

Fuzzy Logic for Automatically Performance Assessment Using CIOWA Model

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Abstract: STEKOM is an institution accommodating almost 500 employees, always evaluates their performance and gives award to them every year's end. Fuzzy logic is very suitable to be used in performance appraisal because it can process complex and variatif data as well as uncertain to be valid data. One of the models in fuzzy logic is the consistency induced ordered weighted averaging method system by reducing the operator averaging mean and assigning a consistency index value used to analyze fuzzy preference relationships, then using the results of the analysis in the preference aggregation process. This study will explain how to apply the consistency induced ordered weighted averaging model in fuzzy logic to assess the performance of STEKOM employees by assigning weight to each attribute and variable, then from the weights and variables will be rated according to the value obtained, so that, the decision will be taken as a solution in giving awards and promotions to employees that can meet the principles of fairness, equality and appropriateness.

Key words: Fuzzy, performance, assessment, CIOWA Model, STEKOM, principles of fairness

INTRODUCTION

Performance assessment is one of the decision making processes undertaken by corporate leaders by considering several criteria with a view to rewarding the employee's work (Palm, 2008). The decision-making process in the assessment is done by considering several alternative solutions that will be the final decision result, the assessment alternatives can be the final value of the employee along with the rank order or the final result of the rules and assessment guidelines that can be used to assess employee performance results (Pfaff *et al.*, 2013). The problems that arise are multi attribute data and the existence of uncertain data and will be used in the assessment of the performance of the work which can affect in decision making. To overcome this problem it can use fuzzy multi attribute decision making concept and here in after referred to as FMADM which is part of fuzzy logic (Karami and Johannson, 2014), this is caused by the concept of FMADM in fuzzy logic which has tolerance to data that is not exact or uncertain. The decision-making process can be done in a more flexible framework and one of them is directed to the ability to simulate a decision-making process with a vague consistency (Anamisa *et al.*, 2016).

In giving awards or promotion positions, STEKOM as an institution that accommodates nearly 500 employees

during this performance appraisal by manual process. The error of assigning a value to an attribute and error in the calculation manually can happen, thus, affecting the determination of the final decision result. The consistency induced ordered weighted averaging model hereinafter referred to as CIOWA in fuzzy logic or FMADM can be a solution to solve errors the CIOWA in FMADM will give weight to each attribute used to measure employee performance based on predetermined criteria (Chen, 2010). If each decision maker has the same degree and degree of importance, the CIOWA operator will be reduced to the averaging mean operator. Each decision maker will be given the authority to have a consistency index value obtained by analyzing the fuzzy preferences relation then using the results of the analysis on the preference aggregation process (Xu *et al.*, 2010) the decision making process can be as (Fig. 1).

Many criteria are considered in the assessment of employee performance in STEKOM, ranging from the quality and quantity of work, knowledge of the type of work, responsibilities in work, cooperation between employees in one department and one another, networking initiative and innovation, discipline of work integrity up to concern for safety and work safety. Each of the criteria will be assigned a value based on the specified weight, from the weighting and the value will be found some alternative solutions for the employee's

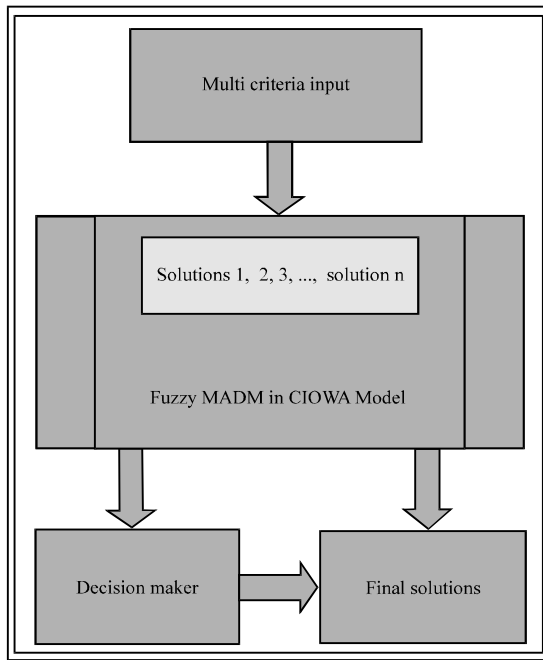


Fig. 1: Decision making process

performance appraisal. Some of these alternative solutions will be ranked based on the highest value through the FMADM process by using the CIOWA Model, so that, a best solution will be found from several emerging solution alternatives. From this solution decision makers or leaders STEKOM will determine the rewards that are tailored to the performance appraisal as well as promotion of office to employees.

