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Tsukamoto Method of Fuzzy Logic for Hotel Quality Determination

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KEYWORDS
Analysis; Quality; Fuzzy Tsukamoto

ABSTRACT
The rapid development of the hospitality industry has increased competition among hotels to provide the best services and facilities to attract customers. This study aims to determine hotel quality using the Tsukamoto method of fuzzy logic. The research measures the quality of hotel facilities, room classes, and prices, all of which contribute to visitor comfort. Data were collected from 10 hotels and processed using the Fuzzy Tsukamoto method to categorize hotel quality as either high or low. The analysis showed that variables such as hotel facilities and room class significantly influence the overall quality rating. The results indicated that hotels with complete facilities and higher room classes tend to score higher in quality. This research demonstrates that the Tsukamoto method provides an effective way to assess hotel quality based on multiple variables.

Introduction

The hospitality industry has seen rapid growth in recent years, leading to increased competition among hotels. According to the theory of service quality by Parasuraman et al. (1985) in (Basri, 2019), the quality of services, particularly in the hospitality sector, is a significant determinant of customer satisfaction and loyalty. This makes the evaluation of hotel quality crucial for staying competitive. The application of fuzzy logic in service quality measurement offers a novel approach that accounts for uncertainty and subjectivity in customer satisfaction metrics. This research aims to provide a structured methodology using the Tsukamoto method of fuzzy logic, which allows for a more nuanced and accurate determination of hotel quality. The urgency of this research is rooted in the increasing need for reliable tools that can help hotels improve their services and remain competitive in a saturated market. Hotel management often receives customer complaints about unsatisfactory hotel quality. So that to find out the quality of a hotel, a research was carried out on several hotels with several hotel facility needs.

To obtain research with appropriate results, the researcher uses the implementation of Fuzzy using the Tsukamoto Method in determining the quality of a hotel with a standard value that has been set for hotel determination by measuring the quality of facilities and room supplies that are able to provide comfort for visitors.

In real life, there are aspects in the real world that are always or usually outside of the mathematical model and are Inexact. This concept of uncertainty is the basic concept of the emergence of the concept of fuzzy logic (Abrori & Primahayu, 2015).

Fuzzy logic is one of the components that form soft computing. Fuzzy logic was first introduced by Prof. Lotfi A. Zadeh in 1965. The basis of Fuzzy's Logic is Fuzzy's set theory. In Fuzzy's set theory, the role of membership degree as a determinant of the existence of elements in a set is very important. Membership value or degree of membership or membership is the main feature of the reasoning with the Fuzzy Logic (Andrian, 2015).

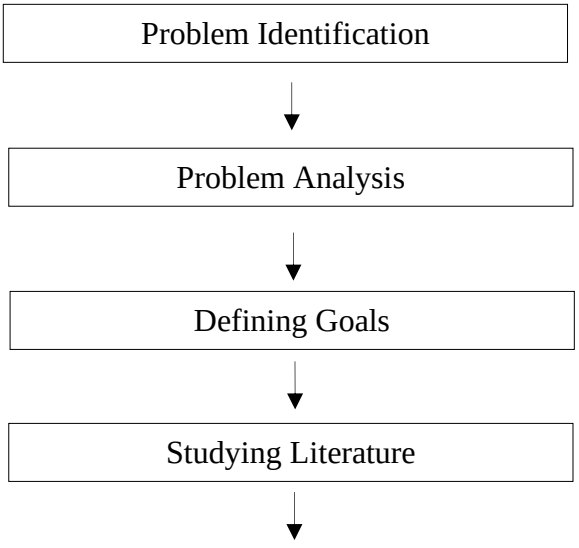
Previous research has applied fuzzy methods in various contexts. For example, Sari and Mahmudi (2015) used Fuzzy Tsukamoto method to determine the eligibility of prospective employees, while Hayadi et al. (2016) applied this method to assess infant health and care. These studies show that fuzzy methods are effective in handling situations involving many variables with high levels of uncertainty. However, the application of fuzzy methods in the context of hotel quality evaluation is still very limited.

