Determination of Roadside Parking Retribution Contract Value using Fuzzy Sugeno Method

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Abstract: The parking facilities in Sleman are one of the sources of regional revenue. However, revenue from parking retribution has not been optimal. The amount of roadside parking retribution deposits is currently determined based on an approved contract between the parking officer and the government, and based on the consideration of the potential parking survey results by the government. The system is deemed unable to maximize the potential of regional revenue from parking retribution because the amount of parking retribution fees is not determined based on the increasing parking revenues. This study intended to investigate the value of contract retribution with the Fuzzy Sugeno Method. The Fuzzy Sugeno method was used to determine the number of retribution deposits based on the specified criteria. Based on the data processing and analysis, the number of new retribution deposits was obtained. The amount of the retribution deposit was different from the amount specified in the contract because the calculation results were determined based on the actual conditions of the set deposit period. This can be used as a correction of the retribution deposit amount so that the government can determine the retribution based on the conditions of the parking manager itself.

1 INTRODUCTION

Parking is one of the community activities that are easily found in Sleman, Yogyakarta. Ideally, parking should be facilitated in a particular parking area, but in reality, there are still many locations that do not have parking facilities. This causes many people parking their vehicles on the roadside. Parking on the roadside certainly has negative impacts on the community, one of which is reducing road capacity for vehicles. More density on-street parking will decrease road capacity (Soejanto et al. 2017). On the other hand, roadside parking also has advantages because the organizers of parking facilities in the roadside space are obliged to pay parking retribution to the Regional Government. The parking retribution is one source of original local revenue that can be used for regional development.

The original local revenue from roadside parking will continue to increase along with the increase of the population. On-street parking is the result of the increasing population activities to meet their needs. The needs of this population then become an opportunity to invest and do development in various fields. Development that is not balanced by adequate parking facilities will force visitors to use the roadside as a parking lot (Soejanto et al. 2017). If the management of revenue from roadside parking retribution is not appropriately managed, then side parking will only harm the community without any profit.

Nowadays, the government has determined the amount of roadside parking retribution deposits based on an agreement with the parking officer and based on the consideration of the potential parking survey results by the government. The system is considered unable to maximize the potential of local revenue from parking retribution because the amount of parking retribution is not determined based on the actual parking revenue. For example, parking revenue simulations that take into account factors such as the time between arrivals, number, and type of vehicles indicate a very significant difference between the contract value and the real parking income of the parking officer (Soejanto et al. 2018). Besides, the parking area is also a factor that influences roadside parking fees (Berlianty et al. 2018).

Based on Sleman Regency Regional Regulation No. 11 the year 2011, the parking retribution (tax)

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rate is set at 20% of income. However, revenue from parking tax has not been optimal. This is because the determination of the value in the contract between the government and the parking manager has not considered the factors that affect the amount of parking retribution revenue. Thus, since the value determination is only done by agreement between the government and the parking manager, it cannot integrate data in the field with the information provided by the parking officer himself.

The current monitoring function has not been optimal because the government does not know exactly how much revenue is obtained by the parking officer. There are many roadside parking that do not provide tickets for parking service users. So it is difficult to know the number of vehicles using the parking service. Parking managers can easily manipulate their income so that the retribution that must be paid can be reduced. For this reason, we need a system that can support government decisions in determining the value of contracts for roadside parking fees.

This study intended to make a decision using the Fuzzy Sugeno Method to take into account public road parking retribution deposits based on the variable parking area, the time between vehicle arrivals, and parking revenue. The decision support system is expected to be able to help the process of determining the amount of parking retribution deposits appropriately so that it can increase Sleman Regency Local Revenue.

Fuzzy logic is a decision-supporting method to represent the uncertainty that accompanies the data received as a result of data processing. Ambiguous parameters can be represented, and then decisions can be made based on fuzzy rules with the Fuzzy Inference System (FIS). Determination of the parking officer's capability to pay a retribution deposit is not currently deemed following the real conditions. The parking officer’s information becomes the only report that evokes the parking capability parameters still subjective. Employing the Sugeno fuzzy method, the decision-making process for the amount of parking retribution deposits will be more appropriate because it has a tolerance to ambiguous parameters.

