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Full Length Research Paper

Aggregating group MCDM problems using a fuzzy Delphi model for personnel performance appraisal

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Personnel performance appraisal is a tool towards achieving organization goals. Its main focus is to increase the abilities, merits and growth of personnel. We looked at the personnel performance appraisal as an element of group decision making model in which personnel are evaluated from different points of view. A fuzzy Delphi method and linguistic terms represented by triangular fuzzy numbers were applied to bring out qualitative and quantitative attributes and assess attributes weights and relative importance of evaluation group's viewpoints. We developed MCDM models for group personnel performance appraisal. All the known MCDM methods have their own advantages and drawbacks and therefore yield different results based on their various techniques. As a consequence, we presented a model for aggregation of the results of MCDM models.

Key words: MCDM, personnel performance appraisal, aggregation, fuzzy Delphi, group decision.

INTRODUCTION

Performance appraisal is an important element in the human resource management system of any organization, both private and public. To channel employees' abilities and efforts to match organizational expectations, organizations should develop a good performance appraisal system that can measure employees' performance with reasonable accuracy, provide employees with feedback on their performance, and give opportunities to employees to correct their weaknesses (Dresang, 1999). Without good performance appraisal systems, managers risk making wrong personnel decisions and adversely affecting organizations' capacity. Good performers may not receive adequate positive feedback and become frustrated and leave, causing the organization to incur high recruitment costs (Bonnie and Mann, 2002). Performance researchers have suggested that satisfaction with the appraisal process is important because it may affect future performance and job satisfaction (Daily and Kirk, 1992; Deming, 1986). Furthermore, there is evidence that perceptions of ineffective performance appraisal may be associated with job turnover (Daily and Kirk, 1992 cited in Lilley and Kinduja, 2007).

Performance appraisal is a human resource management tool that has received much attention for more than seven decades (Landy and Farr, 1980). Formal performance appraisals have been used as inputs to salary adjustments, promotions, training and other decisions that influence employee attitudes and behaviors. As a result, designing appropriate appraisal systems has been a major concern for researchers. Traditionally, the validity and reliability of performance appraisals were the focus of performance appraisal research (Bretz et al., 1992). More recently, researchers have begun to focus on the fairness of the performance appraisal process; because performance in many positions is not objectively measurable, raters are cognitively limited and there is little agreement on what constitutes good performance (Folger et al., 19 92). Then the development of fair performance appraisals has been accepted as a more achievable goal. Therefore, assessing the justice perceptions of rates has become a useful way of evaluating the success of a performance appraisal system (Erdogan et al., 2001).

Performance appraisal systems are widely believed to have high potential to enhance organizational functioning (Cascio, 1991; Gilliland and Langdon, 1989). Among other things, they provide information that can be used for decisions about pay and promotions, identification of training and development needs, criteria for the development and validation of selection systems and documentation of performance levels or behaviors that may merit firing or sanctions.

Unfortunately, both academic and practitioner accounts suggest that many employees are substantially dissatis-

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fied with and reject, the performance appraisal process as it has been implemented in their own organi-zations (Bernardin et al., 1998; Ilgen, 1993; Meyer, 1991). For example, a recent survey of almost 50,000 organizational respondents by Washington D.C.-based consulting firm People IQ (2005) indicated that only 13% of employees and managers, and only 6% of CEOs, believe that their organization's current performance appraisal system is useful (Elicker et al., 2006). The presented study has tended to look at the personnel performance appraisal as an element of a group decision making model in which personnel are evaluated from different points of view, (boss, colleagues, inferior, employee him/herself and customer etc.) The study uses a four section format including a general background; Section 2 describes literature and enumerates some of the common problems with already existing decision making models; Section 3 proposed a new approach by using a fuzzy Delphi method and linguistic terms represented by triangular fuzzy numbers were applied to bring out qualitative and quantitative attributes and assess attribute weights and relative importance of evaluation group's viewpoints. We also extended Topsis, linear assignment, Electre and Borda; so the models were considered as group decision making models. Finally we presented a model for aggregation of the results of the MCDM models. Case study and proposed model are presented; Section 4 talks about the findings and results of the study.

