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Application of the Mamdani Fuzzy Logic Method for Calculating Heavy Equipment Damage Insurance Claims at PT Semen Padang

Meilianti, Nurweni Putri*

Mathematics Study Program, Dharma Andalas University, Padang, Indonesia

* Correspondence e-mail: nurweniputri@gmail.com

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Abstract: Frequent damage to PT Semen Padang heavy equipment poses a significant operational risk and requires insurance claims. Insuranse claims are crucial for minimizing losses withing PT Semen Padang. The amount of insurance claims for heavy equipment damage can be determined based on the level of damage, frequency of occurrence, and age of the equipment. However, calculating the amount of insurance claims is often sebjective and uncertain. Therefore, this study aims to apply the fuzzy logic of the Mamdani method to calculate insurance claims for heavy equipment damage at PT Semen Padang and generate more objective and accurate decisions. The Mamdani method is applied because it is capable of handling uncertain data through fuzzyfication, implied function application, rule composition, and defuzzyfication using the centroid method. The accuracy of the Mamdani method can be seen using the Mean Absolute Percentage Error (MAPE) method. The results of this study concluded that the Mamdani menthod can calculate insurance claims more accurately with a MAPE 0,55%.

Keywords: Fuzzy Logic; Heavy Equipment Damage; Insurance Claims; Mamdani Method; Mean Absolute Percentage Error.

1. Introduction

A Limited Liability Company (*Perseroan Terbatas* or PT) is a legal entity established based on an agreement, operating as a capital partnership with authorized capital divided into shares, and fulfilling the requirements stipulated in Law Number 40 of 2007 (Yani et al., 2024). One of the Indonesian State-Owned Enterprises (SOEs) operating in the cement industry is PT Semen Indonesia (Persero) Tbk (SIG), which owns several subsidiaries, including PT Semen Padang. PT Semen Padang, established on March 18, 1910, in Indarung, West Sumatra, is the first cement manufacturing company in Indonesia and currently has an annual production capacity of approximately 8.5 million tons of cement (Bari, 2022; Firmansyah, 2022). To support its mining, manufacturing, and distribution activities, the company relies heavily on various types of heavy equipment.

The continuous operation of heavy equipment exposes the company to a high risk of equipment failures caused by component wear, mechanical breakdowns, hydraulic system failures, and electrical malfunctions. These failures may disrupt production processes, increase maintenance costs, and reduce operational productivity if not properly managed. In addition to equipment age, the frequency of operation and harsh working environments significantly influence the occurrence of equipment failures. One reported case involved the failure of heavy equipment DK-19 due to extreme environmental conditions (Sampurno, 2023). Consequently, an effective risk management strategy is essential to minimize the financial impact resulting from heavy equipment damage.

One of the most important risk mitigation strategies is insurance protection. According to Law Number 40 of 2014 concerning Insurance, insurance is an agreement between an insurance company and a policyholder that provides financial protection against specified risks. Through the insurance claim process, policyholders are entitled to compensation for losses resulting from insured events in accordance with the terms of the insurance policy (Dewi, 2021). However, determining the appropriate amount of insurance compensation is a challenging task because it depends on several interrelated factors, including the severity of equipment damage, the frequency of damage occurrences, and the age of the equipment. These variables are inherently uncertain and cannot always be assessed accurately using conventional deterministic approaches, leading to subjective and inconsistent claim decisions.

To address this issue, the Fuzzy Logic approach offers an effective solution because it is capable of modeling uncertainty and handling imprecise information. One of the most widely adopted fuzzy inference methods is the Mamdani Fuzzy Inference System (FIS), introduced by Ebrahim Mamdani in 1975. This method consists of four main stages: fuzzification, rule evaluation, inference, and defuzzification to produce a crisp output (Vinsensia, 2018). The Mamdani method is particularly advantageous because it incorporates expert knowledge in the form of linguistic rules, enabling decision-making processes that closely resemble human reasoning under uncertain conditions.