This research seeks to fill the gap by applying the Tsukamoto Fuzzy method in determining hotel quality. By considering variables such as room class, hotel facilities, and price, this study aims to produce a rating system that can assist hotel management in making strategic decisions related to improving service quality. This research also differs from previous studies because it does not only focus on one aspect, such as facilities or price, but combines several important factors that affect customer satisfaction. In this context, this research builds a new contribution by providing a more comprehensive approach in determining hotel quality using the Fuzzy Tsukamoto method.

Thus, this research is expected to make a significant contribution to the literature related to the application of fuzzy logic in the hospitality industry, as well as provide practical solutions for hotel management in overcoming the challenges of quality assessment which is often subjective.

Materials and Methods

The research method can be explained in the form of a research framework This framework is the steps that will be taken in solving the problem to be discussed. The framework of this research can be illustrated in the following figure 1.



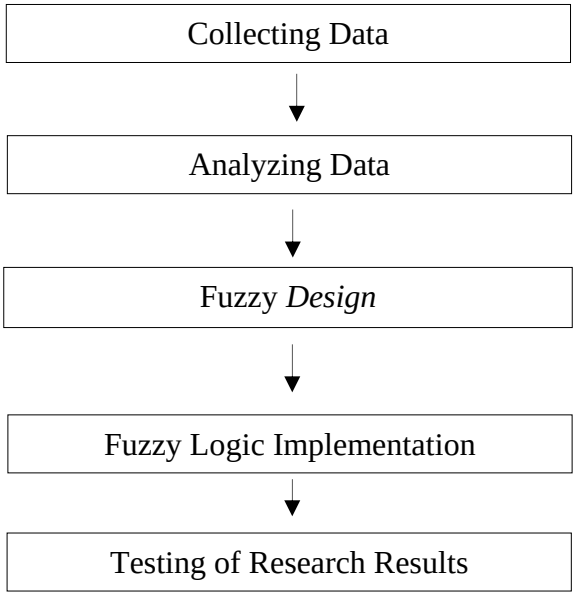


Figure 1. Research Framework

System Analysis and Design

This knowledge-based system contains Fuzzy criteria and sets for each criterion. These criteria are classified into a set of variable languages for determining hotel quality as follows:

1. Room Class Type : Few and Many,
2. Hotel Facilities : Incomplete, Complete, and Very Complete
3. Price : Cheap, Medium, and Expensive

Table 1 is the data taken and observed directly at the research site, which will be presented and analyzed using the Fuzzy Tsukomoto method.

Table 1 Hotel Data

No	Name	Variable		
		Room Class Type	Hotel Facilities	Price
1	Hotel Anordio	4	3	Rp.200.000-Rp.450.000
2	Hotel Triza	5	6	Rp.500.000- Rp.1.000.000
3	Hotel Andini	4	4	Rp.150.000- Rp.450.000
4	Hotel Edotel	5	5	Rp.400.000- Rp.700.000
5	Hotel Aroma	3	2	Rp.200.000- Rp.400.000
6	Hotel Rihan	4	2	Rp.150.000-Rp.450.000
7	Hotel Adi Karya	3	3	Rp.150.000-Rp.450.000
8	Hotel Giszella	6	7	Rp.450.000-Rp.1.000.000
9	Hotel Muthia	4	4	Rp.350.000-Rp.500.000
10	Hotel Langkisau	6	9	Rp.500.000-Rp.1.000.000

The data will be processed using *Fuzzy* logic so that variables can be determined to get *the expected* output.

Table 2 Input and Output Data

Function	Variable	Set
Input	Number of Room Class Types	Little, Many
	Number of Hotel Facilities	Incomplete, Complete, Very Complete
	Hotel Prices	Cheap, Medium, Expensive
Output	Quality	Low, High

Table 3 Fuzzy Input Data

Input	Room Class	Hotel Facilities	Price
A Little	1-4		
Many	3-6		
Incomplate		1-6	
Complate		4-8	
Very Complate		6-10	
Cheap			Rp.150.000-Rp.600.000
Medium			Rp.200.000-Rp.900.000
Expensive			Rp.600.000-Rp.1.000.000