MATERIALS AND METHODS

The research and development method (Mufadhol *et al.*, 2017a-e) becomes an option in developing this employee performance appraisal system as it involves directing several leaders from different departments as decision makers.

Fuzzy logic: The basis of fuzzy logic is the fuzzy set theory. In fuzzy set theory, the role of membership degree or membership function is the main characteristic of reasoning in fuzzy logic. Fuzzy logic is one of the components of soft computing (Pokoradi, 2010).

Variable fuzzy: In this research, fuzzy variable that will be used in employee performance appraisal system is employees.

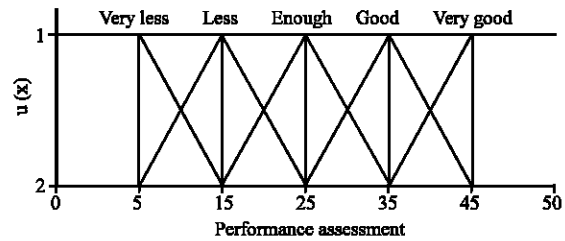


Fig. 2: Fuzzy set of employee variables

Fuzzy set: In the crisp set in fuzzy logic, the value of the membership of an item x in a set A and often written with the term $\mu_A[x]$ can be determined using the formula (Trillas *et al.*, 2009):

$$\mu[x] = \begin{cases} 0; & x \leq a \\ \frac{x-a}{b-a}; & a < x < b \\ 1; & x \geq b \end{cases}$$

Thus, the variable employees in the fuzzy set has 5 values, namely: less once, less, enough, good and excellents shown in Fig. 2.

The universe of discourse: The universe of speech is the total value that is allowed to be operated in a fuzzy variable. The universe of conversation is the set of real numbers that will always rise and increase monotonically from left to right. The universe of speech can be either positive or negative. There are times when the value of this universe of speech has no limit (Shenify and Mazarbhuiya, 2015). Universe talks for employee variables (0-50).

Domain: The fuzzy set domain is the whole value permitted in the universe of speech and can be operated in a fuzzy set (Othman *et al.*, 2008) fuzzy set domain used in this system is: very less = [0-15], less = [5-25], enough = [15-35], good = [25-45] and very good = [35-50] as in Fig. 2.

Fuzzy multi attribute decision making: Fuzzy multi attribute decision making which in short with the term FMADM is a combination of fuzzy logic and multi attribute decision making (Li, 2005). Fuzzy in multi attribute decision making is used to treat the attributes of an alternative that can not be presented completely and contains an element of uncertainty or inconsistency. In general, FMADM has a goal that can be classified into two types, firstly selecting alternatives with attributes that have the best and second characteristics will classify an alternative based on a specific role (Wang *et al.*, 2017).

FMADM resolves the problem by performing rankings, after the process of converting fuzzy data to crisp data. If fuzzy is given data in linguistic form, then data must first be converted to fuzzy form then converted again crisp number (Deni *et al.*, 2013).

Consistency induced ordered weighted averaging model: Consistency induced ordered weighted averaging model called CIOWA is problem solving if every decision maker that has the same degree of importance and is often referred to as homogeneous GDM. In such circumstances, the I-IOWA operator will be directed into an Averaging Mean (AM) operator. Each decision maker has a consistency index value obtained by analyzing the fuzzy preferences relation they provide, then using the result of that analysis on the preference aggregation process. The consistency problem is defined as a transitive additive, using the transitive additive characteristic can be established a consistent fuzzy relation relationship of the fuzzy preference relation is inconsistent (Dudziak and Pkala, 2011), using the formula:

$$P_{ij} = \begin{cases} P_{ij} \\ P_{ii+1} + P_{i+1+2}, \dots, P_{j-1j} + \frac{(i+1)j}{2}; j > i+1 \\ 1 - \hat{P}_{ij} \end{cases}$$