Previous studies have demonstrated that the Mamdani method has been successfully applied to various decision-making problems involving uncertainty, including feasibility assessment, risk evaluation, and classification based on multiple criteria. However, studies focusing on determining insurance claim compensation for heavy equipment damage in the cement industry remain limited. Existing research generally emphasizes heavy equipment maintenance, damage assessment, or operational risk analysis without integrating a fuzzy-based approach for estimating insurance claim compensation. This limitation indicates a research gap that warrants further investigation.

Therefore, this study proposes the application of the Mamdani Fuzzy Inference System to determine the amount of insurance claim compensation for heavy equipment damage at PT Semen Padang using three input variables, namely damage severity, failure frequency, and equipment age. Furthermore, the accuracy of the proposed model is evaluated using the Mean Absolute Percentage Error (MAPE), which compares the estimated compensation values with the actual claim values

(Nabillah, 2020). The proposed approach is expected to provide a more objective, consistent, and accurate decision-support model for determining insurance claim compensation, thereby assisting companies in improving risk management and insurance claim decision-making related to heavy equipment assets.

2. Methods

This study employs the **Mamdani Fuzzy Inference System (FIS)** to determine the amount of heavy equipment damage insurance claims, while the **Mean Absolute Percentage Error (MAPE)** method is used to evaluate the accuracy of the prediction results against the actual claim values.

1. Mamdani Fuzzy Inference System (FIS)

The Mamdani method is one of the most widely used fuzzy inference systems for solving decision-making problems based on rule-based reasoning. The implementation of the Mamdani FIS in this study consists of the following stages.

a. Fuzzy Set Formation (Fuzzification)
The first stage involves defining the input and output variables along with their corresponding fuzzy sets. Subsequently, membership functions are established for each fuzzy set based on the characteristics of the research data. The membership functions may take the form of linear, triangular, or trapezoidal functions, allowing each input value to have a degree of membership within the interval of [0,1].

b. Implication Function (Rule Evaluation)
After defining the fuzzy sets, a fuzzy rule base is constructed to describe the relationship between the input and output variables. The fuzzy rules are expressed in the following form:

$$\text{IF } x \text{ is } A \text{ THEN } y \text{ is } B$$

In this study, the MIN operator is employed as the implication function. Consequently, the firing strength of each rule is determined by the minimum membership degree of all antecedents contained in the rule.

c. Rule Aggregation
The rule aggregation stage combines the outputs generated from all activated fuzzy rules into a single fuzzy output set. The aggregation process uses the MAX operator to determine the maximum membership value among all activated rules. The result of this stage is a unified fuzzy set representing the system output.

d. Defuzzification
The final stage converts the aggregated fuzzy output into a crisp value. This study applies the Centroid (Center of Area, COA) method, in which the final output is determined by calculating the center of gravity of the area under the output membership function. The resulting crisp value represents the recommended insurance claim amount.

2. Mean Absolute Percentage Error (MAPE)

After obtaining the predicted insurance claim values using the Mamdani Fuzzy Inference System, the model performance is evaluated using the Mean Absolute Percentage Error (MAPE). MAPE measures the average percentage difference between the predicted claim values produced by the proposed model and the corresponding actual claim values.
The MAPE value is calculated using the following equation:

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{y_i - \hat{y}_i}{y_i}\right| \times 100\%$$

where:
- n = actual claim value;
- y_i = predicted claim value generated by the Mamdani FIS;
- $\hat{y}_i$ = number of testing data.

A lower MAPE value indicates a higher prediction accuracy of the proposed model in estimating heavy equipment damage insurance claims.

3. Framework of the Mamdani Fuzzy Inference System

Figure X illustrates the research framework of the Mamdani Fuzzy Inference System used in this study. The process begins with collecting heavy equipment damage data, followed by determining the input and output variables. Next, fuzzy sets and membership functions are constructed for each variable during the fuzzification stage. A fuzzy rule base is then developed to model the relationship between the input variables and the insurance claim amount. The inference process is performed using the MIN implication operator, followed by rule aggregation using the MAX operator. Subsequently, the aggregated fuzzy output is converted into a crisp value through the Centroid defuzzification method. Finally, the predicted insurance claim amount is compared with the actual claim value using the Mean Absolute Percentage Error (MAPE) to evaluate the accuracy of the proposed model.