In the Fuzzy input data table, there are 3 variables; the first is the Number of Room Class Types that have a Few and Many sets, where the values ≥ 1 and ≤ 4, which means they enter the set few, while the values ≥ 3 and ≤ 6 which means they enter the set of many. The second is Hotel Facilities, which have a Complete, Incomplete and Very Complete set, where the values of ≥ 1 and ≤ 6 which mean that they enter the Complete set, where the values of ≥ 4 and ≤ 8 mean they enter the Incomplete set, while the values of ≥ 6 and ≤ 10 which means they enter the Very Complete set. The third is Hotel Prices, which have a set of Cheap, Medium and Expensive, where the value of ≥Rp.150,000 and ≤Rp.600,000, which means it enters the Cheap set, where the value of ≥Rp.200,000 and ≤Rp.900,000 goes to the Medium set, while the value of ≥Rp.600,000 and ≤Rp.1,000,000 which means it enters the Expensive set (Abdillah, 2015; Murti et al., 2015).

a. Function of Membership Degree

The membership degree function using the Tsukamoto Method is divided into membership, the number of room class types, the number of hotel facilities, and hotel prices.

Table 4 Membership Function of Room Class Type,

Set	Domain
Few	1-4
Many	3-6

The number of Room Class Types that have a Few and Many sets, where the values ≥ 1 and ≤ 4, which means they enter the set few, while the values ≥ 3 and ≤ 6, which means they enter the set of many.

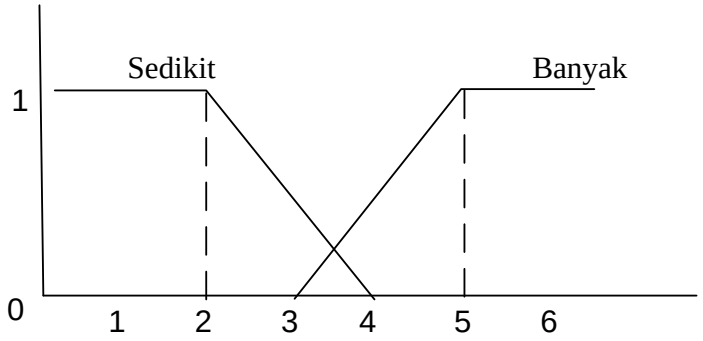


Figure 2. Curve of Number of Room Types

The Slight set uses a membership function in the form of a descending curve, while the Majority set uses a membership function in the form of an ascending curve.

Membership Function:

$$\mu \text{ Little } [x] = \begin{cases} 1; & x \leq 2 \\ (4 - x) / (4 - 2); & 2 \leq x \leq 4 \\ 0; & x \geq 4 \\ 0; & x \leq 3 \end{cases}$$

$$\mu \text{ Many } [x] \begin{cases}) / (5 - 3); & 3 \leq x \leq 5 \\ 1; & x \geq 5 \end{cases}$$

The variable set is Few [1-4], while the variable set Many has a domain [3-6].

Table 5 Functions of Hotel Facility Membership

Set	Domain
Incomplete	1-6
Complete	4-8
Very complete	6-10

The number of Hotel Facilities that have a Complete, Incomplete and Very Complete set, where the values ≥ 1 and ≤ 6, which means they are in the Incomplete set, where the values ≥ 4 and ≤ 8 which means they are in the Complete set, while the values ≥ 6 and ≤ 10 which means they are in the Very Complete set.

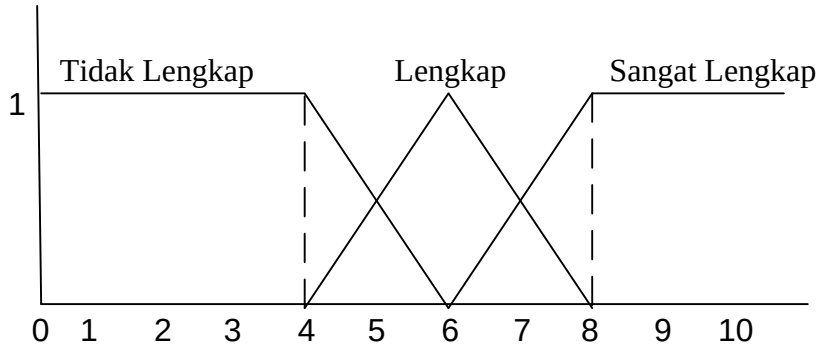


Figure 3. Hotel Facility Curve

Incomplete Sets use a shoulder curve membership function, Complete Sets use a triangular curve membership function, and very complete Sets use a shoulder curve membership function. Membership Function:

