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Implementation of the Mamdani Fuzzy System as a Decision Support for Contract Extensions for Non-Staff Employees in Manufacturing Companies

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Abstract

This study applies the Mamdani Fuzzy method as a decision support system in determining the feasibility of contract extension for non-staff employees in a manufacturing company. Performance assessment is conducted based on seven criteria, namely Attendance (C1), Work Quality (C2), Discipline (C3), Teamwork (C4), Initiative (C5), Responsibility (C6), and Professional Attitude (C7). The assessment uses the company's official linguistic scale: Very Poor (1), Poor (2), Sufficient (3), Good (4), and Very Good (5). Based on company regulations, employees with a total performance score below 23 are declared to have their contracts discontinued (termination), while employees with a score ≥ 23 are entitled to a contract extension or be appointed as permanent employees. The dataset consists of 40 non-staff employees from ten departments. The fuzzy inference process includes fuzzification, rule base formation, min-max inference, and centroid defuzzification. The results showed that 11 employees (27.5%) were recommended to have their contracts terminated, 16 employees (40.0%) were recommended to have their contracts extended, and 13 employees (32.5%) were recommended to be appointed as permanent employees. This system has proven to be able to produce recommendations that are objective, transparent, and in line with official company regulations.

Keywords: *Fuzzy Mamdani; Decision Support System; Performance Assessment; Contract Extension; Non-Staff Employees*

1. Introduction

Human resources (HR) are the most strategic asset for the sustainability and competitiveness of manufacturing companies. One HR element that often escapes systematic attention is non-staff or contract employees. Every company generally has standard provisions regarding performance assessment thresholds as the basis for contract renewal decisions. However, their implementation is often manual and prone to subjectivity in assessments [1]. Lack of objectivity in assessments has the potential to lead to unfairness, reduce employee motivation, and negatively impact the company's operational efficiency.

Decision Support Systems (DSS) have been proven effective in assisting semi-structured and unstructured decision-making [2]. Among the various methods available, fuzzy logic particularly the Mamdani method is known for its ability to handle uncertainty and ambiguity in qualitative and linguistic assessments [3]. This approach is particularly relevant for companies that use language-based category assessment scales such as “Very Good,” “Good,” “Fair,” “Poor,” and “Very Poor,” because fuzzy systems are inherently capable of processing linguistic values into measurable decisions [4].

Several previous studies have applied Mamdani fuzzy logic in the context of HR management. Efendi (2019) implemented Mamdani fuzzy logic for an employee contract extension recommendation system at BCA Bank with six criteria, resulting in more objective recommendations than conventional systems [5]. Arianto (2018) applied a similar method with four criteria to a construction company [1]. Nursyanti et al. (2021) used Mamdani fuzzy logic to support employee recruitment decisions with a significant level of accuracy [6]. Magdalena et al. (2024) demonstrated the effectiveness of Mamdani fuzzy logic in determining employee status through multi-criteria performance assessments [4].

This study developed a Mamdani fuzzy-based DSS that was fully adapted to the official provisions of manufacturing companies, including a linguistic assessment scale (Very Poor–Very Good) and decision threshold (< 23 for termination; ≥ 23 for extension/appointment of permanent employees). The objective of the study was to produce a system capable of providing objective, consistent, and standardized decision recommendations to 40 non-staff employees from ten departments.

2. Research methods

2.1. Data collection

The data used are primary data from the performance evaluation of 40 non-staff employees from ten departments of a manufacturing company, including Security, Maintenance, AMF (Administration, Manufacturing & Facility), Finance & Accounting, SCM (Supply Chain Management), General Support, IT Support, Procurement, Logistics, and Admin. The assessment was conducted by each employee's direct supervisor using seven criteria (C1–C7) guided by the linguistic assessment scale established by the company.

2.2. Company Rating Scale

The company establishes a performance assessment scale based on linguistic categories as listed in Table 2. The company's official provisions state that the total number of scores that must be met to determine contract status is: if the total score is < 23 then the contract is not continued (termination), whereas if the total score is ≥ 23 then the employee is entitled to a contract extension or be appointed as a permanent employee.

Table 1. Employee Performance Assessment Scale (Company Regulations)

Assessment Categories	Mark	Information
Very well	5	Very satisfactory performance, exceeding company targets
Good	4	Satisfactory performance, meeting all set targets
Enough	3	Adequate performance, meeting most targets
Not enough	2	Performance below target, requires improvement
Less than once	1	Very low performance, far below company standards

2.3. Criteria Evaluation

The seven performance assessment criteria used in this study are summarized in Table 3. Each criterion is assessed using a scale of 1–5 according to company regulations.

