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Application of the Fuzzy Mamdani Method to Predict the Number of Customers Based on the Weather and Holidays in a Simple Restaurant on Abdul Hakim Street

Parapat Gultom[*1], Wendy Thianujaya[2], Annisa Hidayati Sirait[2], Abel Kristian[2]

[1]*Department of Mathematics, Universitas Sumatera Utara, Medan, 20155, Indonesia*
[2]*Student of Mathematics, Universitas Sumatera Utara, Medan, 20155, Indonesia*
[*]Corresponding Author: parapat@usu.ac.id

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ABSTRACT

This research aims to optimize marketing strategies in the food industry by applying the Fuzzy Mamdani method. This approach considers factors such as the number of customers, weather conditions, and holidays to forecast the number of customers who will come to a simple restaurant. By using the Fuzzy Mamdani model, this research seeks to generate more effective marketing strategies by taking into account variability in consumer behavior. The results of this research are expected to help food business owners to optimize their raw material inventory more precisely, so as to improve operational efficiency and increase customer satisfaction.

Keyword: Fuzzy Mamdani Method, Marketing Strategy, Number of Customers, Weather, Holiday

1. Introduction

Marketing strategy can be realized in a directed plan in the field of marketing, to obtain an optimal result. Marketing strategy is a very important and influential thing for a business or business. In recent years the business industry in the culinary field has increased quite well[1], [2]. This has encouraged many entrepreneurs to open or create new businesses or develop existing businesses, which at the same time creates competition with other entrepreneurs. It can be seen from the proliferation of eating and drinking places in Medan, especially in susuk, making entrepreneurs have to provide added value to products, services, and services to be provided to consumers who are mostly students. This added value will make consumers choose an attractive place and dish so that it becomes the choice of consumers[3], [4].

Therefore, every entrepreneur will carry out various kinds of marketing strategies in order to increase their sales volume. With the increase in sales volume, the company will also get the desired profit. The better the marketing strategy used by the company, the greater the company's opportunity to expand market share[5], [6].

To achieve the desired sales target, entrepreneurs need to optimize the best marketing strategy that will produce maximum sales results. In doing this optimization, of course, entrepreneurs need to pay attention to important variables in the sales process, such as the number of customers, weather, holidays and others. In this case, the author will only focus on these three variables[7]–[9].

A form or plan that integrates the main objectives, policies and courses of action in an organization into a unified whole. A well-formulated strategy will help organize and allocate resources into a unique and survivable form. Of course, it also takes into account important variables in the sales process.[10], [11]

2. Method

2.1 Strategy

Strategy is defined as a process in determining the plans of leaders who focus on the long-term goals of an organization, followed by the preparation of a way or effort to achieve these goals. Strategies are steps that must be taken to achieve goals. Sometimes the steps to be faced are steep and tortuous, but there are also steps that are relatively easy. In addition, there are many obstacles or trials that must be carried out carefully and purposefully. Strategy is cleanliness and convenience of the premises can also affect sales success in the culinary industry[12], [13].

In some cases, specialized sales strategies are used in the culinary industry, such as special food or drink promotions, certain discounts, or collaborations with online food ordering platforms to increase visibility and reach more customers[14], [15].

In the culinary business, sales are not just about selling products, but also about providing positive experiences to customers, building strong relationships with them, and maintaining customer loyalty to ensure business growth and sustainability. A form or plan that integrates the main objectives, policies and courses of action in an organization into a unified whole. A well-formulated strategy will help organize and allocate resources into a unique and survivable form. Of course, it also takes into account important variables in the sales process[16]–[18].

2.2 Marketing

Marketing is an organizational function and a set of processes for creating, communicating, and delivering value to customers and managing customer relationships in a way that benefits the organization and its shareholders[19], [20]. In marketing there are three important points, namely:

1. Organizational functions
2. Activities of creating, communicating, delivering value
3. Building good relationships with customers

2.3 Marketing Strategy

A marketing strategy is a plan or approach designed to achieve the marketing objectives of a product or service. In this case, of course, it will involve factors such as the number of customers, holidays and weather which will be used to assess trends in consumer behavior. In general, successful companies are companies that implement consumer-oriented marketing concepts, because these companies are able to dominate the market in the long term. In the view of the marketing concept, the company's goals are achieved through the number of sales results obtained every day by considering the number of consumers, holidays and weather, to anticipate waste.