LITERATURE REVIEW

Decision making describes the process through which, the solution of certain problems can be chosen (Hwang and Yoon, 1995). Most important decisions in organizations are made by groups of managers or experts. Managers spend much of their time in decision related meetings (Huber, 1984). Balancing tradeoffs between objecttives is even more important in groups than for individuals, because conflicting objectives and opposing viewpoints are inevitably going to exist. Sycara (1991) presented a framework for problem restructuring based on the goals and goal relationships of the negotiating parties, recognizing this multiplication of goals. Decision making groups can range from cooperative with very similar goals and outlooks, to antagonistic with diametrically opposed objectives. Even in cooperative groups, conflict can arise during the decision process (Poole et al., 1991). If group members have different viewpoints, some method of aggregating preferences and reconciling differenttces are needed. MCDM methods have been developed to solve conflicting preferences among criteria for single decision makers (Corner and Kirkwood, 1991; Keeney and Raiffa, 1976; Korhonen et al., 1984; Saaty, 1980).

In today's world most of the problems that are presented to managers for decision making and even daily problems of each of us, have various dimensions and are formulated with several variants. In other words, we can not make the final decision with optimizing a variant. It is clear that solving these problems is complicated and is not easily possible; especially that most of these variants are contrary to each other and an increase in one of them can cause desirability in the other (Jung, 2001). Using the opinions of several people that take decision instead of one person, of course, causes many intricacies in analyzing on decisions that not only is because of access to collective agreement in ranking of alternatives, but also because of another act like possible differences between members who take group decisions and possible different objectives and criteria that they have (Fletcher, 2001). Multiple attribute decision making (MADM) problems are commonly encountered in everyday aspect of life. They aim at selecting the optimal alternative among some courses of action in the presence of multiple, usually conflicting, attributes (Tsu et al., 2004). A general background on MADM problems can be found in Hwang and Yoon (1981) and (1995) and many eminent references are also given there. Almost all MADM problems require the corresponding decision weight of each attribute, indicating its relative importance. The weights can be prespecified by the decision makers directly or determined by using the Eigen vector method, the weighted least square method, the LINMAP method, the extreme weight approach, the entropy method, e.t.c. There are a great number of weight assessment techniques available (Chen and Hwang, 1992).

Every MADM problem has some attributes that should be recognized by decision makers in due courses. The Delphi study is a method for structuring a group communication process so that the process is effective in allowing a group of individuals to deal with complex problems as a whole (Delbecq et al., 1975). Delphi is primarily a communication device, which is applied when the consensus of experts on an uncertain issue is desired (Linstone and Turoff, 1975). The method consists princepally of knowledgeable and expert contributors completing a form individually and their submitting the results to a central coordinator. The coordinator processes the contributions, looking for central and extreme tendencies and rationales. Then, the results are given as feedback to the respondent group, who are asked to resubmit their views, assisted by the "new" input provided by the coordinator. The Delphi method is successfully used in technical and business related evaluation systems and has a methodical advantage compared to other group discussion methods due to anonymity of experts and avoidance of the dominance of singular opinions (Kenis, 1995). The evaluations made by the experts rely on their individual competence and are subjective, so it is more appropriate to present the data by fuzzy numbers instead of crisp numbers (Buyukozkan, 2004). Fuzzy methods have been developed owing to imprecision in assessing the relative importance of attributes and the performance ratings of alternatives with respect to attributes. Imprecision may arise from a variety of reasons: unquantifiable, incomplete and unobtainable information and partial ignorance. Conventional MADM methods cannot effectively handle problems with such imprecise information. Fuzzy set theory attempts to select prioritize or rank a finite number of courses of action by evaluating a group of predetermined criteria (Gumus 2008). It was formulated, around 30 years ago, by Lotfi Zadeh. A fuzzy set presents a boundary with a gradual contour, by contrast with classical sets, which presents a discrete border. Let U be the universe of discourse and u a generic element of U, then U = {u}. Fuzzy subset Ã, defined in U, is:

Ã= {(u, μÃ(u)) | u, U}.