2 MATERIAL AND METHOD

According to Government Regulations No. 43 the year 1993, parking is a condition in which a vehicle stops at a particular place, whether stated by signs or not. The vehicle goes to a particular place, and after arriving at the destination, the vehicle requires a place to stop with a specific duration. The place to stop is referred to as a parking lot. Based on the Regional Regulation of Sleman Regency No. 6 the year 2015, parking is all activities related to the implementation of parking facilities, including regulation, development, guidance, supervision, and control following their authority. Based on the Sleman Regency Regional Regulation Number 15 the year 2013, retribution is levy imposed on individuals or entities using the provision of unique parking spaces that are provided, owned, or managed by the Regional Government. The amount of parking retributions is regulated in Sleman Regency Regulation No. 15 the year 2013.

Fuzzy logic is part of artificial intelligence that imitates the ability of human thinking in the form of algorithms that are run by machines (Nofriansyah & Defit 2017). Fuzzy logic is an appropriate method for determining an input space into an output space (Kusumadewi & Purnomo 2004). According to (Irwansyah & Faizal n.d.), fuzzy logic does not only use two strict conditions (crisp), namely: yes or no, 0 or 1, but in its use fuzzy logic can display all possibilities between 0 and 1. Fuzzy logic is not fixed in one decision so that it can tolerate uncertainty. The mathematical concepts that underlie fuzzy logic reasoning are straightforward and easy to understand. The advantages of using fuzzy logic (Kusumadewi & Purnomo 2004) include:

1. Fuzzy logic is very flexible.
2. Fuzzy logic can tolerate incorrect data.
3. Fuzzy logic can model very complex nonlinear functions.
4. Fuzzy logic can work with conventional control techniques.
5. Fuzzy logic is based on natural language.

Fuzzy Inference System is a computational framework based on fuzzy set theory, fuzzy rules in the form of IF-THEN, and fuzzy reasoning. There are three methods in fuzzy inference systems that are often used, namely the Tsukamoto method, the Mamdani method, and the Sugeno method. In this study, the determination of the calculation parking retribution using the Sugeno method will be discussed. This system functions to make decisions through specific processes using inference rules based on fuzzy logic. Sugeno's method consists of 2 types, namely:

1. Fuzzy Sugeno Order-Zero model

In general, the form of the Zero-Order Sugeno fuzzy model is formulated in equation one as follows:

$$\text{IF } (x_1 \text{ is } A_1) \cap (x_2 \text{ is } A_2) \cap (x_3 \text{ is } A_3) \ldots \cap (x_N \text{ is } A_N) \text{ THEN } z = k \quad (1)$$

With A_N is the n-th fuzzy set as an antecedent, and k is a constant (firm) consequent.

2. Fuzzy Sugeno Order-One Model

In general, the form of the First Order fuzzy Sugeno model is formulated in equation 2 as follows:

$$IF\ (x_1\ is\ A_1) \cap \dots \cap (x_N\ is\ A_N)\ THEN$$
$$z = p_1 * x_1 + \cdots + p_N * x_N + q \quad (2)$$

With A_N is the n-th fuzzy set as an antecedent and p_1 is a constant (i) to i and q also as a constant in consequence.

To get the output (result), it takes 4 stages as follows:

1. Formation of fuzzy sets

In the Sugeno Method, both input variables and output variables are divided into one or more fuzzy sets.

2. Application function implications

In the Sugeno method, the implication function used is Min (minimum).

3. Composition of Rules

If the system consists of several rules, then the inference is obtained from a combination of rules.