Table 2. Criteria for Non-Staff Employee Performance Assessment

Code	Criteria	Description	Rating Scale
C1	Attendance / Absence	Employee attendance rate during the contract period	1–5 (Poorly–Very Good)
C2	Quality of Work	The quality of work results is in accordance with company standards	1–5 (Poorly–Very Good)
C3	Discipline	Compliance with company regulations and rules	1–5 (Poorly–Very Good)
C4	Teamwork	Ability to work with colleagues and superiors	1–5 (Poorly–Very Good)
C5	Initiative	Ability to provide ideas and solutions independently	1–5 (Poorly–Very Good)
C6	Responsibility	Level of accountability in completing tasks	1–5 (Poorly–Very Good)
C7	Professional Attitude	Ethics, communication, and behavior in the work environment	1–5 (Poorly–Very Good)

2.4. Mamdani Fuzzy Method

The Mamdani Fuzzy Method introduced by Ebrahim Mamdani (1975) is the most popular fuzzy inference method in decision support systems [3]. The inference process consists of four main stages.

a) Fuzzification

At this stage, the total employee performance score (S) with a numerical value (range 7–35) is converted into membership degrees in three input fuzzy sets designed referring to the company's threshold requirements (< 23 / ≥ 23): (1) Not Eligible for scores 7–22, (2) Fairly Eligible for scores 20–28, and (3) Very Eligible for scores 26–35. The membership function uses a combination of the trapezoidal function (for the leftmost and rightmost sets) and the triangular function (for the middle set).

b) Establishing a Rule Base

Fuzzy rules were formulated in the form of IF-THEN statements based on official company regulations and in consultation with HR experts. The rule base was designed so that the company's threshold requirements (< 23 / ≥ 23) were directly reflected in the system logic. Table 4 displays the rule base used.

Table 3. Mamdani Fuzzy Rule Base (As Per Company Provisions)

No	Fuzzy Rules (Rule Base) — As Per Company Terms
R1	IF Performance Value is NOT WORTHY (S < 23) THEN Decision is NOT TO CONTINUE / TERMINATE CONTRACT
R2	IF the Performance Value is SUFFICIENTLY WORTHY (23 ≤ S ≤ 28) THEN the Decision is to EXTEND THE CONTRACT
R3	IF the Performance Value is VERY WORTHY (S > 28) THEN the Decision is to APPOINT AS A PERMANENT EMPLOYEE

c) Inference (Min-Max Implication)
Each rule is evaluated using the minimum operator (min) as an implication function. The outputs of all triggered rules are then combined using the maximum operator (max) to form a representative fuzzy output set.
d) Defuzzification
Defuzzification uses the centroid method (Center of Area/COA) to convert the output fuzzy set into a single numeric value which is then mapped into three decision categories: (1) Discontinue/Terminate Contract, (2) Extend Contract, and (3) Appoint Permanent Employee.

2.5. Design of Variables and Membership Functions

The design of the input and output variables of the fuzzy system referring to company provisions is presented in Table 5. The main boundary points on the input membership function are designed around the threshold value S = 23, with an overlap in the range of 20–26 so that the system can handle borderline cases proportionally and not binary.

Table 4. Design Variables and Membership Functions of the Mamdani Fuzzy System

Component	Information	Value Range	Membership Functions
Input Variables	Performance Value (Total Score 7–35)		
Fuzzy Set	Not Worthy (Inadequate)	[7, 22]	Left trapezoid
	Quite Decent	[20, 28]	Triangle
	Very Decent (Good)	[26, 35]	Right trapezoid
Limitation of Terms	< 23: Not Continued | ≥ 23: Extended / Permanently Appointed		
Output Variable	Contract Extension Decision		
Fuzzy Set	Not Continued / Termination	[0.45]	Left trapezoid
	Contract Extension	[40, 70]	Triangle
	Appointed Permanent Employee	[60, 100]	Right trapezoid

3. Results and Discussion

3.1. Employee Performance Evaluation Dataset

The research dataset includes 40 non-staff employees (n = 40) from ten departments. The total performance score (S) is obtained from the sum of the values of the seven criteria (C1–C7) with a theoretical minimum value range of 7 and a maximum of 35. The average total performance score of all employees is 26.35. Based on official company regulations, the applicable decision limit is S < 23 for contract termination and S ≥ 23 for extension or appointment of permanent employees. Complete data is presented in Table 6.