Where μÃ(u) is designated as membership function or membership grade (also designated as degree of compatibility or degree of truth) of u in Ã. The membership function associates with each element u, of U, a real number μÃ (u), in the interval [0, 1]](Mario 2000). A fuzzy number is a special fuzzy set F= {(x,μF (x), x∈R}, where x takes its values on the real line, R: −∞≤ x ≤∞ and μF(x) is a continuous mapping from R to the closed interval [0,1]. A traingular fuzzy number expresses the relative strength of each pair of elements in the same hierarchy and can be denoted as M = (l, m, u), where l ≤ m ≤ u. The parameters l; m; u; indicate the smallest possible, most promising, and the largest possible values respectively in a fuzzy event. Triangular type membership function of M fuzzy number can be described as in Equation 1. When l=m=u, it is a nonfuzzy number by convention (Onut et al., 2008).

$$\mu M(x)=\begin{cases} 0, & x < l \\ (x-l)/(m-l) & l \le x \le m \\ (u-x)/(u-m) & m \le x \le u \\ 0, & x > u \end{cases} \qquad (1)$$

The main operational laws for two triangular fuzzy numbers M1 and M2 are as follows (Kaufmann et al., 1991):

M1 + M2 = (l1 + l2, m1 + m2, u1 + u2),

M1 × M2 = (l1 × l2, m1 × m2, u1 × u2), (2)

ω × M1 = (ωl1, ωm1, ωu1), ω>0, ω∈R,

M_1^{-1} = (1/u1, 1/m1, 1/l1).

Defuzzification

The result of fuzzy Delphi is a fuzzy number. Therefore, it is necessary that the nonfuzzy method for fuzzy numbers be employed. In other words, defuzzification is a technique to convert the fuzzy number into crisp real numbers; the procedure of defuzzification is to locate the best nonfuzzy performance (BNP) value. There are several available methods to serve this purpose: mean-of-maximum, center-of-area, and α-cut methods (Zhao and Govind, 1991 cited in Tsaura et al., 2002). This study utilizes the center-of-area method due to its simplicity and because it does not require an analyst's personal judgment. The defuzzified value of fuzzy number can be obtained from Equation 3.

$$BNP_{ij}=[(UE_{ij}-LE_{ij})+(ME_{ij}-LE_{ij})]/3+LE_{ij} \quad \forall i,j \qquad (3)$$

Fuzzy Delphi method, introduced by Kaufmann and Gupta (1988), is more suitable than the Delphi method in the real world. Fuzzy Delphi method has been applied by a few researchers (Chang, 2000): The fuzzy Delphi method via fuzzy statistics and membership function fitting and its application to human resources (Buyukozkan, 2004), multiple criteria decision making for e-market place selection (Liang, 2006), constructing performance appraisal indicators for mobility of service industries using Fuzzy Delphi method (Kuo and Chen, 2008) constructing performance appraisal indicators for the mobility of service industries using Fuzzy Delphi method (Yang, 2008) and the six-sigma project selection using national quality award criteria and Delphi fuzzy multiple criteria decision-making methods.

Attribute and assessors group views weights

All MADM methods require information that should be gained based on relative importance of the attribute. This information usually has a serial or main scale. Attribute weights can be allocated to criteria directly by decision makers or by scientific methods and usually is done in uncertain and vague spaces. These weights specify relative importance of every attribute. Usually groups are classified based on their different levels in social status, knowledge and work experience. So every factor that causes an increase or decrease of idea weight should be considered. In this regard, allocating different weight to one's opinion regarding his knowledge and experience related to the subject seems necessary.

Aggregation of opinions by G matrix

One of the important points at personnel performance appraisal in a group is the amount of their correct viewpoints. In this regard every one's idea may have special importance. In these cases the group matrix compilations are calculated as follows:

$$\bar{g}_{ij}=\left[\prod_{p=1}^{N}(r_{ij})^{w_p}\right]^{1/N} \begin{cases} P & \text{Personal} \\ i=1,\ldots,m & \text{Alternative} \\ j=1,\ldots,n & \text{Attribute} \\ w & \text{Decision maker Viewpoint} \end{cases} \qquad (4)$$

So: $\sum W_p = N$

Technique for order preference by similarity to ideal solution (TOPSIS)

The TOPSIS method was developed by (Hwang and Yoon, 1981).This method is based on the concept that the chosen alternative should have the shortest Euclidean distance from the ideal solution and the farthest from the negative ideal solution. The ideal solution is a hypothetical solution for which all attribute values correspond to the maximum attribute values in the database comprising the satisfying solutions; the negative ideal solution is the hypothetical solution for which all attribute values correspond to the minimum attribute values in the database. TOPSIS thus gives a solution that is not only closest to the hypothetically best, but is also the farthest from the hypothetically worst. The main procedure of the TOPSIS method for the selection of the best alternative from among those available is described by Asgharpour (1992), Hwang and Yoon (1981) and Kiran and Agrawal (2008).