$$\mu\text{Tidak Lengkap}[x] = \begin{cases} 1; & x \le 4 \\ (8- x) / (8– 4); & 4 \le x \le 8 \\ 0; & x \ge 8 \end{cases}$$

$$\mu\text{Lengkap}[x] = \begin{cases} 0; & x \le 4 \\ (x - 4) / (6 – 4); & 4 \le x \le 6 \\ (8 – x) / (8 – 6) & 6 \le x \le 8 \\ 1; & x=6 \end{cases}$$

$$\mu\text{Sangat Lengkap}[x] = \begin{cases} 0; & x \le 4 \\ (x – 4) / (6 – 4); & 4 \le x \le 6 \\ 1; & x \ge 8 \end{cases}$$

Incomplete variable sets have domains [1-6], Complete variable sets have domains [4-8], while Very Complete variable sets have domains [6-10].

Table 6 Hotel Price Membership Function

Set	Domain
Cheap	Rp.150.000-Rp.600.000
Medium	Rp.200.000-Rp.900.000
Expensive	Rp.600.000-Rp.1.000.000

Hotel prices that have a set of Cheap, Medium and Expensive, where the value ≥ Rp.150,000 and ≤Rp. 600,000 which means it goes into the Cheap set, where the value is ≥Rp. 200,000 and ≤Rp. 900,000 goes to the Medium set, while the value of ≥600,000 and ≤ Rp.1,000,000 which means it goes to the Expensive set.

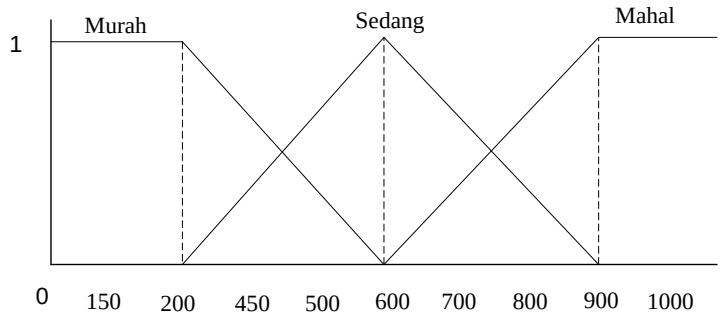


Figure 4. Hotel Price Curve

The Cheap Set uses a membership function in the form of a shoulder curve, the Medium Set uses a membership function in the form of a triangle curve, and while the Expensive Set uses a membership function in the form of a shoulder curve.

Membership Function:

$$\mu\text{Murah}[x] = \begin{cases} 1; & x \le 200.000 \\ (600.000 - x) / (600.000 - 200.000); & 200.000 \le x \le 600.000 \\ 0; & x \ge 600.000 \end{cases}$$

$$\mu\text{Sedang}[x] = \begin{cases} 0; & x \le 200.000 \\ (x - 200.000) / (600.000 - 200.000); & 200.000 \le x \le 600.000 \\ (900.000 - x) / (900.000 - 600.000) & 600.000 \le x \le 900.000 \\ 1; & x=600.000 \end{cases}$$

$$\mu\text{Mahal}[x] = \begin{cases} 0; & x \le 600.000 \\ (x - 600.000) / (900.000 - 600.000); & 600.000 \le x \le 1.000.000 \\ 1; & x \ge 900.000 \end{cases}$$

The Variable Set is Cheap [Rp.150,000-Rp.600,000], the Medium variable set has a domain [Rp.200,000-Rp.900,000], while the *Expensive fuzzy* set has a domain [Rp.600,000-Rp.1000,000].

Table 7 Quality Membership Functions

Set	Domain
Low	0-4
High	3-6

The Output results have Low and High values, where the values of ≥0 and ≤4 mean they enter the Low set, while the values of ≥3 and ≤6 mean they have High values.

