



ANALYSIS OF CUSTOMER SATISFACTION IN COOPERATIVE SERVICES USING THE FUZZY MAMDANI METHOD: A CASE STUDY OF KOMIDA AJIBARANG

Krishna Prafidya Romantica*¹, Agung Nugraha²

^{1,2} Universitas Terbuka, South Tangerang, Indonesia

*Corresponding Author: krishna.prafidya@ecampus.ut.ac.id

<p>Info Article</p> <p>Received : 14 Juli 2025</p> <p>Revised : 10 Agustus 2025</p> <p>Accepted : 22 Agustus 2025</p> <p>Publication : 30 September 2025</p> <p>Keywords: Customer Satisfaction, Cooperative Services, Fuzzy Mamdani Method, Loan Products, Service Quality.</p> <p>Kata Kunci: Kepuasan Pelanggan, Layanan Koperasi, Produk Pinjaman, Kualitas Pelayanan, Metode Fuzzy Mamdani.</p> <p>Licensed Under a Creative Commons Attribution 4.0 International License</p> 	<p>Abstract. <i>This study aims to analyze customer satisfaction at KOMIDA Cooperative Ajibarang by examining the influence of two main factors, namely loan products and service quality. The research adopts a descriptive quantitative approach utilizing the Fuzzy Mamdani inference system for data processing. Data were collected through structured questionnaires and interviews with active cooperative members as respondents. The use of fuzzy logic methods was chosen due to their ability to handle uncertainty and subjectivity in customer perceptions, thereby producing results that more accurately reflect real conditions in the field. The findings reveal that both the offered loan products and the quality of services provided play equally important roles in shaping customer satisfaction. Loan products were assessed as relevant to members' needs, while services characterized by friendliness, efficiency, and clear communication enhanced the positive experience of members in interacting with the cooperative. Most respondents gave positive, indicating that the cooperative's services and products have met, and in many cases closely aligned with, their expectations.</i></p> <p>Abstrak: Penelitian ini bertujuan untuk menganalisis tingkat kepuasan nasabah pada Koperasi KOMIDA Ajibarang dengan menyoroti pengaruh dua faktor utama, yaitu produk pinjaman dan kualitas pelayanan. Kajian ini menggunakan pendekatan deskriptif kuantitatif dengan memanfaatkan sistem inferensi Fuzzy Mamdani dalam pengolahan data. Data dikumpulkan melalui kuesioner terstruktur dan wawancara kepada anggota koperasi aktif sebagai responden. Pemilihan metode logika fuzzy didasarkan pada keunggulannya dalam menangani ketidakpastian serta subjektivitas persepsi nasabah, sehingga hasil yang diperoleh dapat lebih merepresentasikan kondisi nyata di lapangan. Hasil penelitian menunjukkan bahwa produk pinjaman yang ditawarkan serta kualitas pelayanan yang diberikan memiliki kontribusi yang sama penting dalam membentuk kepuasan nasabah. Produk pinjaman dinilai relevan dengan kebutuhan anggota, sementara pelayanan yang ramah, cepat, dan komunikatif mampu meningkatkan pengalaman positif nasabah dalam berinteraksi dengan koperasi. Sebagian besar responden memberikan penilaian positif, menandakan bahwa layanan dan produk yang disediakan telah memenuhi, bahkan mendekati, harapan mereka. Lebih jauh, penggunaan metode Fuzzy Mamdani terbukti efektif sebagai alat analisis untuk mengukur tingkat kepuasan secara komprehensif.</p>
---	---

INTRODUCTION

Customer satisfaction is a key determinant of success in cooperative financial institutions, especially in microfinance settings where service quality and loan products directly influence member loyalty and retention (Luh, 2025). In Indonesia, cooperatives such as KOMIDA have played a vital role in empowering low-income communities by offering accessible financial services tailored to local needs (Tegambwage, 2025).

The concept of customer satisfaction is rooted in marketing theory, where Kotler and Keller define it as a person's feeling of pleasure or disappointment resulting from comparing a product's perceived performance with expectations (Freddy, 2017). This definition highlights the importance of aligning cooperative services with member expectations, particularly in environments where financial literacy and trust are still developing.

Service quality is widely recognized as a primary driver of customer satisfaction in microfinance institutions. Dimensions such as reliability, responsiveness, assurance, and empathy significantly influence member perceptions and behaviors (Kanyurhi & Akonkwa, 2016). In cooperative settings, these attributes are not only operational metrics but also reflections of the institution's commitment to member welfare.