2.4 Sales

Sales refers to the process of selling food, beverages or other related products to consumers. Sales involves many aspects, including food or beverage preparation, attractive product presentation, friendly and efficient customer service, and inventory and stock management. In addition, factors such as taste quality, price, describes the extent to which an element belongs to a fuzzy set. The membership function relates each element in the domain of the set with a membership level value, which is usually in the range between 0 and 1.

There are several types of membership functions commonly used in fuzzy sets, such as triangular membership function, trapezoidal membership function, or Gaussian membership function, each of which is suitable for modeling different levels of membership in fuzzy sets depending on the application context.
Membership functions are an important component in fuzzy modeling because they allow us to express uncertainty and vagueness in a more flexible way than conventional sets. By using membership functions, we can describe precisely the extent to which an element belongs to a fuzzy set, which enables more careful decision-making in uncertain contexts.

2.5 Fuzzy Sets

A fuzzy set is a type of mathematical set that extends the concept of a conventional set by introducing a continuous membership value. In a fuzzy set, each element has a membership value within the set that can range from 0 to 1, indicating the extent to which the element belongs to the set. This allows for better representation of uncertainty or vagueness in modeling and decision-making, especially in contexts where the boundaries between members and non-members are unclear. In a crisp set, the membership value in a set A(μA(ℵ)) has two possibilities, namely :

1. One (1) which means that an item is a member of the set.
2. Zero (0) which means that an item is not a member of a set.

There are several things that are basic in understanding fuzzy logic, among others:

1. Fuzzy variables, namely variables that will be discussed in a fuzzy system.
2. Fuzzy set, which is a group that represents a certain state in a fuzzy variable.
3. The universe of speech, namely all values that are allowed to be operated on in a fuzzy variable.
4. The domain of a fuzzy set, which is all the values allowed in the universe of speech and may be operated in a fuzzy set.

2.6 Membership Function

The membership function in the context of fuzzy sets is a mathematical function that describes the extent to which an element belongs to a fuzzy set. The membership function relates each element in the domain of the set with a membership level value, which is usually in the range between 0 and 1.

There are several types of membership functions commonly used in fuzzy sets, such as triangular membership function, trapezoidal membership function, or Gaussian membership function, each of which is suitable for modeling different levels of membership in fuzzy sets depending on the application context.

Membership functions are an important component in fuzzy modeling because they allow us to express uncertainty and vagueness in a more flexible way than conventional sets. By using membership functions, we can describe precisely the extent to which an element belongs to a fuzzy set, which enables more careful decision-making in uncertain contexts.

2.7 Mamdani Method

The mamdani method is often also known as the max-min method. This method was originally proposed by Ebrahim Mamdani in 1975. The stages required in operating the mamdani method are:

1. Formation of fuzzy sets
2. Application of the implication function in the Mamdani method
3. Rule composition
4. Affirmation (defuzzyfication

2.8 Advantages of Mamdani Method

The Mamdani method is very suitable for solving complex problems with many variables and fuzzy rules.

3 Research Methodology

3.1 Problem identification

Data identification is done by determining the variables needed in calculating and analyzing the problem.
In this study, the research process was influenced by several factors, namely

1. Weather conditions
2. Days off/Holiday

3.2 Data collection

Collecting data needed in calculating and analyzing problems. The data collection process was carried out on April 2, 2024 until completion. Data obtained through direct survey on the object of research.

3.3 Place of research

The research was conducted at Rumah Makan Sederhana located on Jalan Abdul Hakim, Medan.

3.4 Research Method

1. Field research

The research was conducted by interviewing employees, analyzing the problem, and obtaining the information needed.

2. Research

At this stage, it is carried out by looking for sources of theoretical sources regarding fuzzy logic, and programming related to analysis and design.

3. Laboratory research

Research is carried out by designing data.

3.5 Formation of Fuzzy Sets

In the mamdani method, input or output variables are divided into one or more fuzzy sets.

3.6 Affirmation (defuzzy)

This affirmation process is carried out using software assistance.