3. Results and Discussion

The data and variables used in this study consist of heavy equipment damage insurance claim records from PT Semen Padang covering the period from 2020 to 2023. The dataset includes three input variables, namely claim value, claim frequency, and equipment age, while the output variable is the claim reimbursement amount.

The claim value and claim reimbursement amount are expressed in Indonesian Rupiah (IDR). The claim frequency represents the number of claim incidents that occurred for each heavy equipment unit, whereas the equipment age is measured in years. These variables serve as the basis for developing the Mamdani Fuzzy Inference System to estimate the appropriate insurance claim reimbursement. The input and output data used in this study are presented in Table 1.

Table 1. Heavy Equipment Damage Insurance Claim Data of PT Semen Padang (2020–2023)

Year	Heavy Equipment	Claim Value (IDR)	Frequency (Times)	Equipment Age (Years)	Claim Reimbursement (IDR)
2020	EC03	1,016,197,740	5	12	965,387,853
2020	EC03	1,024,314,678	5	15	973,098,944
2020	EK04	414,488,340	3	5	389,488,340
2020	EK04	287,899,112	3	6	262,899,112
2020	EC03 – Mining	813,150,254	5	14	772,492,741
2020	DC10 – Mining	143,092,707	1	11	118,092,707
2021	EC03 – Mining	549,062,761	5	12	521,609,623
2021	DK18 – Mining	1,787,374,680	1	9	1,698,055,946
2022	GC03	1,277,789,879	1	13	1,213,900,385
2022	DK15 (Slipped into Hopper – Mining)	3,889,966,252	1	20	3,864,966,252
2023	EH06 – Mining	3,450,650,088	2	15	3,278,117,584

Based on Table 4.1, the lowest claim value is IDR 143,092,707, while the highest is IDR 3,889,966,252. Therefore, the universe of discourse for the claim value variable is defined on a scale of 0–4 billion IDR. For the claim frequency variable, the minimum observed value is 1 and the maximum is 5. Accordingly, the universe of discourse is defined within the interval [0, 6] occurrences. The equipment age variable ranges from 5 years to 20 years. To adequately accommodate the observed data and allow flexibility for the fuzzy membership functions, the universe of discourse for equipment age is defined within the interval [3, 20] years. The output variable, namely claim reimbursement, has a minimum value of IDR 118,092,707 and a maximum value of IDR 3,864,966,252. Therefore, the universe of discourse for the output variable is defined on a scale of 0–4 billion IDR.

Based on the above analysis, the universes of discourse for the input and output variables are summarized in Table 2.

Table 2. Universe of Discourse for Input and Output Variables

Function	Variable	Universe of Discourse
Input	Damage Level (Billion IDR)	[0–4]
	Damage Frequency (Times)	[0–6]
	Equipment Age (Years)	[3–20]
Output	Claim Reimbursement (Billion IDR)	[0–4]

Based on the data presented in Table 1 and Table 2, the universes of discourse are further partitioned into fuzzy sets to represent the linguistic variables used in the Mamdani Fuzzy Inference System. Each variable is divided into several fuzzy sets according to the characteristics of the observed data. The domains of the fuzzy membership functions are presented in Table 3.

Table 3. Domains of the Fuzzy Membership Functions

Variable	Fuzzy Set	Domain
Damage Level (Billion IDR)	Very Low	[0–1]
	Low	[1–2]
	Moderate	[2–3]
	High	[3–4]
Damage Frequency (Times)	Rare	[0–3]
	Moderate	[1.5–4.5]
	Frequent	[3–6]
Equipment Age (Years)	New	[3–10]
	Medium	[8–15]
	Old	[13–20]
Claim Reimbursement (Billion IDR)	Very Low	[0–1]
	Low	[1–2]
	Moderate	[2–3]
	High	[3–4]

Based on Table 3, the membership functions for both the input and output variables are constructed to represent the corresponding linguistic terms. These membership functions form the basis of the fuzzification process in the Mamdani Fuzzy Inference System.