Loan products also play a crucial role in shaping member satisfaction. Research shows that flexible loan terms, competitive interest rates, and digital accessibility are highly valued by cooperative members and contribute to both satisfaction and financial empowerment (Darmayasa & Yasa, 2021)

To address the complexity and subjectivity of customer satisfaction, fuzzy logic has emerged as a powerful analytical tool. The Mamdani fuzzy inference system, in particular, allows for nuanced modeling of satisfaction levels based on linguistic variables and membership functions (Caraveo-cacep & Vázquez-medina, 2025). This method accommodates uncertainty and imprecision, making it ideal for cooperative settings where perceptions vary widely (Marín Díaz & Carrasco González, 2023).

Previous studies have applied fuzzy logic in various domains, but its use in cooperative satisfaction analysis remains limited. Comparative reviews show that Mamdani controllers offer simplicity and interpretability, making them suitable for cooperative environments (Vidal-martínez et al., 2025). However, most research focuses on descriptive statistics or traditional regression models, leaving a gap in the application of intelligent systems for decision support in cooperatives (Kallmuenzer, Mikhaylov, Chelaru, & Czakon, 2025).

The novelty of this study lies in its integration of the Mamdani fuzzy logic system with cooperative service evaluation, offering a systematic and replicable approach to modeling member satisfaction. Unlike previous models, this approach uses statistical distributions and linguistic rules to capture member perceptions more accurately. This contributes to the development of adaptive decision support systems that can guide cooperative management in service improvement strategies.

Therefore, this article aims to investigate customer satisfaction at KOMIDA Ajibarang Cooperative using the Fuzzy Mamdani method, focusing on the influence of loan products and service quality. The scope includes the development of a fuzzy-based decision support model to assist cooperative management in enhancing service delivery and member engagement.

METHOD

This study employs a quantitative descriptive approach, which is suitable for analyzing structured data and identifying patterns in customer satisfaction within cooperative institutions (Mittal et al., 2023). The method is rooted in positivist philosophy and aims to examine a specific population through data collection and statistical analysis.

The population in this research consists of all active members of KOMIDA Ajibarang Cooperative. The sample was selected using purposive sampling, targeting 100 members who had been part of the cooperative for at least six months. This technique ensures that respondents have sufficient experience to evaluate the services and loan products meaningfully.

Data collection was conducted using structured questionnaires designed to measure indicators of customer satisfaction, including service speed, staff friendliness, clarity of information, procedural ease, facility comfort, and loan product quality. Additionally, in-depth interviews were conducted with selected respondents to gain deeper insights into their expectations and experiences.

For data analysis, the study utilizes the Fuzzy Mamdani Inference System, a method capable of handling uncertainty and subjectivity in customer perceptions. This system is widely used in decision support models for service-based environments. The fuzzy system includes several stages: fuzzification, rule inference, implication and composition, and defuzzification.

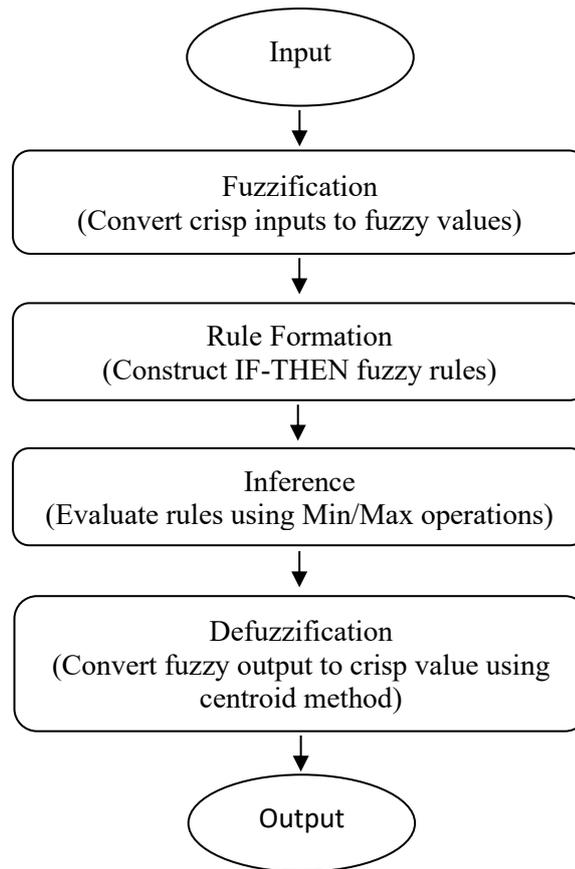


Figure 1 Flowchart of Mamdani Fuzzy Inferences System Analysis Stages

Stage 1: Fuzzy Set Formation

The fuzzy set formation stage is the initial and essential step in the Mamdani fuzzy inference system. In this stage, crisp numerical data, such as customer ratings or service quality scores, are transformed into linguistic variables that can be processed by the fuzzy logic system. This transformation begins with the identification of relevant input and output variables. In the context of this study, the input variables are loan product and service quality, while the output variable is customer satisfaction.