Tabel 1: Data Analyst

No	Days	Weather	Holidays	Number of Customers
1	Monday	C(29°C)	T(100)	50
2	Thursday	C(32°C)	T(100)	45
3	Wednesday	H(24°C)	T(100)	30
4	Tuesday	S(26°C)	T(100)	35
5	Friday	C(32°C)	T(100)	40
6	Saturday	C(30°C)	T(25)	60
7	Sunday	C(31°C)	Y (0)	80
8	Monday	H(23°C)	T(75)	40
9	Tuesday	S(27°C)	T(75)	50

10	Wednesday	C(32°C)	T(100)	45
11	Thursday	C(31°C)	T(100)	35
12	Friday	H(24°C)	T(100)	30
13	Saturday	S(28°C)	T(75)	70
14	Sunday	C(29°C)	Y (0)	90
15	Monday	C(30°C)	T(50)	40
16	Tuesday	S(27°C)	Y (0)	35
17	Wednesday	C(32°C)	T(75)	50
18	Thursday	H(24°C)	T(75)	40
19	Friday	C(31°C)	T(50)	45
20	Saturday	C(29°C)	T(25)	65
21	Sunday	H(22°C)	T(25)	85
22	Monday	S(25°C)	Y (0)	35
23	Tuesday	C(32°C)	T(100)	40
24	Wednesday	C(32°C)	T(100)	45
25	Thursday	H(23°C)	T(75)	55
26	Friday	S(26°C)	T(75)	40
27	Saturday	C(29°C)	T(50)	75
28	Sunday	C(29°C)	Y(0)	95
29	Monday	H(22°C)	T(50)	30
30	Tuesday	**S(28°C)**	**Y (0)**	**35**

4. Results And Discussion

4.1 Data analysis

The data analysis stage is the most important stage in developing a system, because at this stage an evaluation of the identification of existing problems, system design and steps needed for the desired design to the expected analysis will be carried out.

Data analysis is obtained after direct observation in the object of research of a simple restaurant located in Medan Selayang sub-district, Medan city. The data variables obtained are data on the number of customers, weather, and holidays. The data obtained from February 2024 to March 2024 can be seen from the following table:

1. Day { Monday, Tuesday, Wednesday, Thursday, Friday, Saturday, Sunday}
2. Weather { Sunny (C), Rainy (H), Moderate (S)}
3. Holidays { Yes (Y), No (T)}, in this case to make it easier to understand we interpret it in numerical terms which means if 100 = high level of busyness and vice versa with 0.

4.2 Process Analysis

In calculating fuzzy logic mamdani method, several variables are needed which are the input and output of the calculation method. The variables contained in the case of sales in simple restaurants are the number of customers, weather and holidays.

4.3 Fuzzyfication

There are two main variables for input and 1 output variable to determine the number of customers. Weather input 1, holidays input 2, and the number of customers as output. As can be seen in the table below:

Talking Universe

Function	Variable's name	Universe
Input	Weather	(20 – 35)
	Holidays	(0 – 100)
Output	Number of Customers	(20 – 100)

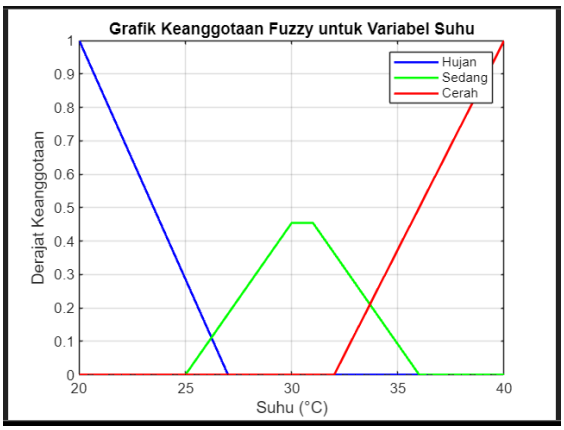
4.4 Analysis for Weather Variables

Weather variables have values expressed as raining, medium and shiny conditions. Where each condition has a predetermined range of values. The range of values set is from the lowest value of 20 $°C$) to the highest value of 40 $°C$). The fuzzy set for input 1 is shown in the following table

Weather Fuzzy Set For Input 1

Variable	Variable Set	Range
Weather	Raining	(20 - 27$°C$)
	Moderate	(25 - 36$°C$)
	Shiny	(32 - 40$°C$)

The fuzzy membership diagram for weather input can be seen in the figure below.