Based on the previously defined universe of discourse, the fuzzy membership functions and their graphical representation for the Damage Level variable are established. This variable is partitioned into four linguistic terms, namely Very Low, Low, Moderate, and High, each represented by an appropriate membership function over the domain of 0–4 billion IDR. The corresponding membership function graph is presented in the following figure.
The graphical representation of the membership functions for the Damage Cost variable is shown in

$$\mu_{Very\ low}[X] = \begin{cases} 1\,, & x \le 0{,}5 \\ \dfrac{1-x}{1-0{,}5}\,, & 0{,}5 < x < 1 \\ 0\,, & x \ge 1 \end{cases}$$

$$\mu_{Low}[X] = \begin{cases} 0, & x \le 1 \cup x \ge 2 \\ \dfrac{x-1}{1{,}5-1}, & 1 < x < 1{,}5 \\ 1, & x = 1{,}5 \\ \dfrac{2-x}{2-1{,}5}, & 1{,}5 < x < 2 \end{cases}$$

$$\mu_{Moderate}[X] = \begin{cases} 0, & x \leq 2 \cup x \geq 3 \\ \dfrac{x-2}{2{,}5-2}, & 2 < x < 2{,}5 \\ 1, & x = 2{,}5 \\ \dfrac{3-x}{3-2{,}5}, & 2{,}5 < x < 3 \end{cases}$$

$$\mu_{High}[X] = \begin{cases} 0\,, & x \leq 3 \\ \dfrac{x-3}{3{,}5-3}\,, & 3 < x < 3{,}5 \\ 1\,, & x \geq 3{,}5 \end{cases}$$

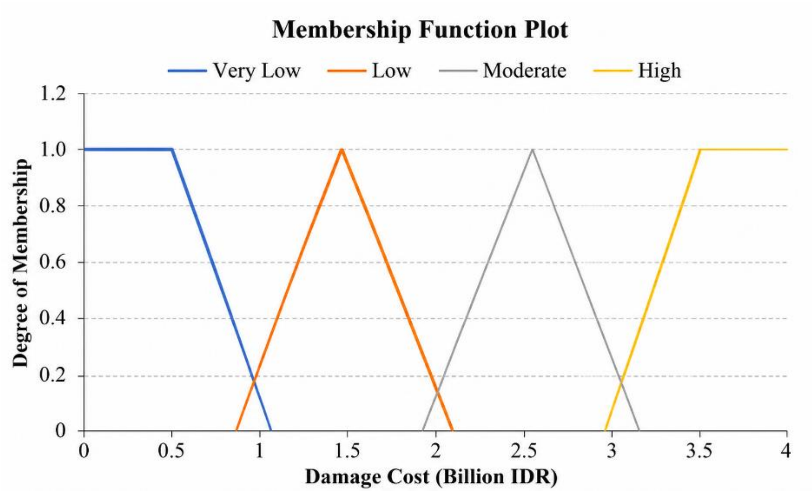

Figure 1. Membership Function of Input Variable: "Damage Level"

Based on the previously defined universe of discourse, the membership functions and graphical representation of the fuzzy sets for the Damage Frequency variable are presented. This variable is represented by three linguistic terms, namely Rare, Moderate, and Frequent.
The membership functions are defined as follows:

$$\mu_{\text{Rare}}(x) = \begin{cases} 1, & x \leq 1 \\ \frac{3-x}{3-1}, & 1 < x < 3 \\ 0, & x \geq 3 \end{cases}$$

$$\mu_{\text{Moderate}}(x) = \begin{cases} 0, & x \leq 1.5 \ \cup \ x \geq 4.5 \\ \frac{x-1.5}{3-1.5}, & 1.5 < x < 3 \\ 1, & x = 3 \\ \frac{4.5-x}{4.5-3}, & 3 < x < 4.5 \end{cases}$$

$$\mu_{\text{Frequent}}(x) = \begin{cases} 0, & x \leq 3 \\ \dfrac{x-3}{5-3}, & 3 < x < 5 \\ 1, & x \geq 5 \end{cases}$$