Each variable is defined within a specific domain, typically ranging from 0 to 100. Within this domain, several fuzzy sets are constructed to represent qualitative categories such as: *very dissatisfied*, *dissatisfied*, *satisfied*, and *very satisfied*.

These fuzzy sets allow the system to interpret and process subjective or vague information in a structured and objective manner. This is particularly important in customer satisfaction analysis, where perceptions are often imprecise and vary between individuals.

Stage 2: Fuzzification

Fuzzification is the second stage in the Mamdani fuzzy inference process, where crisp numerical input values are transformed into fuzzy values. This step is essential for enabling the system to interpret real-world data that is often uncertain, imprecise, or subjective. In the context of this study, input data, such as customer ratings on loan products and service quality, are collected through structured questionnaires and mapped into fuzzy linguistic categories (Moussaoui & Radenovi, 2025).

Each input value is evaluated using membership functions, which determine the degree to which the value belongs to a fuzzy set. These functions are defined over specific ranges within the domain (0–100), and each fuzzy set, such as “Very Dissatisfied,” “Dissatisfied,” “Satisfied,” and “Very Satisfied”, has its own function that assigns a membership value between 0 and 1.

Loan Product Indicator

The loan product is one of the key input variables analyzed in this study to assess the level of customer satisfaction in the cooperative. This indicator encompasses several service aspects, including speed of service, staff friendliness, clarity of information, ease of procedures, and comfort of facilities.

During the fuzzification stage, the numerical values obtained from the questionnaire responses are converted into linguistic values based on their degree of membership in four fuzzy sets: “Very Dissatisfied”, “Dissatisfied”, “Satisfied”, and “Very Satisfied”. Each fuzzy set is defined by a membership function (denoted as μ), which determines how strongly a given input value belongs to a particular category.

Customers who fall under the “Very Dissatisfied” category regarding loan products are evaluated using a specific membership function. This function defines the degree to which a numerical input value (e.g., from a questionnaire) belongs to the fuzzy set labeled “Very Dissatisfied”. The general form of the membership function $\mu(x)$ used in this study is based on a linear decreasing function, where the membership value decreases as the input value increases within a defined range. The formula applied is as follows (Martin & Nilawati, 2018):

$$\mu_{VD}(x) = \begin{cases} 1, & x \leq a \\ \frac{b-x}{b-a} & a \leq x \leq b \\ 0, & x > b \end{cases}$$

This function ensures that values closer to the lower bound of the domain (e.g., 0–25) are strongly associated with the *Very Dissatisfied* category, while values approaching the upper bound gradually lose their membership.

Customers who fall under the “Dissatisfied” category regarding loan products are evaluated using a trapezoidal membership function. This function is designed to represent a gradual increase and decrease in membership values across a defined range, allowing for partial membership in the fuzzy set.

The general form of the membership function $\mu(x)$ for this category is:

$$\mu_D(x) = \begin{cases} 0, & x \leq a \text{ or } x > b \\ \frac{x - a}{c - a} & a \leq x \leq c \\ \frac{b - x}{b - c}, & c < x \leq b \end{cases}$$

where $c = \frac{a+b}{2}$.

This function ensures that values near the middle of the range (e.g., 26–50) have higher membership in the “Dissatisfied” category, while values at the edges gradually lose their membership. It allows the fuzzy system to interpret customer ratings that are not clearly satisfied or dissatisfied, but somewhere in between.

Customers who fall under the “Satisfied” category regarding loan products are evaluated using a trapezoidal membership function, which allows for a smooth transition between satisfaction levels. This function is particularly useful for modeling responses that are not strictly binary, capturing the gradual nature of customer perceptions.

The general form of the membership function $\mu(x)$ for the “Satisfied” fuzzy set is as follows:

$$\mu_S(x) = \begin{cases} 0, & x \leq a \text{ or } x > b \\ \frac{x - a}{c - a} & a \leq x \leq c \\ \frac{b - x}{b - c}, & c < x \leq b \end{cases}$$

where $c = \frac{a+b}{2}$.

This function ensures that values near the center of the defined range (e.g., 51–75) have the highest membership in the “Satisfied” category, while values closer to the boundaries gradually lose their membership. It reflects the reality that customer satisfaction is often expressed in degrees rather than absolutes.

Customers who fall under the “Very Satisfied” category regarding loan products are evaluated using a linear increasing membership function. This function is designed to

represent a strong positive perception, where higher input values correspond to higher degrees of membership in the fuzzy set.