Reliable fuzzy preference relationships, \hat{P} obtained from $\hat{P} = f(\hat{P})$ distance between P^k and \hat{P}^k . The distance between can be used as a measure of matrix consistency P^k obtained from:

$$CI^k = d(P^k, \hat{P}^k) = \sqrt{\sum_{i=1}^n \sum_{j=1}^n (P_{ij}^k - \hat{P}_{ij}^k)^2}$$

When value $1 - CI^k$ getting closer to 1 indicates that the information provided by the decision maker to $-k, e^k$, more consistent.

RESULTS AND DISCUSSION

Assessment criteria and matching level: The employee performance appraisal will be conducted by involving many criteria, so that, the results will be obtained optimally and fair. The criteria used based on the data obtained from STEKOM will then be processed and will produce data in the form of degree of compatibility of each criterion that has been determined from each assessor. The rankings of employee performance appraisal results that have been ranked from the highest to the lowest will be based on the sum of weighted attributes that have been calculated with the concept of Fuzzy Multi Attribute Decision Making (FMADM) with problem solving using Consistency

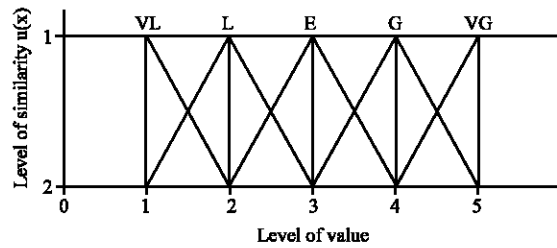


Fig. 3: Graph of weight level

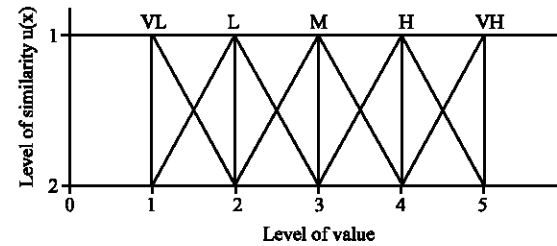


Fig. 4: Standard of the expected assessment

Induced Ordered Weighted Averaging (CIOWA) Model (Peker *et al.*, 2017). The criteria for assessment in the employee performance appraisal used will be adjusted to the STEKOM’s interests: quality of work (C1), quantity of work (C2), knowledge of employment (C3), responsibility (C4), cooperation (C5), network work (C6) initiative (C7), work discipline (C8) intergritas (C9), concern for safety and security (C10).

Importance rating and matching rating: The level of importance for criterion will be determined based on the weighted value assigned to the number and the matching of rating on alternative (assessor) for each criterion is: Very Less (VL) = 1, Less (L) = 2, Enough (E) = 3, Good (G) = 4 and Very Good (VG) = 5 as in Fig. 3.

And for its importance rating to be used as the standard of the expected assessment of each criterion is: Very Low (VL) = 1, Low (L) = 2, Medium (M) = 3, High (H) = 4, Very High (VH) = 5. The weight value can be shown in Fig. 4.

Based on the criteria and rating of each alternative fit (employee) on each criteria that have been determined, then the weighting of each of the criteria that have been converted with numbers. The criteria used in employee performance appraisal are as follows:

Quality of work (C1): The ability to complete its work in accordance with the quality standard that has been determined with interest rating: Very High (VH) in the Table 1.

Table 1: Rating of quality match of results of work

Quality of work	Values
Very less	1
Less	2
Enough	3
Good	4
Very good	5

Table 2: Rating match quantity of work results

Quantity of work	Values
Very less	1
Less	2
Enough	3
Good	4
Very good	5

Table 3: Rating of occupational knowledge match

Knowledge of the hasik work	Values
Very less	1
Less	2
Enough	3
Good	4
Very good	5

Table 4: Rating match of responsibility

Responsible	Values
Very less	1
Less	2
Enough	3
Good	4
Very good	5

Table 5: Rating match of cooperation

Cooperation	Value
Very less	1
Less	2
Enough	3
Good	4
Very good	5

Quantity of work (C2): The ability to produce or complete work according to, the given work load has an interest rating: Very High (VH) in Table 2.

