$U_{1.0}$	$U_{1.0}$
	MS	$U_{1.0}$	$MS_{0.6}$	$MS_{1.0}$	$FS_{0.8}$	$FS_{1.0}$
	FS	$U_{1.0}$	$MS_{1.0}$	$FS_{1.0}$	$FS_{1.0}$	$S_{0.8}$
	S	$U_{1.0}$	$FS_{0.8}$	$S_{0.8}$	$S_{1.0}$	$E_{0.8}$
	E	$U_{1.0}$	$FS_{1.0}$	$S_{1.0}$	$E_{0.8}$	$E_{1.0}$

Here, one can observe that safety has been given the highest importance and if rating for 'safety' is 'unsatisfactory' then 'Overall Rating' is 'unsatisfactory' no matter how well employee has performed on 'Work-Attitude' analysis. A surface viewer for FIS4 is shown in figure 8.

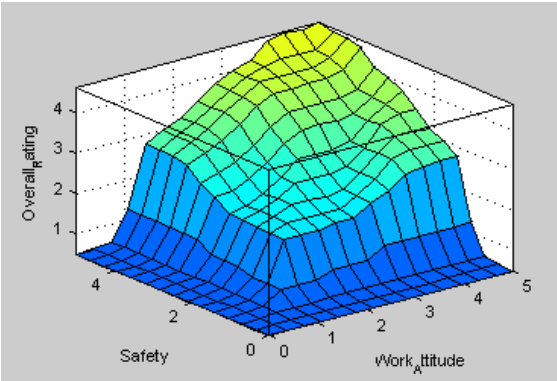

Figure 8 Surface Viewer for FIS4

IV. SIMULATION OF MULTI STAGE FUZZY MODEL FOR PERFORMANCE APPRASAL SYSTEM

Model for proposed stage wise fuzzy reasoning was developed in Matlab Simulink software (Fuzzy Logic Toolbox). Fuzzy Logic controller was used to link FIS1, FIS2, FIS3 and FIS4. A fully functional fuzzy logic model is shown in figure 9.

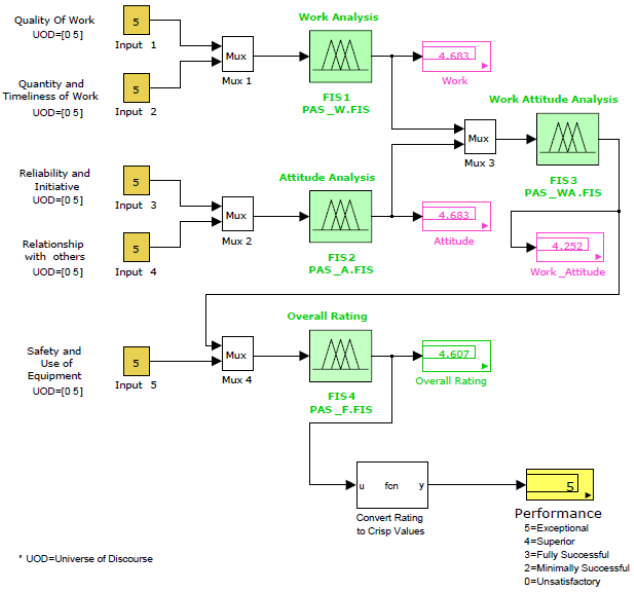

Figure 9 Stage wise Fuzzy Reasoning - Simulink Model

Results of various simulations for different sets of critical element ratings are shown in Tables 8, 9 and 10 as follows:

Table 8 Simulation data set 1

Critical Element	Rating	Stage wise Fuzzy model output				Final Rating
		Work	Attitude	WA	Overall	
Quality	5	4.68		4.25	4.6	5 Exceptional
Quantity	5					
Reliability	5		4.68			
Relationship	5					
Safety	5					

Traditional non fuzzy approach to rating in the Table 8 would rate employee performance as 5 (Exceptional). However consider the scenario in Table 9 where safety element is rated to 3. Here traditional non- fuzzy approach would rate employee to 4.6 (Exceptional) whereas fuzzy reasoning approach would rate employee to 3 (successful) because 'safety' is given more weight over other elements.