The general form of the membership function $\mu(x)$ for this category is:

$$\mu_{vs}(x) = \begin{cases} 0, & x \leq a \\ \frac{x-a}{b-a} & a \leq x \leq b \\ 1, & x > b \end{cases}$$

This function ensures that values closer to the upper bound of the domain (e.g., 76–100) are strongly associated with the “Very Satisfied” category. It reflects the idea that customers who give high ratings are fully satisfied with the loan product offered by the cooperative.

The same membership function formulas used to evaluate customer satisfaction with loan products also apply to the variable service quality, which is assessed using the same four fuzzy categories: “Very Dissatisfied”, “Dissatisfied”, “Satisfied”, and “Very Satisfied”. Each category is defined within a specific domain (e.g., 0–100) and represented by a membership function that determines the degree to which a numerical input belongs to that category.

For the “Very Dissatisfied” category, a linear decreasing function is used, where the membership value is 1 at the lowest score and gradually decreases to 0 as the score increases. The “Dissatisfied” and “Satisfied” categories use trapezoidal functions, allowing for partial membership across a range of values, with the highest membership at the midpoint. Finally, the “Very Satisfied” category uses a linear increasing function, where membership starts at 0 and increases to 1 as the score approaches the upper bound.

Stage 3: Implication Function and Rule Composition

In the Mamdani fuzzy inference approach, the implication function and rule composition are key components that determine how fuzzy inputs are processed to generate fuzzy outputs. The implication function uses the Min operator to evaluate fuzzy logic statements involving the logical AND, while the rule composition applies the Max operator for statements involving logical OR.

The general formula for implication and rule composition in the Mamdani fuzzy system is expressed as:

$$a = \min(\mu_A(x), \mu_B(y))$$

where:

- $\mu_A(x)$ is the membership value of input variable A (e.g., loan product),

- $\mu_B(y)$ is the membership value of input variable B (e.g., service quality),
- a is the degree of truth for the rule's premise, which is then used to determine the fuzzy output.

This process ensures that the fuzzy system can logically combine multiple inputs and apply the appropriate rules to generate meaningful fuzzy conclusions. The use of Min and Max operators allows the system to handle overlapping and conflicting rules in a consistent and interpretable way.

Stage 4: Defuzzification

Defuzzification is the final step in the Mamdani fuzzy inference process, where the aggregated fuzzy output is converted into a single crisp value for practical decision-making. The most widely used method for defuzzification is the centroid method (also known as the center of gravity method). This approach calculates the crisp output as the center of area under the aggregated fuzzy output set, ensuring that the result reflects the combined influence of all activated rules and their respective degrees of truth.

Mathematically, the centroid method is expressed as:

$$\mu(x) = \frac{\int_a^b x \cdot \mu(x) dx}{\int_a^b \mu(x) dx}$$

where:

- $\mu(x)$ is the membership value of the output variable,
- a and b are the lower and upper bounds of the output domain.

Defuzzification is crucial because, while fuzzy logic allows for nuanced reasoning and overlapping categories, real-world applications require a definite output for decision-making. The centroid method is favoured for its ability to provide a balanced and representative crisp value from the fuzzy output set.

RESULTS AND DISCUSSION

The results of this study are based on data collected from 100 active customers of KOMIDA Ajibarang Branch through structured questionnaires. The analysis focused on two main indicators “Loan Product” and “Service Quality”, each evaluated using four fuzzy satisfaction categories “Very Dissatisfied”, “Dissatisfied”, “Satisfied”, and “Very Satisfied”. The Mamdani fuzzy inference system was applied to process the data and interpret customer perceptions in a structured and quantitative manner.

Table 1. Fuzzification Results for Loan Product and Service Quality Indicators

Indicator	Satisfaction Category	Fuzzification Results
Loan Product	Very Dissatisfied	0.96
	Dissatisfied	0.00
	Satisfied	1.00
	Very Satisfied	0.00
Service Quality	Very Dissatisfied	0.96
	Dissatisfied	0.00
	Satisfied	1.00
	Very Satisfied	0.00

Source: Processed primary data (2025)

Table 1 presents the results of the fuzzification process for both *loan product* and *service quality* indicators. The data were obtained from primary surveys of 100 active members of KOMIDA Ajibarang in 2025 and then processed using the Mamdani fuzzy inference system.

For the *loan product* variable, the highest membership value is observed in the “Satisfied” category ($\mu = 1.00$), indicating that the majority of respondents perceive the cooperative’s loan products positively and in line with their expectations. A significant portion also falls under the “Very Dissatisfied” category ($\mu = 0.96$), suggesting that although most customers are satisfied, a small segment of members still express strong dissatisfaction with the loan product features, such as repayment flexibility or loan procedures. Meanwhile, the “Dissatisfied” and “Very Satisfied” categories record very low membership values ($\mu = 0.00$), showing little association with respondents’ evaluations.