4. Defuzzification

The input of the defuzzification process is a fuzzy set that is obtained from a composition of fuzzy rules, while the output produced is a number in the fuzzy set. So if a fuzzy set is given in a certain range, then a certain crisp value must be taken as output. In the Sugeno Method, defuzzification is done by finding a weighted average with equation 3 as follows:

$$z = \frac{\sum_{i=1}^{n} a_i z_i}{\sum_{i=1}^{n} a_i} \quad (3)$$

With : a_i: a predicate on the i-rule, z_i: output on the i-rule

3 RESULT AND DISCUSSION

In this study, the data was taken from nine parking locations, both registered and unregistered parking along Affandi Street, Sleman, Yogyakarta. The parking location is chosen based on the level of visitor crowds and various parking spaces. The data on the number of contract value can be seen in Table 1 as follows:

Table 1. Parking retribution contract value

No	Location	Contract Value (IDR)
1	Restaurant A	300.000
2	Restaurant B	Unregistered
3	Restaurant C	500.000
4	Restaurant D	Unregistered
5	Grocery	Unregistered
6	Print Service	Unregistered
7	Electrical Store	300.000
8	Mobile Phone Counter	300.000
9	Restaurant E	400.000

Data processing began with simulating a model to obtain data for one month. The simulation was conducted by observing the time of arrival, parking time, and parking capacity for five days. The simulation model was built using Promodel Simulation Software. The results of the simulation were the number of vehicles parked for one month to obtain income data for one month. The results of the observations and simulations were used as fuzzy inputs. There were two variables determined in this study, namely, input and output variables. Input variables consisted of the parking area, inter-arrival time, and parking retribution revenue while the output variable was the capability of the parking officer.

Table 2. Real retribution revenue for fuzzy input

No	Location	Area (m^2)	Inter-arrival time (minute)	Revenue
1	Restaurant A	35	12,87	IDR 1.724.000
2	Restaurant B	19	15,51	IDR 2.041.000
3	Restaurant C	82	6,62	IDR 5.076.000
4	Restaurant D	21	8,71	IDR 3.649.000
5	Grocery	40	7,18	IDR 4.138.000
6	Print Service	26	9,26	IDR 2.975.000
7	Electrical Store	40	16,17	IDR 1.882.000
8	Phone Counter	37	23,38	IDR 1.422.000
9	Restaurant E	19	9,67	IDR 2.580.000

The steps of processing data using fuzzy methods were as follows:

1. Fuzzification

Fuzzification is a process of mapping non-fuzzy variables (numerical variables) into fuzzy variables (linguistic variables). In this step, the fuzzy set of each variable is determined as follows.

- A variable parking area consists of three sets, namely Wide, Medium, and Narrow, with the universal speaker [0, + ∞].
- The inter-arrival time variable consists of three fuzzy sets; those are often, normal, and rare with the universal speaker [0, + ∞].
- The parking revenue variable consists of three sets, namely High, Normal, and Low, with the universal speaker [0, + ∞].
- The output variable of the RTJU deposit amount decision consists of three sets; they are Able, Normal, and Insufficient.

2. Determination of domain and membership functions

- The domain is the value of the fuzzy set of each variable. In determining the fuzzy set domain, a quartile of the universal speaker is used to determine the fuzzy set domain.

Table 3. Fuzzy set of parking lot area

Variable	Set	Domain	Curve
Wide area	Narrow	[0, 50,5]	Left-shoulder
	Medium	[34,75, 66,25]	Triangle
	Wide	[50,5, +∞]	Right-shoulder

Table 4. The fuzzy set o inter-arrival time

Variable	Set	Domain	Curve
Inter-arrival time	Often	[0, 15]	Left-shoulder
	Normal	[10,81, 19,19]	Triangle
	Rare	[15, +∞]	Right-shoulder

Table 5. Fuzzy set of parking revenue

Variable	Set	Domain	Curve
Parking revenue	Low	[0, 3249000]	Left-shoulder
	Normal	[2335500, 4162500]	Triangle
	High	[3249000, +∞]	Right-shoulder

Table 6. Fuzzy set of retribution deposit

Variable	Set	Decision
Deposit	Insufficient	15% of Revenue
	Normal	20% of Revenue
	Able	25% of Revenue

After determining the domain of each variable, then the fuzzy set could be represented by the membership function as follows.