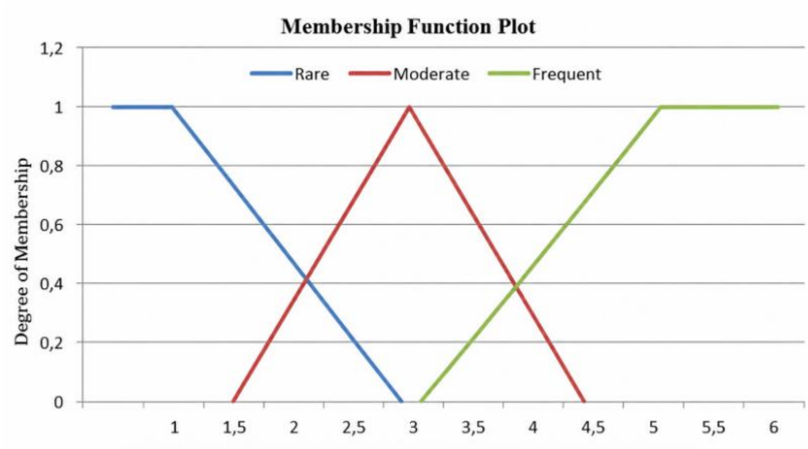

Figure 2. Membership Function of Input Variable: "Frequency"

Based on the previously defined domain, the membership functions and the graphical representation of the fuzzy set membership degrees for the equipment age variable are presented as follows. The membership functions are defined by:

$$\mu_{\text{new}}(x) = \begin{cases} 1, & x \leq 5 \\ \dfrac{10 - x}{10 - 5}, & 5 < x < 10 \\ 0, & x \geq 10 \end{cases}$$

$$\mu_{\text{moderate}}(x) = \begin{cases} 0, & x \leq 8 \text{ or } x \geq 15 \\ \dfrac{x - 8}{11.5 - 8}, & 8 < x < 11.5 \\ 1, & x = 11.5 \\ \dfrac{15 - x}{15 - 11.5}, & 11.5 < x < 15 \end{cases}$$

$$\mu_{\text{old}}(x) = \begin{cases} 0, & x \leq 13 \\ \dfrac{x - 13}{18 - 13}, & 13 < x < 18 \\ 1, & x \geq 18 \end{cases}$$

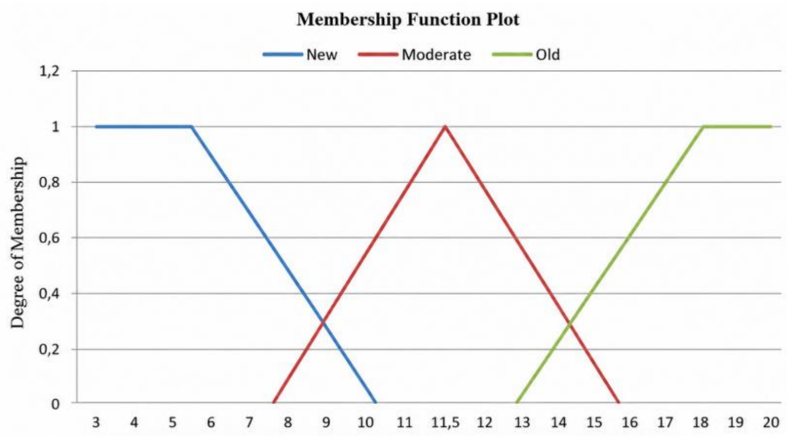

Figure 3. Membership Function of Input Variable: "Equipment Age"