For the *service quality* variable, the fuzzification results follow a similar pattern. The “Satisfied” category again achieves the highest membership value ($\mu = 1.00$), reflecting that cooperative members generally consider KOMIDA’s service delivery (such as staff friendliness, responsiveness, and clarity of information) as adequate. However, the “Very Dissatisfied” category also records a relatively high value ($\mu = 0.96$), signaling that certain members remain critical of specific service aspects. As with loan products, the “Dissatisfied” and “Very Satisfied” categories show no significant membership ($\mu = 0.00$).

Overall, the fuzzification results suggest that most cooperative members perceive KOMIDA’s loan products and service quality as satisfactory. Nevertheless, the presence of high values in the “Very Dissatisfied” category highlights the need for management to pay closer attention to segments of members who still experience dissatisfaction,

ensuring that improvements can be directed toward more inclusive and consistent service quality.

Implication Function and Rule Composition

This study uses two main input variables, namely loan products and service quality, each divided into four fuzzy sets: “Very Dissatisfied” (SKP), “Dissatisfied” (KP), “Satisfied” (P), and “Very Satisfied” (SP). Thus, a total of $4 \times 4 = 16$ fuzzy rule combinations are formed, where each rule reflects a specific condition that influences the output, which is the customer satisfaction level.

Rule 1

If Loan Product is SKP and Service Quality is SKP, then the Customer Satisfaction Level is SKP.

$$a = \min(\mu_{\text{Loan Product SKP}}(1), \mu_{\text{Service Quality SKP}}(0)) = \min(0.96; 0.96) = 0.96.$$

Rule 2

If Loan Product is SKP and Service Quality is KP, then the Customer Satisfaction Level is SKP.

$$a = \min(\mu_{\text{Loan Product SKP}}(1), \mu_{\text{Service Quality SKP}}(1)) = \min(0.96; 0) = 0.$$

Rule 3

If Loan Product is SKP and Service Quality is P, then the Customer Satisfaction Level is SKP.

$$a = \min(\mu_{\text{Loan Product SKP}}(1), \mu_{\text{Service Quality SKP}}(63)) = \min(0.96; 1.00) = 0.96.$$

Rule 4

If Loan Product is SKP and Service Quality is SP, then the Customer Satisfaction Level is SKP.

$$a = \min(\mu_{\text{Loan Product SKP}}(1), \mu_{\text{Service Quality SKP}}(35)) = \min(0.96; 0) = 0.$$

Rule 5

If Loan Product is KP and Service Quality is SKP, then the Customer Satisfaction Level is SKP.

$$a = \min(\mu_{\text{Loan Product SKP}}(6), \mu_{\text{Service Quality SKP}}(0)) = \min(0; 0.96) = 0.$$

Rule 6

If Loan Product is KP and Service Quality is KP, then the Customer Satisfaction Level is KP.

$$a = \min(\mu_{\text{Loan Product SKP}}(6), \mu_{\text{Service Quality SKP}}(1)) = \min(0; 0) = 0.$$

Rule 7

If Loan Product is KP and Service Quality is P, then the Customer Satisfaction Level is KP.

$$a = \min(\mu_{\text{Loan Product SKP}}(6), \mu_{\text{Service Quality SKP}}(63)) = \min(0; 1.00) = 0.$$

Rule 8

If Loan Product is KP and Service Quality is SP, then the Customer Satisfaction Level is KP.

$$a = \min(\mu_{\text{Loan Product SKP}}(6), \mu_{\text{Service Quality SKP}}(35)) = \min(0; 0) = 0.$$

Rule 9

If Loan Product is P and Service Quality is SKP, then the Customer Satisfaction Level is P.

$$a = \min(\mu_{\text{Loan Product SKP}}(9), \mu_{\text{Service Quality SKP}}(0)) = \min(0; 0.96) = 0.$$

Rule 10

If Loan Product is P and Service Quality is KP, then the Customer Satisfaction Level is P.

$$a = \min(\mu_{\text{Loan Product SKP}}(63), \mu_{\text{Service Quality SKP}}(1)) = \min(1; 0) = 0.$$

Rule 11

If Loan Product is P and Service Quality is P, then the Customer Satisfaction Level is P.

$$a = \min(\mu_{\text{Loan Product SKP}}(63), \mu_{\text{Service Quality SKP}}(63)) = \min(1.00; 1.00) = 1.00.$$

Rule 12

If Loan Product is P and Service Quality is SP, then the Customer Satisfaction Level is P.

$$a = \min(\mu_{\text{Loan Product SKP}}(63), \mu_{\text{Service Quality SKP}}(35)) = \min(1.00; 0) = 0.$$

Rule 13

If Loan Product is SP and Service Quality is SKP, then the Customer Satisfaction Level is SP.