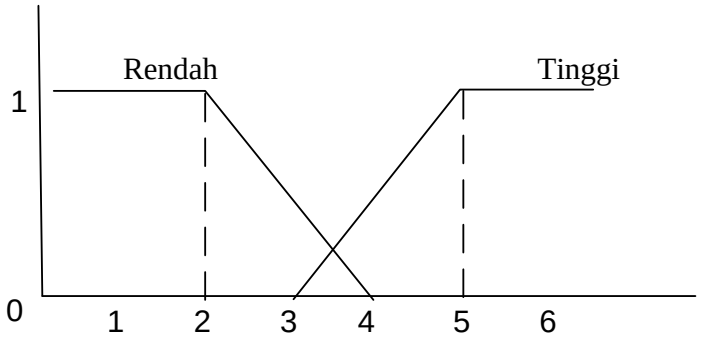


Figure 5. Hotel Quality Curve

The Lower Set uses a membership function in the form of a descending curve, while the High Set uses a membership function in the form of an ascending curve.
Membership Function:

$$\mu \text{ Rendah } [x] \begin{cases} 1; & x \le 2 \\ (4 - x) / (4 - 2); & 2 \le x \le 4 \\ 0; & x \ge 4 \end{cases}$$

$$\mu \text{ Tinggi } [x] : \begin{cases} 1; & x \le 3 \\ (x - 3) / (5 - 3); & 3 \le x \le 5 \\ 0; & x \ge 5 \end{cases}$$

The variable set is Low [0-4], while the variable set is High which has a domain [3-5].

Results and Discussions

Implementation and Results

The hotel data obtained is then grouped into 3 variables: the Number of Room Class Types, the Number of Hotel Facilities, and the number of Hotel Prices. Table 8 shows the data taken for testing this system, which includes as many as 10 hotels in the Painan area.

Table 8 Hotel Data

No	Name	Variable		
		Room Class Type	Hotel Facilities	Price
1	Hotel Anordio	4	3	Rp.200.000 – Rp.450.000
2	Hotel Triza	5	6	Rp.500.000 – Rp.1.000.000
3	Hotel Andini	4	4	Rp.150.000 – Rp.450.000
4	Hotel Edotel	5	5	Rp.400.000 – Rp.700.000
5	Hotel Aroma	3	2	Rp.200.000 – Rp.400.000
6	Hotel Rihan	4	2	Rp.150.000 – Rp.450.000

7	Hotel Adi Karya	3	3	Rp.150.000 – Rp.450.000
8	Hotel Giszella	6	7	Rp.450.000 – Rp.1.000.000
9	Hotel Muthia	4	4	Rp.350.000 – Rp.500.000
10	Hotel Langkisau	6	9	Rp.500.000 – Rp.1.000.000

The value of the Hotel Data Raw Data table will be processed into a table to calculate the Number of Room Class Types, Number of Hotel Facilities and Hotel Prices.

a. Results of Hotel Data Definition

The results of this defuzzification can be in the form of variables such as the number of room class types, number of hotel facilities, and hotel prices in achieving hotel quality. Whether the hotel has Low or High quality, these 3 variables will produce a Hotel Quality Decision in the form of Low or High based on the query described in the previous chapter (Amelia, 2013). Here, the results look like those in Table 9.

Table 9 Display of Hotel Data Definition

No	Hotel Name	Room Class Variable			Hotel Facility Variables			
		Room Class	Few μ	Many μ	Hotel Facilities	Incomplete μ	Complete μ	Very Complete μ
1	Anordio	4	0,00	0.50	3	0,75	0,25	0,00
2	Triza	5	0,00	1,00	6	0,00	0,00	1,00
3	Andini	4	0,00	0.50	4	1,00	0,00	0,00
4	Edotel	5	0,00	1,00	5	0,50	0,50	0,00
5	Aroma	3	0.50	0,00	2	0,88	0,13	0,00
6	Rihan	4	0,00	0.5,00	2	0,63	0,38	0,00
7	Adi Karya	3	0.50	0,00	3	1,00	0,00	0,00
8	Giszella	6	0,00	1,00	7	0.25	0,75	0,00
9	Muthia	4	0,00	0.50	4	0,50	0,00	0,00
10	Langkisau	6	0,00	1,00	9	0.25	0,75	0,00

Table 10 Hotel Data Defuzzyfication Display (Advanced)