Knowledge about work (C3): The employee's knowledge of his duties and work, has an interest rating: Very High (VH) in Table 3.

Responsibility (C4): The responsibility of the employee to the task that has become his work and has an interest rating: High (H) in Table 4.

Cooperation (C5): The ability to work collectively with colleagues with an interest rating: High (H) in Table 5.

Networking (C6): Is an understanding of all organizations related to their, respective ministries of interest rating: High (H) in Table 6.

Table 6: Rating match of networking

Networking	Values
Very less	1
Less	2
Enough	3
Good	4
Very good	5

Table 7: Rating match of initiative

Initiative	Values
Very less	1
Less	2
Enough	3
Good	4
Very good	5

Table 8: Rating match discipline of work

Discipline of work	Values
Very less	1
Less	2
Enough	3
Good	4
Very good	5

Table 9: Rating of integrity match

Integrity	Values
Very Less	1
Less	2
Enough	3
Good	4
Very good	5

Table 10: Rating of Safety and Security

Safety and security	Values
Very less	1
Less	2
Enough	3
Good	4
Very good	5

Initiative (C7): The ability to express ideas of importance rating: High (H) in Table 7.

Discipline of work (C8): The understanding and implementation of company regulations has an interest rating: High (H) in Table 8.

Integrity (C9): The desire to keep the values that exist in the company has an interest rating: High (H) in Table 9.

Caring for safety and security (C10): A concern for the implementation of work safety while maintaining a work culture that has become a workplace culture of rating importance: High (H) in Table 10.

Calculation process of problem solving: The determination and calculation of each attribute with the concept of FMADM by using the Consistency Induced Ordered Weighted Averaging (CIOWA) method which will be used as a reference in making a decision is to find

Table 11: Rating of matching in alternative criterion

Alternative	Rating result									
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
A1	G	E	E	G	G	G	E	G	VG	G
A2	G	G	E	E	E	E	E	G	G	E
A3	VG	G	G	G	G	G	G	C	G	G

Table 12: Rating of interests of each criteria

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Importance rating	VH	VH	VH	H	H	H	H	H	H	H

the C_i value, to determine the matching of each alternative on each criterion, make the decision based on the criteria (C_i), then perform the matrix normalization based on the equation which is adjusted to the type of attribute, so that, a normalized matrix R will be obtained. The final result is obtained from the ranking process that is by summing the matrix multiplication of normalized R with the weight vector to obtain the largest value chosen as the best alternative (A_i) as the last solution (Xu, 2014). Previously mentioned that there are several criteria that will be used in the process of employee performance appraisal which will be used as a reference in decision making. Each value assigned by each alternative in each criterion is a match value (the largest value is best), then all given criteria are assumed to be profit criteria. So, the equations used are:

$$CI^k = d(P^k, \tilde{P}^k) = \sqrt{\sum_{i=1}^n \sum_{j=1}^n (P_{ij}^k - \tilde{P}_{ij}^k)^2}$$

where R_{ij} is the normalized performance rating of alternative A1 on attribute C_j ; $i = 1, 2, \dots, m$ and $j = 1, 2, \dots, n$.

Weight and preference matches: The preferable value for each alternative (V_i) is given as an example for the employee performance appraisal process by employee name Djarot and as the first Appraiser (A1) = Mufadhoh, second Appraiser (A2) = Siswanto and third Appraiser (A3) = Maya. This performance appraisal will be completed using the FMADM concept with the CIOWA method on STEKOM and the three assessors have assigned the following values such as Table 11.

Where the management has determined the weight of preference (Standard Value) which is the interest rating as follows in Table 12.