$$a = \min(\mu_{\text{Loan Product SKP}}(31), \mu_{\text{Service Quality SKP}}(0)) = \min(0; 0.96) = 0.$$

Rule 14

If Loan Product is SP and Service Quality is KP, then the Customer Satisfaction Level is SP.

$$a = \min(\mu_{\text{Loan Product SKP}}(31), \mu_{\text{Service Quality SKP}}(1)) = \min(0; 0) = 0.$$

Rule 15

If Loan Product is SP and Service Quality is P, then the Customer Satisfaction Level is SP.

$$a = \min(\mu_{\text{Loan Product SKP}}(31), \mu_{\text{Service Quality SKP}}(63)) = \min(0; 1.00) = 0.$$

Rule 16

If Loan Product is SP and Service Quality is SP, then the Customer Satisfaction Level is SP.

$$a = \min(\mu_{\text{Loan Product SKP}}(31), \mu_{\text{Service Quality SKP}}(35)) = \min(0; 0) = 0.$$

The fuzzy inference system in this study is constructed from a total of sixteen rules, derived from the combination of four satisfaction categories for *loan products* and four categories for *service quality*. Each rule represents a logical relationship between the two input variables and the resulting customer satisfaction output. The implication function applies the Min operator to determine the firing strength of each rule, while the overall composition uses the maximum operator to aggregate the outcomes of all active rules.

For instance, *Rule 1* states that if loan product is “Very Dissatisfied” and service quality is “Very Dissatisfied,” then customer satisfaction is “Very Dissatisfied.” This captures the scenario where poor performance on both indicators leads to the lowest satisfaction outcome. Similarly, *Rule 11* specifies that if loan product is “Satisfied” and service quality is “Satisfied,” then customer satisfaction is “Satisfied.” This rule reflects the alignment between moderately positive perceptions of both indicators and a corresponding satisfaction level. At the highest end, *Rule 16* establishes that if loan

product is “Very Satisfied” and service quality is “Very Satisfied,” then customer satisfaction is “Very Satisfied.”

The remaining rules account for mixed combinations, such as when loan product is rated “Dissatisfied” but service quality is rated “Satisfied,” or vice versa. In such cases, the system balances the membership values of both inputs, ensuring that the final satisfaction output reflects the relative weight of each factor. This approach allows the Mamdani fuzzy inference system to capture nuanced customer perceptions, where one dimension may compensate for weaknesses in another.

Overall, the rule base ensures that all possible scenarios are covered, from the lowest to the highest satisfaction levels. By employing the minimum/maximum composition method, the system can integrate overlapping or conflicting evaluations, thereby producing a comprehensive fuzzy output that mirrors the complexity of real-world customer experiences.

Defuzzification

Defuzzification is the final stage in the Mamdani fuzzy inference process, which converts the aggregated fuzzy output into a single crisp value for decision-making. In this study, the Centroid (Center of Gravity) method was applied because it provides a balanced representation of the aggregated fuzzy set.

In our system, the aggregation stage yields a maximum Minimum (rule-firing) value of 1.00 for *Rule 11*, mapped to the output domain [51, 75] in the evaluation category “Satisfied.” Under this condition, the aggregated output is

$$\mu(x) = \frac{\int_{51}^{75} x \cdot \mu(x) dx}{\int_{51}^{75} \mu(x) dx} = \frac{1.512}{24} = 63.$$

The defuzzified score of 63, which falls within the interval [51 – 75], corresponds to the linguistic set “Satisfied (P)”. This indicates that members of KOMIDA Ajibarang generally perceive both the loan product and service quality dimensions as adequate and in line with their expectations. In other words, customers recognize that the cooperative provides products that are relevant to their financial needs and services that are delivered in a professional and responsive manner. The score also highlights that, although there are still respondents who express dissatisfaction, as evidenced by the fuzzification values observed in the “Very Dissatisfied” category, the overall balance of perceptions remains positive, with satisfaction outweighing dissatisfaction.

From a methodological perspective, this result is consistent with the fuzzy Mamdani inference process, which emphasizes the aggregation of multiple rules into a single, interpretable outcome. The fact that *Rule 11* achieved the highest firing strength ($\mu = 1.00$) reinforces the finding that most cooperative members cluster around the mid-level positive evaluations rather than at the extremes of “very dissatisfied” or “very satisfied.” This pattern suggests that the cooperative has successfully met baseline expectations, but there remains scope to elevate member perceptions into the “Very Satisfied” category through continuous improvements in service quality and product innovation.