Linear assignment

In this method, each alternative priority at every attribute is used to achieve a Zero-One Programming model and through the solution of this model, all alternatives will be ranked. The main procedure of the linear assignment method for the selection of the best alternative from among those available is described by Asgharpour (1992), Azar (2002) and Hwang and Yoon (1981).

Elimination et choice translating reality (Electre)

This method is established based on outranking concept and the results of this method are based on repertory ranking. In this method $A_P \longrightarrow A_q$ alternatives, *p* and *q* do not have priority on each other but decision maker accepts priority of A_p to A_q. The main procedure of the Electre method for the selection of the best alternative from among those available is described by Asgharpour (1992), Azar (2002), Hwang and Yoon (1981) and Karni et al. (1990).

Borda method

The "method of marks" voting procedure proposed by the French scientist Jean-Charles de Borda (1733–1799) in Paris in 1781represents an important step in the develop-ment of modern electoral systems and indeed in the theory of voting more generally (Reilly, 2002). In this method every decision maker (DM) already ranks alternatives based on per attribute and then noting a heavy matrix of group agreement, inlieu of *n* rank gained by *m* alternative, will get to zero-one programming model to solve it and attain all alternative ranks. The main procedure of the Borda method for the selection of the best alternative based on group agreement from among those available is described by Asgharpour (20 03). In this research project, every decision maker gives preferences to per alternative based on every attribute. In multiple attribute group decision making by interval scale for qualitative attributes and relative scale for quantitative attributes, Euclidean conversion is used to make r_{ij} dimensionless as follows (Asgharpour 2003):

$$r_{ij(p)} = \frac{r_{ij(p)}}{\sqrt{\sum_{i=1}^{m} (r_{ij(p)})^2}} \begin{cases} m=i,\dots,1 & \text{Alternative} \\ n=j,\dots,1 & \text{Attribute} \\ k=p,\dots,1 & \text{Decision maker} \end{cases} \quad (5)$$

Step 1: Consider the proper value (DM weights) of every decision making group member idea.

$$N_{ijw}=N_{ij}\times w_k \quad (6)$$

N_{ij} is an element for privileges dimensionless matrix for per DM and w_k is the weight of per DM idea.

Step 2: A *n* matrix was formed, while the rows of matrix are alternatives and its columns are DM opinions. So an *n* matrix in lieu of *n* attribute was established, (R_j).

Step 3: The linear sum would be reached in lieu of *P* decision maker and the final grade of every alternative in lieu of an attribute will be calculated. In this matrix the line with the highest mark is the first rank and the line with the lowest mark is *m* rank.

$$\left(\sum_{p=1}^{N} r_{ij} \right) \quad (7)$$

Step 4: *QG* matrix will be worked out based on supposed *w* vector (attributes weights); the rows of the matrix show alternatives and the columns represent order, and elements of the matrix are the sum of the weights of each alternative calculated based on its rank attained in the attribute sets.

Step 5: Alternatives will be classified based on resulting matrix from earlier step and each transportation or zero-one programming methods.

$$\begin{aligned} Max \quad & w = \sum_{i=1}^{m} \sum_{j=1}^{m} \gamma_{ij} Y_{ij} \\ S.T \quad : \; & \sum_{i=1}^{m} Y_{ij} = 1 \\ & \sum_{j=1}^{m} Y_{ij} = 1 \\ & Y_{ij} = \begin{cases} 1 \\ 0 \end{cases} \end{aligned} \quad (8)$$