Fuzzy preference matrix: The CIOWA Model in FMADM requires that the matrix value of the fuzzy preferences be consistent. A consistent matrix is required in determining the sum and matrix values normalized by

the weighted vector to obtain the largest value selected as the best alternative as a solution (Nadaban and Dzitac, 2016). Matrix formed from match table in employee performance appraisal as follows:

Matrix of matching table:

$$P^1 = \begin{bmatrix} 4 & 3 & 3 & 4 & 4 & 4 & 3 & 4 & 5 & 4 \\ 4 & 4 & 3 & 3 & 3 & 3 & 3 & 4 & 4 & 3 \\ 5 & 4 & 4 & 4 & 4 & 3 & 3 & 3 & 4 & 4 \end{bmatrix}$$

From the matrix can be done normalization matrix P^1 as follows:

$$\begin{aligned} \hat{P}_1^1 &= P_1^1 = 4, \hat{P}_2^1 = P_2^1 = 3, \hat{P}_3^1 = P_3^1 = 3, \\ \hat{P}_4^1 &= P_4^1 = 4, \hat{P}_5^1 = P_5^1 = 4, \hat{P}_6^1 = P_6^1 = 4, \\ \hat{P}_7^1 &= P_7^1 = 3, \hat{P}_8^1 = P_8^1 = 4, \hat{P}_9^1 = P_9^1 = 5, \\ \hat{P}_{10}^1 &= P_{10}^1 = 4, \hat{P}_{11}^1 = P_{11}^1 = 4, \hat{P}_{12}^1 = P_{12}^1 = 4, \\ \hat{P}_{13}^1 &= P_{13}^1 = 3, \hat{P}_{14}^1 = P_{14}^1 = 3, \hat{P}_{15}^1 = P_{15}^1 = 3, \\ \hat{P}_{16}^1 &= P_{16}^1 = 3, \hat{P}_{17}^1 = P_{17}^1 = 3, \hat{P}_{18}^1 = P_{18}^1 = 4, \\ \hat{P}_{19}^1 &= P_{19}^1 = 4, \hat{P}_{20}^1 = P_{20}^1 = 3, \hat{P}_{21}^1 = P_{21}^1 = 5, \\ \hat{P}_{22}^1 &= P_{22}^1 = 4, \hat{P}_{23}^1 = P_{23}^1 = 4, \hat{P}_{24}^1 = P_{24}^1 = 4, \\ \hat{P}_{25}^1 &= P_{25}^1 = 4, \hat{P}_{26}^1 = P_{26}^1 = 3, \hat{P}_{27}^1 = P_{27}^1 = 3, \\ \hat{P}_{28}^1 &= P_{28}^1 = 3, \hat{P}_{29}^1 = P_{29}^1 = 4, \hat{P}_{30}^1 = P_{30}^1 = 4 \end{aligned}$$

Thus, a consistent relation of fuzzy preferences can be obtained through a preferential relation fuzzy P^1 , so, it can be searched for value \hat{P}^1 use:

$$\begin{aligned} \hat{P}_1^1 &= P_1^1 = 4 \\ \hat{P}_2^1 &= P_2^1 = 3 \\ \hat{P}_3^1 &= P_2^1 + P_{13}^1 + \frac{1+1-3}{2} = 3+3-0.5 = 5.5 \\ \hat{P}_4^1 &= P_2^1 + P_{13}^1 + P_{24}^1 + \frac{1+1-4}{2} = 3+3+4-1 = 9 \\ \hat{P}_5^1 &= P_5^1 = 4 \\ \hat{P}_6^1 &= P_6^1 = 4 \\ \hat{P}_7^1 &= P_7^1 + P_{13}^1 + \frac{1+1-3}{2} = 3+3-0.5 = 5.5 \\ \hat{P}_8^1 &= P_8^1 + P_{13}^1 + P_{24}^1 + \frac{1+1-8}{2} = 4+3+4-3 = 8 \\ \hat{P}_9^1 &= P_9^1 = 5 \\ \hat{P}_{10}^1 &= P_{10}^1 = 10 \\ \hat{P}_{11}^1 &= 1 - P_2^1 = 1-3 = 2 \\ \hat{P}_{12}^1 &= P_{12}^1 = 4 \end{aligned}$$