Furthermore, the score of 63 can be benchmarked against other fuzzy satisfaction studies. For instance, in a fuzzy-based evaluation of public services, scores in the “Satisfied” interval often represent institutions that meet operational standards but have not yet achieved excellence (Martin & Nilawati, 2018). Likewise, comparative studies on microfinance services report that satisfaction levels in this range tend to correlate with customer retention but not necessarily with high levels of loyalty or advocacy (Tegambwage, 2025). In this context, KOMIDA Ajibarang’s position indicates a solid foundation of trust among its members, while also pointing to the strategic need for service differentiation and more personalized loan products to push satisfaction scores closer to the “Very Satisfied” range (76–100).

Comparison with recent literature. While centroid is widely used and often preferred for stability and interpretability, recent comparative studies show that no single defuzzification method is universally superior. For instance, in a production-planning setting (daily tofu output), MOM achieved the best accuracy among centroid, bisector, MOM/SOM/LOM, highlighting that the shape of the aggregated surface and task objectives can shift the optimal choice (Mada, Dethan, & Maharani, 2022). A control-oriented comparison likewise reports performance differences across centroid/area-based and modal methods in Mamdani controllers, underscoring the importance of method-dependent behaviour (Kulikova, 2021). Method-selection guidelines within the last decade also recommend reporting and justifying the chosen method and conducting a sensitivity analysis to demonstrate robustness of conclusions (Talon & Curt, 2017).

Moreover, a comparative study in the medical domain, specifically diagnosing coronary artery disease, found that the centroid method achieved 95% accuracy on test data, outperforming the Mean of Maxima (MOM) method, which scored around 90%

(Patil, Patil, Kiran, Hope, & Hosptal, 2021). This supports the idea that centroid is especially well suited in contexts where outputs must reliably reflect a balanced view of multiple activated rules rather than being overly influenced by peak membership values. For customer satisfaction studies, this suggests that centroid helps avoid over-emphasizing extreme perceptions and gives a more stable, moderate assessment that better aligns with most respondents' feelings.

In addition, research on air quality assessment shows that the choice of defuzzification method can significantly influence the outcome depending on the membership functions used and the shape of the aggregated fuzzy set. In "Evaluating the Impact of Membership Functions and Defuzzification Methods in a Fuzzy System: Case of Air Quality Levels", authors compared several defuzzification techniques and found differences in the crisp output depending on how skewed or symmetric the aggregated fuzzy sets were (Lima, Patiño-León, Orellana, & Zambrano-Martinez, 2025). This implies that in your study, even though centroid gave a score of 63, the shape of the aggregated membership function (whether sharply peaked or broad) matters; if the membership functions for "Satisfied" or adjacent categories are wide or overlapping, that can moderate or buffer sharp changes in the final score.

Finally, broader evidence from industrial engineering also shows that while centroid is often preferred for interpretability and balance, alternative methods may perform better under specific decision-making goals. For example, "Fuzzy Extent Analysis: comparison of defuzzification methods" examined ranking fuzzy weights in FAHP and concluded that some simpler methods (e.g., average of interval bounds) produced comparable results when the aggregated fuzzy sets were narrow and less overlapping (Ahmed & Kilic, 2016). Thus, a recommendation for studies like yours is to include a sensitivity analysis: compute the defuzzified score using one or two other methods (e.g., MOM or bisector) and check whether the "Satisfied" categorization remains robust. If the outcome remains consistent, the confidence in the centroid-based conclusion increases; if not, one may need to argue more about why centroid is the appropriate choice in this cooperative context.

CONCLUSION

The study concludes that the overall customer satisfaction level at KOMIDA Ajibarang is categorized as "Satisfied," with a defuzzification score of 63. This indicates that customers have a positive perception of both loan products and service quality. The

application of the Fuzzy Mamdani method has proven to be an effective analytical tool for evaluating customer satisfaction under conditions of uncertainty and subjectivity. Furthermore, these findings suggest that improving service quality and loan product offerings can significantly enhance customer loyalty. The results provide valuable insights into developing more effective marketing and service strategies to sustain and strengthen customer satisfaction.