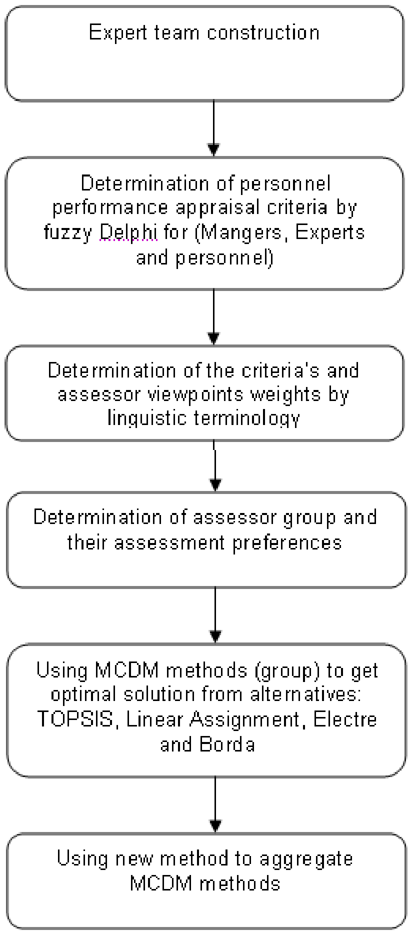

Figure 1. The performance appraisal procedure.

PROPOSED METHODOLOGY (PERSONNEL PERFORMANCE APPRAISAL ALGORITHM)

Decision making models for improving or solving a problem need to propose alternatives (solutions or scenarios) and decision making attributes. These attributes and alternatives in most cases should be distinguished by judge of experts at the beginning and before making decision (Hwang and Yoon, 1995). The implementation of the proposed methodology has six stages shown in Figure 1. The model assumes that a set of experts for a decision problem is identified first. Next a set of assessment criteria will be nominated by these group members for three assessment criteria by group MCDM methods. The final group decision is made through the aggregation method.

Empirical study

This study was performed in the Iran Energy Efficiency Organization active in the field of energy consumption optimizing in Iran.

At the first stage, an expert team of 21 including vice managers, middle managers, organization experts and personnel from different department was formed.

At the second stage using the fuzzy Delphi method with its five stages, the criteria of personnel performance appraisal were determined by a committee for each organization's department for the three groups: managers, experts and personnel (Table 1).

At the third stage, let *u* equal to 1. Thus, the evaluation can be a precise number ranging from 0 to 1, a range of numerical values defined by any two numbers between 0 and 1, a fuzzy linguistic variable, or a triangular fuzzy number. The fuzzy linguistic variable has triangular membership functions as defined in Table 2. The traingular membership function is shown in Figure 2.

Next, the expert team (comprising five experts from the technical department) determines weight importance of the criteria and weight importance of the assessor's viewpoints by using linguistic terms. Table 3 depicts the triangular fuzzy numbers that match linguistic equivalents of numerical data for technical department.

After obtaining the performance measures in terms of fuzzy numbers, we defuzzified the fuzzy numbers into crisp numbers, using the center-of-area method as Equation 3 to defuzzy the fuzzy numbers (Table 4).

We obtained criteria weights like the assessor group weights by applying triangular fuzzy numbers.

In the next stage P1, P2, P3, P4 and P5 alternatives are allocated to 5 middle managers from technical department being assessed by four different assessors (boss, colleague, inferior, employee him/herself).

At the fifth stage individual judgments given by each assessor was converted to normalized data matrix, using Equation 5. Then by using Equation 4 and assessor's group weights in Table 4, we considered the value of group assessor viewpoint and yield the group matrix G (Table 5). For example the first element of matrix G was calculated as follows:

$$\bar{g}_{11} = (g_{11}^{W1} \times g_{11}^{W2} \times g_{11}^{W3} \times g_{11}^{W4}) =$$
$$(0.484^{0.320} \times 0.472^{0.254} \times 0.524^{0.242} \times 0.41^{0.175}) = 0.497$$

TOPSIS method: Regarding the group matrix $G_{m\times n}$ shown in Table 5, the input title for weighted normalized data matrix $V = G_{m\times n} \cdot W_{n\times n}$ and the continuation of TOPSIS algorithm method, alternatives were classified based on assessor group (Table 6).

A set of alternatives are generated in descending order in this step, according to the value of Cli indicating the most preferred and least preferred feasible solutions. A higher value of Cli is preferred:

P3 >> P1 >> A4 >> P2 >> P5

Linear assignment method: We ranked alternatives by using group matrix G shown in Table 5 based on per attributes (Table 7).

Table 1. The qualitative and quantitative criteria of mangers for technical department.