Based on the previously defined domain, the membership functions and graphical representation of the fuzzy membership degrees for the claim replacement variable are presented below. The membership functions are defined as follows:

$$\mu_{Very\ low}[Z] = \begin{cases} 1, & z \leq 0{,}5 \\ \dfrac{1-z}{1-0{,}5}, & 0{,}5 < z < 1 \\ 0, & z \geq 1 \end{cases}$$

$$\mu_{Low}[Z] = \begin{cases} 0, & z \leq 1 \cup z \geq 2 \\ \dfrac{z-1}{1{,}5-1}, & 1 < z < 1{,}5 \\ 1, & z = 1{,}5 \\ \dfrac{2-z}{2-1{,}5}, & 1{,}5 < z < 2 \end{cases}$$

$$\mu_{Moderate}[Z] = \begin{cases} 0, & z \leq 2 \cup z \geq 3 \\ \dfrac{z-2}{2{,}5-2}, & 2 < z < 2{,}5 \\ 1, & z = 2{,}5 \\ \dfrac{3-z}{3-2{,}5}, & 2{,}5 < z < 3 \end{cases}$$

$$\mu_{High}[Z] = \begin{cases} 0, & z \leq 3 \\ \dfrac{z-3}{3{,}5-3}, & 3 < z < 3{,}5 \\ 1, & z \geq 3{,}5 \end{cases}$$

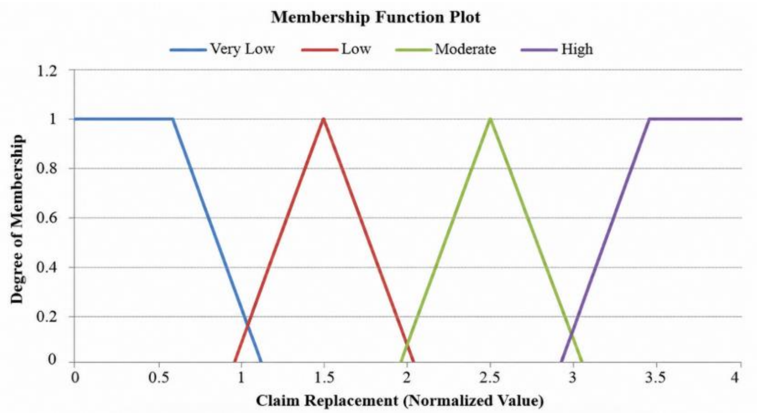

Figure 4. Membership Function of the Output Variable "Claim Replacement"

Based on the developed 144 fuzzy logic rules, eight representative rules were selected to capture the most dominant relationship patterns between the input variables (damage level, frequency, and equipment age) and the output variable (claim replacement). These rules were selected based on their frequency of occurrence and their influence on the inference results. Consequently, rules with relatively low significance or infrequent occurrence were excluded from the analysis. The eight fuzzy logic rules used in this study are presented as follows:

- R1: IF Damage Level is High AND Frequency is Rare AND Equipment Age is Moderate, THEN Claim Replacement is High.
- R2: IF Damage Level is High AND Frequency is Rare AND Equipment Age is Old, THEN Claim Replacement is High.
- R3: IF Damage Level is High AND Frequency is Moderate AND Equipment Age is New, THEN Claim Replacement is High.
- R4: IF Damage Level is High AND Frequency is Moderate AND Equipment Age is Moderate, THEN Claim Replacement is High.
- R5: IF Damage Level is High AND Frequency is Moderate AND Equipment Age is Old, THEN Claim Replacement is High.
- R6: IF Damage Level is High AND Frequency is Frequent AND Equipment Age is New, THEN Claim Replacement is High.
- R7: IF Damage Level is High AND Frequency is Frequent AND Equipment Age is Moderate, THEN Claim Replacement is High.
- R8: IF Damage Level is High AND Frequency is Frequent AND Equipment Age is Old, THEN Claim Replacement is High.

1. R1: IF Damage Level is High AND Frequency is Rare AND Equipment Age is Moderate, THEN Claim Replacement is High.
   Damage Level = IDR 3.450.650.088, which lies within the interval IDR 3,000,000,000 ≤ x ≤ IDR 3,500,000,000. Therefore,

$$\mu_{\text{High}}(3.450.650.088) = \frac{x-3}{3.5-3} = 0.90 \text{ (in billions of IDR)}$$