No	Hotel Name	Price Variables				Hotel Rating Value (z)	Hotel Rating
		Price	Cheap μ	Medium μ	Expensive μ		
1	Anordio	300000	0,75	0,25	0,00	2,25	Rendah
2	Triza	1000000	0,00	0,00	1,00	3,00	Tinggi
3	Andini	200000	1,00	0,00	0,00	2,50	Rendah
4	Edotel	400000	0,50	0,50	0,00	2,00	Rendah
5	Aroma	250000	0,88	0,13	0,00	2,38	Rendah
6	Rihan	350000	0,63	0,38	0,00	2,13	Rendah

7	Adi Karya	200000	1,00	0,00	0,00	2,50	Rendah
8	Giszella	500000	0.25	0,75	0,00	2,75	Tinggi
9	Muthia	400000	0,50	0,00	0,00	2,00	Rendah
10	Langkisau	500000	0.25	0,75	0,00	2,75	Tinggi

The results of analyzing data from 10 hotels using the Fuzzy Tsukamoto method show that the variables of room class and hotel facilities play a significant role in determining hotel quality. The raw data that includes room class, facilities, and price are categorized in fuzzy sets for the fuzzification process.

The data processing results show that hotels with more facilities and more room classes tend to get higher quality scores. For example, Hotel Triza, which has the most number of room classes and very complete facilities, gets a high quality score. In contrast, a hotel like Hotel Aroma, which has fewer facilities and room classes, is categorized as a low-quality hotel. In addition, price also affects hotel quality, but the effect is not as great as facilities and room classes (Fuady & Zulisa, 2023).

System Implementation

a) Main Page View

The main page view shows the main page view. The appearance is as shown in figure 6

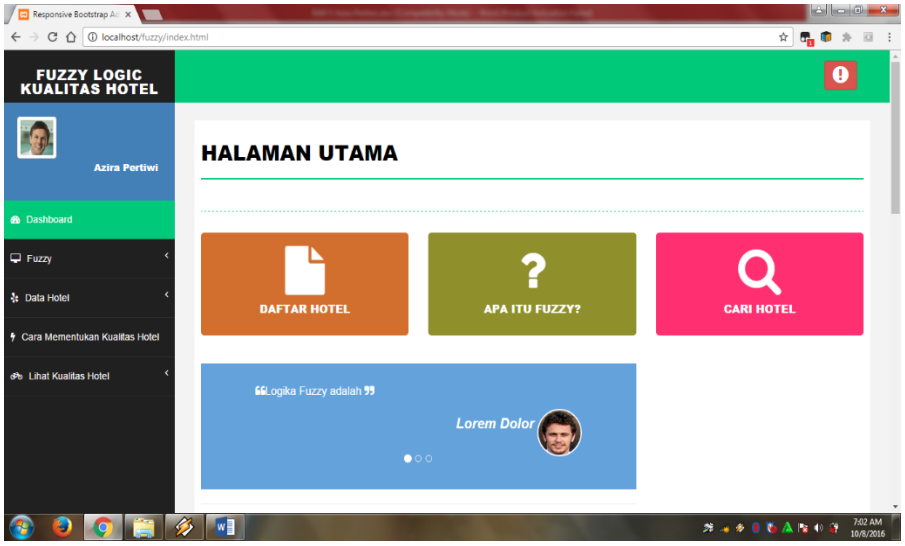


Figure 6. Main Page Display

On the main page view there is a hotel data menu, how to determine hotel quality and see hotel quality.

b) Page View of Add Hotel Data

In this new data addition view, we can enter new hotel data and go directly to the latest data of *Fuzzy's calculation.*