Criteria	Linguistic variable				
	Very Low	Low	Middle	High	Very High
Organizing					
Proper decision making					
Punishment and reward					
Creativity and innovation					
Presenting good suggestions for organization promotion					
Good conduct toward colleagues and customers					
Considering ethics and morals					
Responsibility and accountability					
Optimum resource allocation					
Up to date Information and knowledge					
Creating suitable job environment (win-win)					
Training, learning and growth					
Experience					
Education					
Enthusiasm					
Intelligence					
Writing and speaking eloquently					
Planning					
Leadership					
Controlling					
Number of articles					
Criticism openness					
Merit basis					
Problem solving					
Goal setting ability					
Mastery in foreign languages					
Number of publications					
Number of presentations					
Organization loyalty					
Coordinating					
Perseverance					
Proper expectation from inferior					
Active and effective participation in the meetings					

Alternatives were ranked by using Table 7 and the continuation of the linear assignment algorithm and the solution of zero-one programming:

P2>>P4>>P1>>P3>>P5

Electre method: Using attribute weights vector and group matrix G shown in Table 5, dimensionless matrix was achieved:

$V = G_{m\times n} \cdot W_{n\times n}$

Relative preferences of alternatives were achieved using Table 8 and the continuation of Electre algorithm model:

P3>>P1~P2>>P4~P5

Borda method: Individual judgments given by each assessor were converted to normalized data matrix, using Equation 5. We considered the correct idea value (DM weights based on Table 4) of every decision making group member based on (Equation 6) and formed *n* matrix where the rows of matrix are alternatives and its columns are DM opinions according to each attribute. So we had *n* matrix in lieu of *n* attribute (Table 9). The linear sums were reached using Equation 7 and final rank of every alternative in lieu of attribute was calculated. In this

Table 2. The triangular fuzzy numbers for personnel performance appraisal.

Linguistic variable	Membership function
Very Low (VL)	(0.0, 0.0, 0.25)
Low (L)	(0.0, 0.25, 0.5)
Middle (M)	(0.25, 0.5, 0.75)
High (H)	(0.5, 0.75, 1.0)
Very High (VH)	(0.75, 1.0, 1,0)

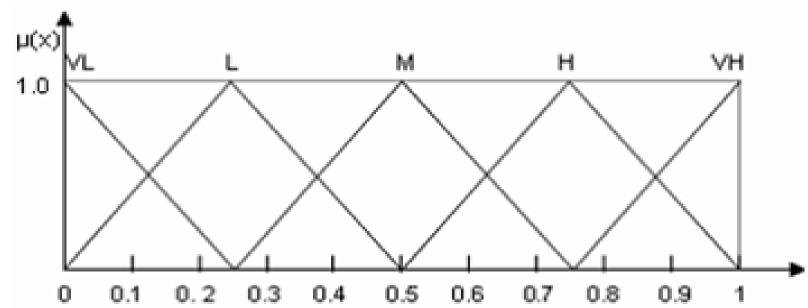

Figure 2. The triangular fuzzy membership function for personnel performance appraisal.

matrix, the row with the highest total received the first rank and the row with the lowest sum, least rank.

Considering the supposed *w* vector (attributes weights) and continuing the Borda algorithm method, alternatives were classified based on zero-one programming method:

$$Max: 0/0737h_{11} + 0/4284h_{12} + ... + 0/5714h_{55}$$

$$S.T \ : \sum_{i=1}^{5}\sum_{j=1}^{5} h_{ij} = 1$$

$$\sum_{j=1}^{5}\sum_{i=1}^{5} h_{ij} = 1$$

$$h_{ij} = 0,1$$

P3>>P1>>P4>>P2>>P5

The aggregated MCDM methods: Hwang and Yoon's book, one of the important MADM methods references, suggested ranking by several techniques and then taking their average to resolve differences between decision making techniques. In intense different cases, averaging results possibly neutralizes differences and the final answer may be invalid (Ghazinorie and Tabatabaiean, 2002). Therefore, in the present model, the alternatives ranking by different techniques were converted into Borda count, that is personnel were evaluated via four methods:

TOPSIS: S1 = P3 >> P1 >> P4 >> P2 >> P5

Linear Assignment: S2 = P2>>P4>>P1>>P3>>P5

Electre: S3 = P3>>P1~P2>>P4~P5

Borda: S4 = P3>>P1>>P4>>P2>>P5

as shown in Table 10.

We divided *S3* into two parts to resolve the node as shown in Table 11.