Table 5. Employee Performance Evaluation Input Dataset (n = 40)

No	Code	Department	C1	C2	C3	C4	C5	C6	C7	Total (S)
1	NS-101	Security	3	4	4	4	3	3	3	**24**
2	NS-102	Security	4	4	3	4	4	3	4	**26**
3	NS-103	Security	3	3	4	3	3	3	4	**23**
4	NS-104	Maintenance	5	5	5	5	5	5	5	**35**
5	NS-105	General Support	3	4	3	4	3	3	4	**24**
6	NS-106	SCM	4	4	4	4	4	3	4	**27**
7	NS-107	AMF	4	3	4	2	3	3	4	**23**
8	NS-108	Finance & Accounting	5	5	4	4	4	5	5	**32**
9	NS-109	AMF	5	5	5	5	5	5	4	**34**
10	NS-110	Maintenance	4	5	5	5	4	5	5	**33**
11	NS-111	AMF	5	5	4	4	4	4	4	**30**
12	NS-112	Security	3	3	3	3	3	3	3	**21**
13	NS-113	Security	4	3	3	3	3	3	3	**22**
14	NS-114	Security	4	4	4	4	4	4	4	**28**
15	NS-115	Security	3	4	4	3	4	3	4	**25**
16	NS-116	Maintenance	3	3	3	3	2	2	3	**19**
17	NS-117	Maintenance	4	4	4	4	3	3	4	**26**
18	NS-118	Maintenance	5	4	4	5	4	5	5	**32**
19	NS-119	Maintenance	2	2	3	2	2	2	2	**15**
20	NS-120	Maintenance	4	4	4	3	4	3	4	**26**

No	Code	Department	C1	C2	C3	C4	C5	C6	C7	Total (S)
21	NS-121	AMF	5	5	4	5	5	4	5	**33**
22	NS-122	AMF	3	3	4	3	3	3	3	**22**
23	NS-123	AMF	4	4	4	4	4	4	4	**28**
24	NS-124	SCM	3	3	3	3	3	3	4	**22**
25	NS-125	SCM	4	5	4	5	5	4	5	**32**
26	NS-126	SCM	4	4	4	4	4	3	4	**27**
27	NS-127	Finance & Accounting	4	4	4	4	4	4	4	**28**
28	NS-128	Finance & Accounting	3	3	3	4	3	3	3	**22**
29	NS-129	Finance & Accounting	5	5	5	5	4	5	5	**34**
30	NS-130	General Support	3	3	4	3	3	3	3	**22**
31	NS-131	General Support	4	4	4	4	3	3	4	**26**
32	NS-132	General Support	5	4	5	4	4	4	5	**31**
33	NS-133	IT Support	5	4	5	4	5	4	5	**32**
34	NS-134	IT Support	3	3	3	3	3	3	4	**22**
35	NS-135	IT Support	4	4	4	4	4	4	4	**28**
36	NS-136	Procurement	3	3	3	3	2	2	3	**19**
37	NS-137	Procurement	4	4	4	4	3	3	4	**26**
38	NS-138	Logistics	2	2	2	3	2	2	2	**15**
39	NS-139	Logistics	4	4	4	4	4	4	5	**29**
40	NS-140	Admin	5	5	4	4	4	4	5	**31**

3.2. Fuzzification and Inference Process

The following presents an example of the inference process for three employees representing each decision category.
Example 1: Employee NS-138, Logistics (S = 15) — Discontinued
With S = 15 which is completely in the Infeasible set [7, 22], the obtained membership degrees are: μ(Infeasible) = 1.0; μ(Quite Feasible) = 0; μ(Very Feasible) = 0. Rule R1 is triggered with strength α = 1.0. After centroid defuzzification, the output value falls into the "Not Continued" set. Decision: Not Continued / Contract Termination.
Example 2: Employee NS-115, Security (S = 25) — Contract Extension
With S = 25 in the Fairly Feasible set [20, 28], the membership degrees are: μ(Not Feasible) = 0; μ(Fairly Feasible) = (28 – 25) / (28 – 20) = 0.375 ≈ 0.38; μ(Very Feasible) = 0 (because 25 < 26). The R2 rule is triggered with α = 0.38. Defuzzification produces a value in the "Extend Contract" set. Decision: Extend Contract.
Example 3: Employee NS-104, Maintenance (S = 35) — Appointed Permanent Employee
With S = 35 at the upper boundary of the Very Feasible set [26, 35], the membership degrees are: μ(Not Feasible) = 0; μ(Quite Feasible) = 0; μ(Very Feasible) = 1.0. Rule R3 is triggered with α = 1.0. Defuzzification produces a value in the set "Appointed as a Permanent Employee". Decision: Appointed as a Permanent Employee.

3.3. Inference Sample Validation

Table 6 presents a summary of the inference process for five sample employees representing each decision category.