REFERENCES

- Ahmed, F., & Kilic, K. (2016). FUZZY EXTENT ANALYSIS: COMPARISON OF DEFUZZIFICATION METHODS. Proceedings of the International Conference on Industrial Engineering and Operations Management, 8-10 March, 1013–1018.
- Caraveo-cacep, M. A., & Vázquez-medina, R. (2025). FUZZY CLASSIFIER BASED ON MAMDANI INFERENCE AND STATISTICAL FEATURES OF THE TARGET POPULATION. 1–22.
- Darmayasa & Yasa. (2021). THE INFLUENCE OF RELATIONSHIP MARKETING ON CUSTOMER LOYALTY: CUSTOMER SATISFACTION AS A MEDIATION VARIABLE. International Research Journal of Management, IT & Social Sciences, 8(6), 648–660.
- Freddy, R. (2017). CUSTOMER SERVICE SATISFACTION & LOYALTY. 45.
- Kallmuenzer, A., Mikhaylov, A., Chelaru, M., & Czakon, W. (2025). ADOPTION AND PERFORMANCE OUTCOME OF DIGITALIZATION IN SMALL AND MEDIUM-SIZED ENTERPRISES. Review of Managerial Science, 19(7), 2011–2038. <https://doi.org/10.1007/s11846-024-00744-2>
- Kanyurhi & Akonkwa. (2016). INTERNAL MARKETING, EMPLOYEE JOB SATISFACTION, AND PERCEIVED ORGANIZATIONAL PERFORMANCE IN MICROFINANCE INSTITUTIONS. International Journal of Bank Marketing, 34(5), 773–796.
- Kulikova. (2021). COMPARING THE VARIOUS DEFUZZIFICATION METHODS OPERATION IN THE MAMDANI TYPE FUZZY CONTROLLERS IN AUTOMATIC CONTROL SYSTEMS. AIP Conference Proceedings, 2389(1).
- Lima, J. F., Patiño-León, A., Orellana, M., & Zambrano-Martinez, J. L. (2025). EVALUATING THE IMPACT OF MEMBERSHIP FUNCTIONS AND DEFUZZIFICATION METHODS IN A FUZZY SYSTEM: CASE OF AIR

- QUALITY LEVELS. *Applied Sciences* (Switzerland), 15(4), 1–16.
<https://doi.org/10.3390/app15041934>
- Luh, P. K. (2025). EXAMINING THE EFFECT OF INTELLECTUAL CAPITAL EFFICIENCY ON MICROFINANCE INSTITUTIONS' PERFORMANCE: THE CASE OF A DEVELOPING ECONOMY. *Management Matters*, (September). <https://doi.org/10.1108/manm-04-2024-0026>
- Mada, G. S., Dethan, N. K. F., & Maharani, A. E. S. H. (2022). THE DEFUZZIFICATION METHODS COMPARISON OF MAMDANI FUZZY INFERENCE SYSTEM IN PREDICTING TOFU PRODUCTION. *Jurnal Varian*, 5(2), 137–148. <https://doi.org/10.30812/varian.v5i2.1816>
- Marín Díaz, G., & Carrasco González, R. A. (2023). FUZZY LOGIC AND DECISION MAKING APPLIED TO CUSTOMER SERVICE OPTIMIZATION. *Axioms*, 12(5). <https://doi.org/10.3390/axioms12050448>
- Martin, M., & Nilawati, L. (2018). MODEL FUZZY MAMDANI UNTUK PENILAIAN TINGKAT KEPUASAN PELAYANAN PENGADUAN MASYARAKAT. *Jurnal Informatika*, 5(2), 237–247. <https://doi.org/10.31311/ji.v5i2.4170>
- Mittal, V., Han, K., Frennea, C., Blut, M., Shaik, M., Bosukonda, N., & Sridhar, S. (2023). CUSTOMER SATISFACTION, LOYALTY BEHAVIORS, AND FIRM FINANCIAL PERFORMANCE: WHAT 40 YEARS OF RESEARCH TELLS US. *Marketing Letters*, 34(2), 171–187. <https://doi.org/10.1007/s11002-023-09671-w>
- Moussaoui, A., & Radenovi, S. (2025). FUZZY METRIC SPACES : A SURVEY ON FIXED POINT RESULTS , CONTRACTION PRINCIPLES AND SIMULATION FUNCTIONS. 4.
- Patil, M., Patil, V., Kiran, A., Hope, J., & Hosptal, C. (2021). Copyright © 2021 WOLTERS KLUWER HEALTH , Inc . All rights reserved . 39(March), 2021.
- Talon, A., & Curt, C. (2017). SELECTION OF APPROPRIATE DEFUZZIFICATION METHODS: APPLICATION TO THE ASSESSMENT OF DAM PERFORMANCE. *Expert Systems with Applications*, 70, 160–174. <https://doi.org/10.1016/j.eswa.2016.09.004>
- Tegambwage, A. G. (2025). MULTILEVEL RELATIONSHIPS AND LOYALTY IN THE MICROFINANCE INDUSTRY: EVIDENCE FROM TANZANIA. *Journal of Business and Socio-Economic Development*, 5(1), 71–83. <https://doi.org/10.1108/JBSED-01-2023-0006>

Vidal-martínez, R., García-martínez, J. R., Rojas-galván, R., Álvarez-alvarado, J. M., Gozález-lee, M., & Rodríguez-reséndiz, J. (2025). A REVIEW OF MAMDANI , TAKAGI – SUGENO , AND TYPE-2 FUZZY CONTROLLERS FOR MPPT AND POWER MANAGEMENT IN PHOTOVOLTAIC SYSTEMS. 1–32.