Then we created a matrix with its rows as MCDM methods and its columns, as the ranks. The elements of the matrix show alternatives as shown in Table 12.

Step 2: We proposed a matrix called "S" with its rows showing alternatives and its' columns MCDM methods. S matrix was filled out paying attention to each alternative's rank in each MCDM methods (Table 13).

Step 3: Change each column of S matrix into Borda count, that is alternative with first rank would have m-1 relative value by P alternatives and the alternative with second rank, m-2 relative value. In the same way, alternatives with m rank would receive zero relative values. So it converts an interval scale into a kind of relative scale and makes addition feasible (Table 14).

Step 4: Obtaining total sum of the rows of S matrix. The alternative sum with the highest value would be considered

Table 3. Fuzzy performance measurement of assessor group done by experts.

Expert Team	Assessors			
	Manager	Colleagues	Inferior	Employee him/herself
Expert 1	VH	M	M	VL
Expert 2	VH	H	M	M
Expert 3	VH	VH	H	M
Expert 4	H	H	H	M
Expert 5	VH	M	H	H
Expert 1	0.75,1,1	0.25,0.5,0.75	0.25,0.5,0.75	0,0,0.25
Expert 2	0.75,1,1	0.5,0.75,1	0.25,0.5,0.75	0.25,0.5,0.75
Expert 3	0.75,1,1	0.75,1,1	0.5,0.75,1	0.25,0.5,0.75
Expert 4	0.5,0.75,1	0.5,0.75,1	0.5,0.75,1	0.25,0.5,0.75
Expert 5	0.75,1,1	0.25,0.5,0.75	0.5,0.75,1	0.5,0.75,1

Table 4. Defuzzifying the performance measures of assessor group.

Expert Team	Assessors			
	Manager	Colleagues	Inferior	Employee him/herself
Expert 1	0.92	0.5	0.5	0.083
Expert 2	0.92	0.75	0.5	0.5
Expert 3	0.92	0.92	0.75	0.5
Expert 4	0.75	0.75	0.75	0.5
Expert 5	0.92	0.5	0.75	0.75
Total	40.43	30.42	30.25	20.333
Weight	0.320	0.254	0.242	0.175

Table 5. Group matrix G aggregation.

Gm×n	X1	X2	X3	X4	X5	…X33
P1	0.4973	0.4730	0.3953	0.4811	0.4153	0.3934
P2	0.4071	0.4224	0.419	0.3535	0.4514	0.4438
P3	0.5099	0.4878	0.4826	0.5347	0.5046	0.4936
P4	0.4392	0.4316	0.448	0.4623	0.4594	0.4164
P5	0.3622	0.3884	0.3812	0.3335	0.3133	0.4431

Table 6. Relative closeness to the ideal solution.

	P1	P2	P3	P4	P5
Cli^+	0.4632	0.3725	0.8165	0.4511	0.3559

Table 7. Alternatives Rank based on each attribute.

	X1	X2	X3	X4	X5	…X33
P1	2	2	4	2	4	5
P2	4	4	3	4	3	2
P3	1	1	1	1	1	1
P4	3	3	2	3	2	4
P5	5	5	5	5	5	3

Step 1: Alternative ranking is based on different MCDM methods, so that a node is created in alternative ranking considered as the first rank and the lowest represents the last rank. The ranks obtained in step 4 are in fact final rank for all the MCDM methods used (Table 15).

Conclusion

Personnel evaluation is one of the most important and complicated aspects of human resource management. A new proposed personnel performance appraisal model was used in this study, in which personnel are evaluated from different points of view and evaluation errors are minimized.

Table 8. Matrix V.

Gm×n	X1	X2	X3	X4	X5	…X33
P1	0.0173	0.0171	0.0132	0.0144	0.0124	0.0139
P2	0.0149	0.0152	0.014	0.0106	0.0135	0.0125
P3	0.0186	0.0176	0.0162	0.016	0.0151	0.0173
P4	0.016	0.0156	0.015	0.0138	0.0137	0.0168
P5	0.0132	0.014	0.0128	0.01	0.0094	0.0114

Table 9. Matrix (R_j) based on attribute X1.