Table 6. Sample Results of Mamdani Fuzzy Inference

Code	Department	S	Membership Value	Decision
NS-138	Logistics	15	μ(TL)=1.0; μ(CL)=0; μ(SL)=0	Not Continued / Termination
NS-119	Maintenance	15	μ(TL)=1.0; μ(CL)=0; μ(SL)=0	Not Continued / Termination
NS-103	Security	23	μ(TL)=0; μ(CL)=0.38; μ(SL)=0	Contract Extension
NS-115	Security	25	μ(TL)=0; μ(CL)=0.63; μ(SL)=0	Contract Extension
NS-104	Maintenance	35	μ(TL)=0; μ(CL)=0; μ(SL)=1.0	Appointed Permanent Employee

Recapitulation of Decision Results

Based on the Mamdani fuzzy inference process applied to all 40 employees, referring to the company's official provisions (< 23 = Not Continued; ≥ 23 = Extended/Permanently Appointed), the recapitulation results were obtained as presented in Table 8.

Table 7. Summary of the Results of the Decision to Extend Non-Staff Employee Contracts

Score Range	Fuzzy Category	Company Decision	Number of employees
7 – 22	Not Worthy (Inadequate)	Discontinuation / Termination of Contract	11 (27.5%)
23 – 28	Quite Decent	Contract Extension	16 (40.0%)
29 – 35	Very Decent (Good)	Appointed Permanent Employee	13 (32.5%)
Total	–	–	40 (100%)

From Table 8 it is known that 11 employees (27.5%) received a recommendation to not continue/terminate the contract because The total performance score is below the company threshold (S < 23), namely: NS-112 (S = 21), NS-113 (S = 22), NS-116 (S = 19), NS-119 (S = 15), NS-122 (S = 22), NS-124 (S = 22), NS-128 (S = 22), NS-130 (S = 22), NS-134 (S = 22), NS-136 (S = 19), NS-138 (S = 15). A total of 16 employees (40.0%) received a recommendation to extend their contracts with a score range of 23–28, and 13 employees (32.5%) were recommended to be appointed as permanent employees because they had a total performance score above 28. Overall, 72.5% of employees (29 out of 40 people) met the company's requirements for contract extension.

3.4. Discussion

The results of the study show that the Fuzzy Mamdani method is able to integrate official company provisions (threshold < 23 / ≥ 23) into a more refined and proportional inference system than the conventional binary approach. The main advantage lies in the system's ability to handle cases around the threshold gradually; employees with a score of 21 or 22 who are right at the bottom limit are not immediately treated the same as employees with a score of 15, because their fuzzy membership degree in the "Not Eligible" set is already close to zero at a value of 22 [3].

This finding is in line with Efendi's (2019) research which concluded that fuzzy Mamdani produces more objective and transparent contract extension recommendations [5], and Arianto (2018) who emphasized the ability of fuzzy-based systems to reduce the subjectivity of contract employee evaluations [1]. The novelty of this research lies in the integration of the company's official threshold provisions along with a linguistic scale ("Very Poor" to "Very Good") directly into the design of the membership function and fuzzy rule base, so that the resulting system is fully aligned with the HR policies in force in the company.

From an HR management perspective, the distribution of results shows that the majority of non-staff employees (72.5%) meet the requirements for continuation, indicating that the recruitment and development process for non-staff employees is progressing quite well. However, 11 employees (27.5%) who fall below the threshold require a structured performance coaching program. This system also has the potential to be integrated into the company's HR management information system to expedite the evaluation process and reduce the administrative burden on HR.

4. Conclusion

This study successfully applied the Fuzzy Mamdani method as a decision support system for non-staff employee contract extensions in a manufacturing company, by fully integrating the company's linguistic assessment scale (Very Poor = 1 to Very Good = 5) and official thresholds (< 23 = Not Continued; ≥ 23 = Extended/Permanently Appointed) into the system design. Based on the evaluation of 40 non-staff employees using seven performance criteria, the results obtained were: 11 employees (27.5%) were recommended to Not Continue/Terminate Contracts, 16 employees (40.0%) were recommended to Extend Contracts, and 13 employees (32.5%) were recommended to be Appointed as Permanent Employees.

The Mamdani Fuzzy Method has been proven to translate the company's strict threshold provisions into a more proportional inference system and can handle ambiguity in employee cases around the threshold value. This system provides more transparent, consistent, and accountable recommendations than conventional assessments. Further development is recommended by adding weighting between criteria using the Analytic Hierarchy Process (AHP) method, as well as validation testing using historical data on company contract renewal decisions to empirically measure the system's accuracy.

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