Weather Variable Membership Function

From the fuzzy membership diagram, the equation of the rain fuzzy set can be seen:

$$\mu_r(raining) = \begin{cases} 1\,;20 \\ \dfrac{20-a}{7}\,;20 < a < 27 \\ 0\,;a \geq 27 \end{cases}$$

Moderate fuzzy set equation

$$\mu_r(moderate) = \begin{cases} \frac{a-25}{5} ; 25 \leq a < 30 \\ \frac{32-a}{4} ; 32 < a < 36 \\ 0 ; a \leq 25 \; atau \; a \geq 36 \end{cases}$$

Shiny fuzzy set equation

$$\mu_r(Shiny) = \begin{cases} 0 ; a \leq 32 \\ \frac{a-32}{8} ; 32 < a < 40 \\ 1 ; 40 \end{cases}$$

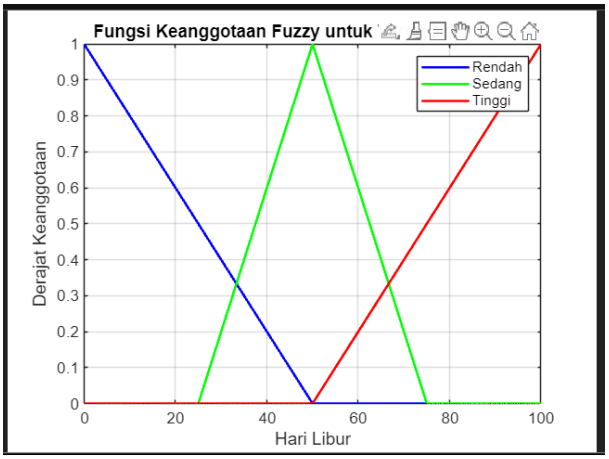
4.5 Analysis for Customer Quantity Variable

The customer quantity variable has values expressed in low, medium, and high conditions. Each condition has a predetermined range of values from the lowest value of 20 to the highest value of 100, based on the data report.

Fuzzy Set of Holidays for Input 2

Variable	Fuzzy Set Variable	Range
Holiday	Low	(0 – 50)
	Medium	(25 – 75)
	High	(50 – 100)

The fuzzy membership diagram for holiday input can be seen in the image below



Membership Function for Holiday Variable

From the fuzzy membership diagram, the equation of the fuzzy set "low" can be observed:

$$\mu_r(low) = \begin{cases} 1 ; 0 \\ \frac{40-a}{40} ; 0 < a < 40 \\ 0 ; a \geq 50 \end{cases}$$

The equation of the fuzzy set "medium":

$$\mu_r(medium) = \begin{cases} \frac{a-25}{25} ; 25 \leq a < 50 \\ \frac{50-a}{25} ; 50 \leq a \leq 75 \\ 0 ; a \leq 25 \ or \ a \geq 75 \end{cases}$$

The equation of the fuzzy set "high":

$$\mu_r(high) = \begin{cases} 0 ; a \leq 50 \\ \frac{a-50}{50} ; 50 \leq a \leq 100 \\ 1 ; 100 \end{cases}$$

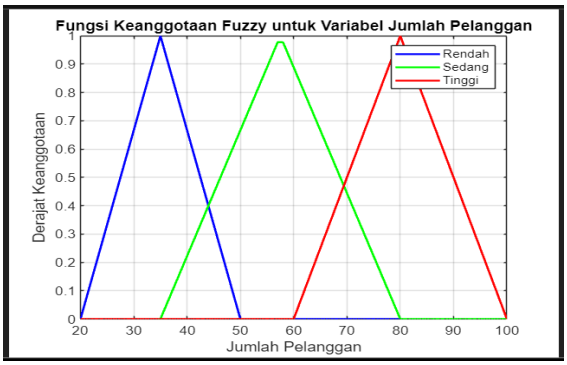
4.6 Analysis for Customer Quantity Variable

The customer quantity variable has values expressed in low, medium, and high conditions. Each condition has a predetermined range of values from the lowest value of 20 to the highest value of 100, based on the data report.