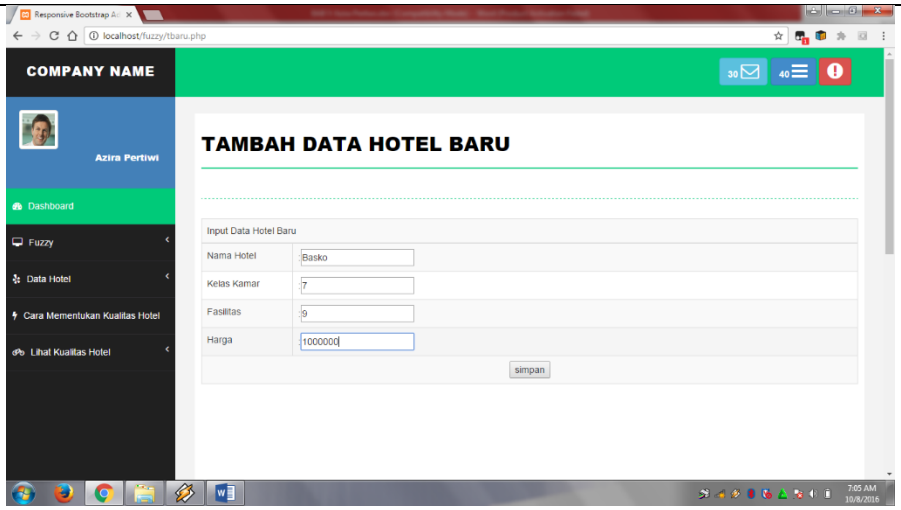
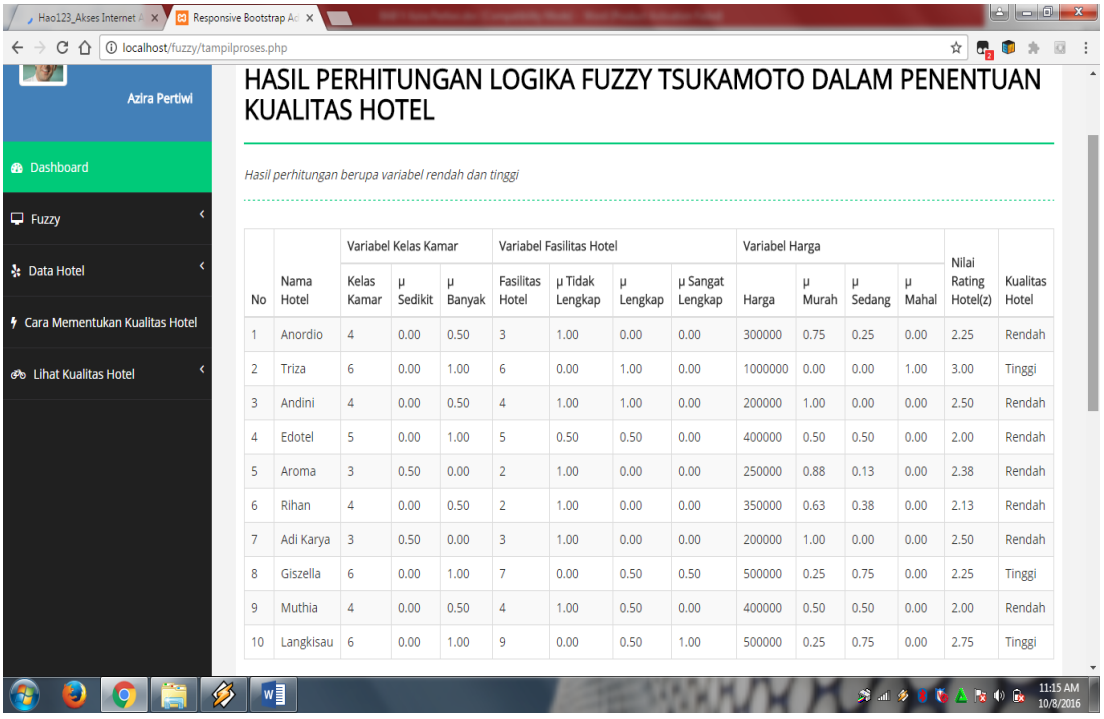


Figure 7. Page View of Add Hotel Data

On the page view, add hotel data can input new data containing hotel name, room class, facilities and hotel prices.

c) Hotel Quality Calculation Page View

This is the end result of a hotel quality calculation that has low and high inputs