Table 9 Simulation data set 2

Critical Element	Rating	Stage wise Fuzzy model output				Final Rating
		Work	Attitude	WA	Overall	
Quality	5	4.68		4.25	3.27	3 Full Successful
Quantity	5					
Reliability	5		4.68			
Relationship	5					
Safety	3					

Now look at the rating data in table 10 where traditional non fuzzy approach would rate employee to 4 (Superior). Here, manager may apply his judgmental skill and would try to rate employee to lower rating. Whereas the result of fuzzy reasoning approach clearly shows that employee's overall rating is 0 (unsatisfactory).

Table 10 Simulation data set 3

Critical Element	Rating	Stage wise Fuzzy model output				Final Rating
		Work	Attitude	WA	Overall	
Quality	1	0.73		0.56	0.53	0 Unsatisfactory
Quantity	4					
Reliability	5		4.68			
Relationship	5					
Safety	5					

Analyzing Relative Performance of an Employee Using Similarity Measures

Once the performance rating is done using traditional non fuzzy approach, next step in the process would be to analyze

the performance data and analyze how different employees have performance relative to each other.

This analysis will help management to determine cut out level for the employee eligible for reward, bonus pay or promotions.

Fuzzy relations can help organizations to analyze relative performance of an employee. There are two most prevalent similarity methods to develop fuzzy relation matrix 1) Cosine Amplitude and 2) Max-Min Method [6].

For the sake of simplicity of calculation we will use Max-Min similarity method to develop fuzzy relations.

A performance matrix for typical case of five employees may look like Table 11.

Table 11 A performance matrix

	E1	E2	E3	E4	E5
Quality of work	4	5	2	4	3
Quantity	5	4	4	5	3
Reliability	5	4	5	5	5
Relationship	5	5	3	3	4
Safety	5	5	5	3	5

Normalizing above values will give us following matrix,

Table 12 A normalized performance matrix

	E1	E2	E3	E4	E5
Quality of work	0.8	1	0.4	0.8	0.6
Quantity	1	0.8	0.8	1	0.6
Reliability	1	0.8	1	1	1
Relationship	1	1	0.6	0.6	0.8
Safety	1	1	1	0.6	1

We will use following equation, to find out relation matrix using Max-Min method [9].

$$r_{ij} = \frac{\sum_{k=1}^{m} \min(x_{ik}, x_{jk})}{\sum_{k=1}^{m} \max(x_{ik}, x_{jk})}, \quad \text{where } i, j = 1, 2, \ldots, n$$

----- (1)

n = 5 = Total numbers of employee.
i, j = 1,2,…., n=5
m= Number of critical elements = 5,
$r_{i,j}$ = Result of pair wise comparison of two employees
x_i, x_j = Performance set of employee

Now applying equation 1 to Table 12 will give us following tolerance relation matrix (Table 13).

Table 13 Tolerance relation matrix using Max-Min Similarity Method

	E1	E2	E3	E4	E5
E1	1	0.88	0.79	0.83	0.83
E2	0.88	1	0.75	0.72	0.79
E3	0.79	0.75	1	0.77	0.86
E4	0.83	0.72	0.77	1	0.74
E5	0.83	0.79	0.86	0.74	1

Analyzing the above matrix will tell how one employee has performed relative to other employees.

1 = Most Similar Performance
0 = Most Dissimilar Performance

For example, from the first row of Table 3, it is obvious that relative to employee E1, Employee E3 is the most dissimilar performer (0.79). Also Employees E4 & E5 have similar performance (0.83) with respect to E1.

Similarly other comparison analysis can be derived.

V. CONCLUSION

The Performance Appraisal System can be designed on two fuzzy approaches. The first approach that is traditional fuzzy approach consists of five linguistic fuzzy input variables (critical elements) that map to one single fuzzy output variable without any intermediate fuzzy reasoning and uses too many rules. The second approach classifies the critical elements with their relevance and uses fuzzy logic in multi

stage approach. Looking at the simulation data, the stage wise fuzzy reasoning has more logical approach to performance analysis. Also, organizations have flexibility to give different important factor to different critical element as per organizational goal.

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