Frequency = 2, which lies within the interval 1 ≤ x ≤ 3. Therefore,

$$\mu_{\text{Rare}}(2) = \frac{3-x}{3-1} = \frac{3-2}{3-1} = 0.50$$

Equipment Age = 15 years, which satisfies the condition x ≥ 15. Therefore,

$$\mu_{\text{Moderate}}(15) = 0$$

The firing strength of Rule 1 is obtained using the minimum operator:

$$\alpha_1 = \mu_{\text{High}} \cap \mu_{\text{Rare}} \cap \mu_{\text{Moderate}} = \min\,(\mu_{High}[0{,}9], \mu_{Rare}[0{,}5], \mu_{Moderate}[0]) = 0$$

2. R2: IF Damage Level is High AND Frequency is Rare AND Equipment Age is Old, THEN Claim Replacement is High.

   Damage Level = IDR 3.450.650.088, which lies within the interval IDR 3,000,000,000 ≤ x ≤ IDR 3,500,000,000. Therefore,

   $$\mu_{\text{High}}(3.450.650.088) = \frac{x-3}{3.5-3} = 0.90 \text{ (in billions of IDR)}$$

   Frequency = 2, which lies within the interval 1 ≤ x ≤ 3. Therefore,

   $$\mu_{\text{Rare}}(2) = \frac{3-x}{3-1} = \frac{3-2}{3-1} = 0.50$$

   Equipment Age = 15 years, which satisfies the condition $13 \leq x \leq 18$. Therefore,

   $$\mu_{\text{Old}}(15) = \frac{x-13}{18-13} = \frac{15-13}{18-13} = 0{,}4$$

   The firing strength of Rule 2 is obtained using the minimum operator:

   $$\alpha_1 = \mu_{\text{High}} \cap \mu_{\text{Rare}} \cap \mu_{\text{old}} = \min\big(\mu_{High}[0{,}9], \mu_{Rare}[0{,}5], \mu_{Moderate}[0{,}4]\big) = 0{,}4$$

Using the same procedure, the firing strengths for the remaining rules were obtained.

3. R3: IF Damage Level is High AND Frequency is Moderate AND Equipment Age is New, THEN Claim Replacement is High, with $\alpha_3 = \min\,(0{,}9; 0{,}3; 0) = 0$.
4. R4: IF Damage Level is High AND Frequency is Moderate AND Equipment Age is Moderate, THEN Claim Replacement is High, with $\alpha_4 = \min\,(0{,}9; 0{,}3; 0) = 0$.
5. R5: IF Damage Level is High AND Frequency is Moderate AND Equipment Age is Old, THEN Claim Replacement is High, with $\alpha_5 = \min(0{,}9; 0{,}3; 0{,}4) = 0{,}3$.

6. R6: IF Damage Level is High AND Frequency is Frequent AND Equipment Age is New, THEN Claim Replacement is High, with $\alpha_6 = \min(0{,}9; 0; 0) = 0$.
7. R7: IF Damage Level is High AND Frequency is Frequent AND Equipment Age is Moderate, THEN Claim Replacement is High, with $\alpha_7 = \min(0{,}9; 0; 0) = 0$.
8. R8: IF Damage Level is High AND Frequency is Frequent AND Equipment Age is Old, THEN Claim Replacement is High, with $\alpha_8 = \min\,(0{,}9; 0; 0{,}4) = 0$.

Based on the results of the implication function application for each rule, the max method was used to perform the composition among the rules. From the implication function results of each rule, rules R2 and R5 produced fuzzy output values, where R2 = 0.4 and R5 = 0.3. Using the max method, the highest value is selected, which is the value from R2 of 0.4. Therefore, the resulting fuzzy output for the high claim replacement category is 0.4.

Figure 5. Fuzzy Output for Large Claim Replacement

After obtaining the fuzzy output value of 0.4, the resulting area is divided into two parts, namely Region 1 and Region 2. The obtained values are $t_1 = 3{,}2$.