Fuzzy Set of Customer Quantity for Output

Variable	Fuzzy Set Variable	Range
Customer Count	Low	(20– 50)
	Medium	(35 – 80)
	High	(60 – 100)

The fuzzy membership diagram for the holiday input can be seen in the image below.



Membership Function for Customer Quantity Variable

From the fuzzy membership diagram, the equation of the fuzzy set "low" can be observed:

$$\mu_r(low) = \begin{cases} 1 ; 35 \\ \frac{a-20}{15} ; 20 < a < 35 \\ 0 ; a \geq 50, and \ a = 20 \end{cases}$$

The equation of the fuzzy set "medium":

$$\mu_r(medium) = \begin{cases} \frac{a-35}{20} ; 35 \leq a < 55 \\ \frac{55-a}{25} ; 55 \leq a \leq 80 \\ 0 ; a \leq 35 \ or \ a \geq 80 \end{cases}$$

The equation of the fuzzy set "high":

$$\mu_r(high) = \begin{cases} 0\,;a \leq 60\ and\ a = 20 \\ \dfrac{a-60}{20}\,;60 < a < 80\ and\ \dfrac{80-a}{20}\,;80 < a < 100 \\ 1\,;80 \end{cases}$$

4.7 Formation of Roles

From the two fuzzy inputs and one output, we will determine the rules. There are 8 rules obtained based on the input and output.

Role Formation

No	Variable		
	weather	**Holiday**	**Customer Count**
1	Low	High	Low
2	Low	Medium	Low
3	low	Low	Low
4	Medium	High	Medium
5	Medium	Medium	Médium
6	Medium	Low	High
7	High	High	High
8	High	Medium	High

4.8 Data processing with fuzzy mamdani

Manual fuzzy data processing aims to provide an explanation of the application's operation. The process is as follows:

Example:

For a day with weather=29^0C and Non-Holiday = 75^0C. the steps in data processing to determine the number of customers are as follows:

1. Determining Fuzzy Sets The weather variable has been defined in three fuzzy sets: rainy, moderate, and sunny. It is known that the weather at 29°C falls into the fuzzy sets of rainy, moderate, and sunny. Thus, the membership level follows the following function.
    a) Fuzzy set of Rainy Weather (29) = 27-29 / 7 = 0,0 The value 29 is not included in the rainy weather range, so the result obtained is 0,0.
    b) Fuzzy set of Moderate Weather (29) = 32 - 29 / 4 = 0,75. The value 29 is within the moderate weather range, so the result obtained is 0,75.
    c) Fuzzy set of Clear Weather (29) = 29 - 32 / 8 = -0,375. Since the value 29 is not included in the clear weather range, the result obtained is 0,0.

    The variable "holiday" has been defined in three fuzzy sets: low, moderate, and high. The holiday on day 75 falls into the moderate and high fuzzy sets. Thus, the membership levels are as follows according to the following function.
    a) Fuzzy set of Low Holiday (75) = 40 - 75 / 40 = -0,875. Since the value 75 is not included in the low holiday range, the result obtained is 0,0.
    b) Fuzzy set of Moderate Holiday (75) = 75 - 25 / 25 = 2. Since the value 75 is not included in the moderate holiday range, the result obtained is 2.
    c) Fuzzy set of High Holiday (75) = 75 - 50 / 50 = 0,5. Since the value 75 falls within the high holiday range, the result obtained is 0,5.

2. Inference

    [Rule 1] IF (Rainy) and (High Holiday) THEN (Low Customer).