No	Nama Hotel	Variabel Kelas Kamar			Variabel Fasilitas Hotel				Variabel Harga				Nilai Rating Hotel(z)	Kualitas Hotel
		Kelas Kamar	μ Sedikit	μ Banyak	Fasilitas Hotel	μ Tidak Lengkap	μ Lengkap	μ Sangat Lengkap	Harga	μ Murah	μ Sedang	μ Mahal		
1	Anordio	4	0.00	0.50	3	1.00	0.00	0.00	300000	0.75	0.25	0.00	2.25	Rendah
2	Triza	6	0.00	1.00	6	0.00	1.00	0.00	1000000	0.00	0.00	1.00	3.00	Tinggi
3	Andini	4	0.00	0.50	4	1.00	1.00	0.00	200000	1.00	0.00	0.00	2.50	Rendah
4	Edotel	5	0.00	1.00	5	0.50	0.50	0.00	400000	0.50	0.50	0.00	2.00	Rendah
5	Aroma	3	0.50	0.00	2	1.00	0.00	0.00	250000	0.88	0.13	0.00	2.38	Rendah
6	Rihan	4	0.00	0.50	2	1.00	0.00	0.00	350000	0.63	0.38	0.00	2.13	Rendah
7	Adi Karya	3	0.50	0.00	3	1.00	0.00	0.00	200000	1.00	0.00	0.00	2.50	Rendah
8	Giszella	6	0.00	1.00	7	0.00	0.50	0.50	500000	0.25	0.75	0.00	2.25	Tinggi
9	Muthia	4	0.00	0.50	4	1.00	0.50	0.00	400000	0.50	0.50	0.00	2.00	Rendah
10	Langkisau	6	0.00	1.00	9	0.00	0.50	1.00	500000	0.25	0.75	0.00	2.75	Tinggi

Figure 8. View of Hotel Quality Calculation Page

On the display of the hotel quality calculation page, this is the final result of the calculation of 3 variables that have the final result of hotel quality.

The results of this study are in line with previous research that emphasizes the importance of service quality and facilities in determining customer satisfaction (Parasuraman et al., 1988) (Ali et al., 2021; Omar et al., 2016). In this case, the use of the Fuzzy Tsukamoto method demonstrates effectiveness in overcoming the uncertainty of quality assessment, as well as incorporating several variables that influence customer perceptions of hotel quality.

However, this study also makes an important new contribution by introducing the Fuzzy Tsukamoto method in the context of hotel quality evaluation, which has not been widely explored in the existing literature. Previous studies using fuzzy logic were mostly applied in different fields, such as employee eligibility determination Sari and Mahmudy, (2015) and infant health) Hayadi et al., (2016). Therefore, this research expands the scope of fuzzy application in the hospitality sector (Ali et al., 2021; Doborjeh et al., 2022; Horng et al., 2018).

Research Gap

Although the Fuzzy Tsukamoto method has been widely used in other fields, such as employee eligibility assessment or health care, this study fills a *research gap* in the context of hotel quality assessment. Most of the previous research related to hotel quality still uses traditional methods, which tend to be less effective in handling the uncertainty and subjectivity inherent in variables such as facilities and customer comfort.

In addition, this study also fills a literature gap in terms of combining several important variables-room class, amenities, and price-in one fuzzy-based rating system. Previous studies that focused on one aspect, such as price or facilities, were unable to provide a comprehensive picture of the factors that determine overall hotel quality. The Tsukamoto Fuzzy Method provides a holistic approach in evaluating hotel quality, by considering multiple variables simultaneously.

Critical Evaluation

Although the results of this study show that room class and hotel facilities are the dominant factors in determining hotel quality, these results need to be further evaluated with a larger sample. Only 10 hotels were involved in this study, which may not be enough to provide a strong generalization across the hospitality industry in Indonesia. In addition, although this study successfully demonstrated the effectiveness of the Fuzzy Tsukamoto method, there are challenges in applying more complex algorithms for broader data-driven decision-making (Lu et al., 2019; Wang et al., 2021).

Future research could expand the scope by increasing the number of hotels studied and incorporating other variables, such as online reputation or customer ratings on digital platforms, to provide a more complete understanding of the factors that influence hotel quality.

Conclusion

In this study, 3 Fuzzy input variables were used: the Number of Hotel Class Types, the Number of Hotel Facility Types, and Hotel Prices. To determine Hotel Quality, calculations are made using the largest value. To analyze the testing of this research, a PHP program is used to determine queries in database processing.

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