$$\begin{aligned} \hat{P}_{13}^i &= P_{13}^i = 3 \\ \hat{P}_{14}^i &= P_{13}^i + P_{24}^i + \frac{2+1-4}{2} = 3+4-0.5 = 6.5 \\ \hat{P}_{15}^i &= 1-P_{11}^i = 1-4 = 3 \\ \hat{P}_{16}^i &= P_{16}^i = 3 \\ \hat{P}_{17}^i &= P_{17}^i = 3 \\ \hat{P}_{18}^i &= P_{18}^i + P_{24}^i + \frac{2+1-8}{2} = 4+4-2.5 = 5.5 \\ \hat{P}_{19}^i &= P_{19}^i = 4 \\ \hat{P}_{20}^i &= P_{20}^i = 3 \\ \hat{P}_{21}^i &= 1-P_3^i = 1-3 = 2 \\ \hat{P}_{22}^i &= 1-P_{13}^i = 1-3 = 2 \\ \hat{P}_{23}^i &= P_{23}^i = 4 \\ \hat{P}_{24}^i &= 1-P_4^i = 1-4 = 3 \\ \hat{P}_{25}^i &= 1-P_4^i = 1-3 = 2 \\ \hat{P}_{26}^i &= P_{24}^i = 4 \\ \hat{P}_{27}^i &= 1-P_5^i = 1-4 = 3 \\ \hat{P}_{28}^i &= 1-P_{15}^i = 1-3 = 2 \\ \hat{P}_{29}^i &= P_{25}^i = 4 \\ \hat{P}_{30}^i &= P_6^i = 4 \end{aligned}$$

Thus it can be determined \hat{p}^i resulting in a consistent new matrix.

New matrix after normalization:

$$\hat{P}^i = \begin{bmatrix} 4 & 3 & 5.5 & 9 & 4 & 4 & 5.5 & 8 & 5 & 4 \\ 2 & 4 & 3 & 6.5 & 3 & 3 & 3 & 5.5 & 4 & 3 \\ 2 & 2 & 4 & 3 & 2 & 4 & 3 & 2 & 4 & 4 \end{bmatrix}$$

From the new matrix after the normalization process can be known value of CI^k to determine the result of the calculation, so, from the value CI^k the value is obtained $1-CI^k = \{6, 5, 5, 5, 4, 3\}$ because the value of $1-CI^k$ getting closer 1, then the matrix can be said to be consistent.

Final calculation of rating weight: The latter value is the final solution of some solutions that are an alternative choice in giving rewards and promotions to each employee based on performance during the assessment process. The final calculation of rating can be applied online with internet management must be optimal (Mufadhhol *et al.*, 2017a-c).

From the value of w this can be seen that w_1 has the greatest value, so, it can be concluded that W_1 is the first alternative that will be chosen from several alternatives found.

$$\begin{aligned} W_1 &= Q\left(\frac{6.5}{5+4+3+2}\right) = \sqrt{\frac{6.5}{14}} = 0.681 \\ W_2 &= Q\left(\frac{6.5+5.5}{14}\right) - Q\left(\frac{6.5}{14}\right) = \sqrt{\frac{2.625}{14}} - \sqrt{\frac{6.5}{14}} = 0.248 \\ W_3 &= Q\left(\frac{6.5+5.5+4}{14}\right) - Q\left(\frac{6.5+5.5}{14}\right) = \\ &= \sqrt{\frac{1.142}{14}} - \sqrt{\frac{0.857}{14}} = 0.038 \\ W_4 &= Q(1) - Q\left(\frac{6.5+5.5+5}{14}\right) = 1 - \sqrt{\frac{1.214}{14}} = 0.294 \end{aligned}$$

CONCLUSION

Fuzzy logic can be used to assess employee performance with the concept of Fuzzy Multi Attribute Decision Making (FMADM) using the Consistency Induced Ordered Weighted Averaging (CIOWA) method. Assessment criteria are done by weighting through interest rating system and match rating, so that, a consistent matrix is obtained after a normalization process occurs on the fuzzy preference matrix. The last value obtained is an information indicator that is very important for the leader as a decision maker in determining the solution to give awards and promotions. This employee performance appraisal is not done subjectively but is done objectively through the CIOWA method, so that, the final solution taken can be appropriate and fair for all employees based on work performance.

RECOMMENDATIONS

For further research, this method can be combined using expert systems using rule based reasoning (Mufadhhol *et al.*, 2017a-c) and the system can be accessed by smartphone (Wibowo *et al.*, 2018).

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