R1-X1	D1	D2	D3	D4	∑	Ranks
P1	0.1555	0.119	0.1153	0.0848	0.4747	2
P2	0.1383	0.077	0.0922	0.106	0.4135	4
P3	0.1728	0.1401	0.1153	0.0848	0.513	1
P4	0.1383	0.119	0.0922	0.0901	0.4397	3
P5	0.1037	0.098	0.0692	0.0954	0.3663	5

Table 10. Node creation in alternative ranking.

S3	First	Second	Third	Fourth	Fifth
Electre method	P_3	P_1 , P_2	P_4 , P_5		

Table 11. Node development.

S3	First	Second	Third	Fourth	Fifth
Electre S31	P_3	P_1	P_2	P_4	P_5
Electre S32	P_3	P_2	P_1	P_5	P_4

Table 12. Matrix of MCDM methods and alternatives priority.

S	First	Second	Third	Fourth	Fifth
TOPSIS S_1=	P_3	P_1	P_4	P_2	P_5
linear S_2=	P_2	P_4	P_1	P_3	P_5
Electre S_{31}=	P_3	P_1	P_2	P_4	P_5
Electre S_{32}=	P_3	P_2	P_1	P_5	P_4
Borda S_4=	P_3	P_1	P_4	P_2	P_5

Table 13. Alternatives rank in MCDM method.

Alternatives \ Methods		S_1	S_2	S_{31}	S_{32}	S_4
	P_1	2	3	2	3	2
	P_2	4	1	3	2	4
S_p=	P_3	1	4	1	1	1
	P_4	3	2	4	5	3
	P_5	5	5	5	4	5

Table 14. Conversion of S matrix in to Borda count.

Alternatives \ Methods		S_1	S_2	S_{31}	S_{32}	S_4
	P_1	3	2	3	2	3
	P_2	1	4	2	3	1
S_P=	P_3	4	1	4	4	4
`	P_4	2	3	1	0	2
	P_5	0	0	0	1	0

Table 15. Final Ranking of aggregated MCDM.

	P_1	13		2
	P_2	11		3
$S_P=$	P_3	17		1
	P_4	8	$\Rightarrow$	4
	P_5	1		5

$P_3 >> P_1 >> P_2 >> P_4 >> P_5.$

Table 16. Comparison of pervious personnel performance appraisal, MCDM and proposed aggregation models.

Aggregated model	Methods					Previous assessment grade	Alternatives
	S4	S3	S2	S1	S1		
2	2	2	3	2	0.463	29.75	P_1
3	2	4	1	4	0.372	29.75	P_2
1	1	1	4	1	0.816	29.75	P_3
4	3	3	2	3	0.451	29.75	P_4
5	3	5	5	5	0.355	28	P_5

The proposed methodology was successfully applied to solve the personnel performance appraisal problem. We used fuzzy Delphi and linguistic terms represented by traingular fuzzy numbers to bring out qualitative and quantitative attributes and to assess attributes weights and relative importance of the evaluation group's viewpoints. The proposed approach offers a solution to the MCDM problem such as TOPSIS, linear assignment and Electre as group decision making models. We extended TOPSIS, linear assignment and Electre using aggregated matrix; so the models are considered group decision models. In Borda method, decision makers rank alternatives on the basis of each attribute; the increase in alternatives and attributes, makes the ranking of alternatives on the basis of each attribute very difficult. The proposed model solves this difficulty in that every decision maker gives his/her preference to each alternative based on every attribute and these data would be normalized later on. Considering the fact that the relative importance of assessors' viewpoints is not mentioned in the Borda method, the mentioned model solved this problem by using the relative importance of assessors' viewpoints after they were normalized thus, the obtained result seems to be more valid. All the known MCDM methods have their own advantages and drawbacks and yield different results because of the various techniques they use. In order to solve this problem, a new aggregated model was developed. The results of the newly developed aggregated model are compared with previous personnel performance appraisal models (the evaluation of the subordinate from a manager's point of view) (Table 16).

As can be seen in Table 16, previous assessment grade column (the evaluation of the subordinate from the manager's point of view), all alternatives are approximately equal except one; but in personnel performance appraisal using fuzzy Delphi method and triangular fuzzy numbers and group decision making models, the performance difference between the subjects under evaluation is the highest (P3) that is why we believe that mathematical models in performance appraisal are more accurate and efficient. The use of the newly presented aggregated model omits the differences between the results of decision making techniques (seen in S1, S2, S3 and S4) and the final result seems more valid.

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