α_1 = min ($\mu_{weather}$ [29], $\mu_{holiday}$ [75]) = min (0,0 ; 0,5) = 0,0

[Rule 2] IF (Rainy) and (Moderate Holiday) THEN (Low Customer).
α_2 = min ($\mu_{weather}$ [29], $\mu_{holiday}$ [75]) = min (0,0 ; 2) = 0,0

[Rule 3] IF (Rainy) and (Low Holiday) THEN (Low Customer).
α_3 = min ($\mu_{weather}$ [29], $\mu_{holiday}$ [75]) = min (0,0 ; 0,0) = 0,0

[Rule 4] IF (Moderate Weather) and (High Holiday) THEN (Moderate Customer).
α_4 = min ($\mu_{weather}$ [29], $\mu_{holiday}$ [75]) = min (0,75 ; 0,5) = 0,5

[Rule 5] IF (Moderate Weather) and (Moderate Holiday) THEN (Moderate Customer).
α_5 = min ($\mu_{weather}$ [29], $\mu_{holiday}$ [75]) = min (0,75 ; 2) = 0,75

[Rule 6] IF (Moderate Weather) and (Low Holiday) THEN (High Customer).
α_6 = min ($\mu_{weather}$ [29], $\mu_{holiday}$ [75]) = min (0,75 ; 0,0) = 0,0
[Rule 7] jika (Cuaca cerah) and (hari libur tinggi) maka (jumlah pelanggan tinggi).
α_7 = min (μ_{cuaca} [29], $\mu_{hari\ libur}$ [75]) = min (0,0 ; 0,5) = 0,0

[Rule 8] jika (Cuaca cerah) and (hari libur sedang) maka (jumlah pelanggan tinggi).
α_8 = min (μ_{cuaca} [29], $\mu_{hari\ libur}$ [75]) = min (0,0 ; 2) = 0,0

3. Defuzzification

The final step in this process is defuzzification or also called the crisp stage. The method used is the centroid method.
The following is a way to convert fuzzy sets into real numbers:
[Rule 1] α_1 = 0,0, then x :
Number of Customers (Low) = (x - 20) / 15 = 0,0 = hence x= 20

[Rule 2] α_2 = 0,0, then x :
Number of Customers (Low) = (x - 20) / 15 = 0,0 = hence x= 20

[Rule 3] α_3 = 0,0, then x :
Number of Customers (Low) = (x - 20) / 15 = 0,0 = hence x= 20

[Rule 4] α_4 = 0,5, then x :
Number of Customers (Moderate) = (x - 35) / 20 = 0,0 = hence x= 45

[Rule 5] α_5 = 0,75, then x :
Number of Customers (Moderate) = (x - 35) / 20 = 0,0 = hence x= 50

[Rule 6] α_6 = 0,0, then x :
Number of Customers (Low) = (x - 60) / 20 = 0,0 = hence x= 60 the same goes for 7 and 8

Therefore, by using defuzzy weighted average method we obtain :

$$Z_1 = \frac{(0{,}5 * 45) + (0{,}75 * 50)}{(0{,}5 + 0{,}75)}$$

$$Z_1 = \frac{(22{,}5) + (33{,}75)}{(1{,}25)}$$
$$Z_1 = 45\ (Moderate)$$

5. Results

Conclusion

Based on research conducted at Rumah Makan Sederhana in Medan City by implementing a new system using fuzzy logic, it can be concluded that the Fuzzy Mamdani method has significant potential in making strategic decisions related to marketing. This research shows that by considering variables such as the number of customers, weather conditions and holidays, the Fuzzy Mamdani method can help predict the number of customers who will come to the restaurant. In this way, food business owners can optimize raw material supplies more precisely, increase operational efficiency and increase customer satisfaction. These findings confirm that the use of the Fuzzy Mamdani method in a marketing context has significant added value in improving business performance and success.

Suggestion

a. Further Application
   It is recommended to continue the development and application of the Fuzzy Mamdani method in the context of restaurant marketing or other businesses. Further research could focus on testing and validating these models across different types of businesses and environments.
b. Variable Expansion
   To improve forecast accuracy, consider expanding the variables considered in the model, such as customer demographic data, industry trends, or other economic factors that may influence consumption patterns.
c. Parameter Optimization
   Carry out further optimization of the parameters in the Fuzzy Mamdani model to ensure that the model provides optimal and reliable results in decision making.
d. Information System Development
   Consider integrating the Fuzzy Mamdani model into an existing management information system or developing a new system that supports data and analysis-based decision making.
e. Training and Education
   Disseminate knowledge about fuzzy logic concepts and their practical applications to stakeholders in the food industry, including business owners, managers and staff, through relevant training and education.

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