The fuzzy membership function for the large claim replacement variable is defined as follows:

$$\mu_{High}[Z] = \begin{cases} 0\,, & z \leq 3 \\ \dfrac{z-3}{3{,}5-3}\,, & 3 < z < 3{,}2 \\ 0{,}4\,, & z \geq 3{,}2 \end{cases}$$

The defuzzification process is performed using the Centroid (Center of Gravity) method. The numerator is calculated based on the centroid approach as follows:

$$\int_{3}^{3,2} \mu_{High} z(z)\, dz = \int_{3}^{3,2} \frac{z-3}{3{,}5-3} z\, dz \quad = \frac{1}{0{,}5}\int_{3}^{3,2} (z-3)z\, dz = 0{,}12.$$

$$\int_{3,2}^{3,5} \mu_{High} z\,(z) dz = \int_{3,2}^{3,5} 0{,}4\, z\, dz = 0{,}402.$$

The results are summed as follows :

$$\int_{3}^{3,2} \frac{z-3}{3,5-3} z\, dz + \int_{3,2}^{3,5} 0,4\, z\, dz = 0,12 + 0,402 = 0,522.$$

Next, the denominator value is calculated using the centroid method:

$$\int_{3}^{3,2} \mu_{Berat}(z)\, dz = \int_{3}^{3,2} \frac{z-3}{3,5-3} dz = 0,04$$

$$\int_{3,2}^{3,5} \mu_{Berat}(z) dz = \int_{3,2}^{3,5} 0,4\, dz = 0,12$$

The results are summed as follows :

$$\int_{3}^{3,2} \frac{z-3}{3,5-3} dz + \int_{3,2}^{3,5} 0,4\, dz = 0,04 + 0,12 = 0,16.$$

After that, the summation of the numerator and denominator values is substituted into equation above, resulting in the final defuzzification value:

$$Z^* = \frac{\int \mu\, z(z)\, dz}{\int \mu\, (z) dz} = \frac{0,522}{0,16} = 3,26.$$

Based on the calculation results using the Mamdani method, the crisp value for claim replacement is 3.26. According to Table 3, the crisp value of claim replacement at 3.26 falls within the range of values greater than 3, which indicates that the claim replacement in 2023 is categorized as large.

Based on the method previously applied, namely the Mamdani method, the final prediction result from the defuzzification process obtained a crisp value for claim replacement (z^*) of 3.26 billion as the predicted calculation value ($\hat{y}_i$). Therefore, the following result is obtained:

$$MAPE = \frac{1}{n}\sum_{i=1}^{n} \left|\frac{z-z^*}{z}\right| \times 100\% = \left|\frac{3.278.117.548 - 3.260.000.000}{3.278.117.548}\right| \times 100\% = 0,55\%.$$

The analysis of the Mean Absolute Percentage Error (MAPE) method for the Mamdani method shows that the prediction accuracy is very high. Based on the calculation using one data sample, the obtained MAPE value is 0.55%, which is below 10%. This result indicates excellent prediction performance. The MAPE calculation confirms that the Mamdani method is highly accurate and effective for calculating and predicting data in this research.

4. Conclusion

Based on the results of this study regarding the application of the Mamdani fuzzy logic method for determining insurance claim replacement due to heavy equipment damage at PT Semen Padang, it can be concluded that the Mamdani method is capable of producing a claim replacement prediction value that is close to the actual value. Using input variables consisting of damage level, damage frequency, and equipment age, the defuzzification process produced a predicted claim replacement value of Rp3,260,000,000**,** while the actual insurance claim replacement value in 2023 was Rp3,278,117,548. The difference between the predicted and actual values is relatively small, and both values are included in the same large claim replacement category within the domain [3,4]**.**

The accuracy evaluation using the Mean Absolute Percentage Error (MAPE) method resulted in an error value of **0.55%**. This value is below the 10% threshold, indicating that the Mamdani method provides a very high level of prediction accuracy with a minimal error rate. The obtained MAPE value demonstrates that the proposed method has excellent performance in estimating insurance claim replacement values.

Based on these results, it can be concluded that **the** Mamdani fuzzy logic method can be applied as an alternative approach in a decision support system for determining the amount of insurance claim replacement due to heavy equipment damage at PT Semen Padang. This method provides a systematic and flexible approach by considering multiple factors that influence the claim value, thereby supporting more effective and accurate decision-making processes.

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