- Variable membership function for parking lots

$$\mu_{Narrow}[x] = \begin{cases} 1, & x \leq 34{,}75 \\ \dfrac{50{,}5 - x}{15{,}75}, & 34{,}75 \leq x \leq 50{,}5 \\ 0, & x \geq 50{,}5 \end{cases}$$

$$\mu_{Medium}[x] = \begin{cases} 0, & x \leq 34{,}75 \; atau \; x \geq 66{,}25 \\ \dfrac{x - 34{,}75}{15{,}75}, & 34{,}75 \leq x \leq 50{,}5 \\ \dfrac{66{,}25 - x}{31{,}5}, & 50{,}5 \leq x \leq 66{,}25 \end{cases}$$

$$\mu_{Wide}[x] = \begin{cases} 0, & x \leq 50{,}5 \\ \dfrac{x - 50{,}5}{15{,}75}, & 50{,}5 \leq x \leq 66{,}25 \\ 1, & x \geq 66{,}25 \end{cases}$$

- Variable membership function for inter-arrival time

$$\mu_{often}[x] = \begin{cases} 1, & x \leq 10{,}81 \\ \dfrac{15 - x}{4{,}19}, & 10{,}81 \leq x \leq 15 \\ 0, & x \geq 15 \end{cases}$$

$$\mu_{Normal}[x] = \begin{cases} 0, & x \leq 10{,}81 \; atau \; x \geq 15 \\ \dfrac{x - 10{,}81}{4{,}19}, & 10{,}81 \leq x \leq 15 \\ \dfrac{19{,}19 - x}{8{,}38}, & 15 \leq x \leq 19{,}19 \end{cases}$$

$$\mu_{rare}[x] = \begin{cases} 0, & x \leq 15 \\ \dfrac{x - 15}{4{,}19}, & 15 \leq x \leq 19{,}19 \\ 1, & x \geq 19{,}19 \end{cases}$$

- Variable membership function for parking revenue

$$\mu_{low}[x] = \begin{cases} 1, & x \leq 2335500 \\ \dfrac{3249000 - x}{913500}, & 2335500 \leq x \leq 3249000 \\ 0, & x \geq 3249000 \end{cases}$$

$$\mu_{Normal}[x] = \begin{cases} 0, & x \leq 2335500 \; atau \; x \geq 4162500 \\ \dfrac{x - 2335500}{913500}, & 2335500 \leq x \leq 3249000 \\ \dfrac{4162500 - x}{1827000}, & 3249000 \leq x \leq 4162500 \end{cases}$$

$$\mu_{high}[x] = \begin{cases} 0, & x \leq 3249000 \\ \dfrac{x - 3249000}{913500}, & 3249000 \leq x \leq 4162500 \\ 1, & x \geq 4162500 \end{cases}$$

3. Designing the Rule Base System

The Rule Base System is a rule that contains fuzzy implications expressed in the form of IF ... THEN. In this study, an implication function was used, namely the AND (MIN function).

Table 7. Rule of fuzzy logic

No	Rule	Area	Inter-arrival time	Revenue	Retribution Deposit
1.	R1	Narrow	Rare	Low	Insufficient
2.	R2	Narrow	Rare	Normal	Insufficient
3.	R3	Narrow	Rare	High	Able
4.	R4	Medium	Rare	Low	Insufficient
5.	R5	Medium	Rare	Normal	Normal
6.	R6	Medium	Rare	High	Able
7.	R7	Wide	Rare	Low	Insufficient
8.	R8	Wide	Rare	Normal	Normal
9.	R9	Wide	Rare	High	Able
10.	R10	Narrow	Normal	Low	Insufficient
11.	R11	Narrow	Normal	Normal	Normal
12	R12	Narrow	Normal	High	Able
13	R13	Medium	Normal	Low	Insufficient
14	R14	Medium	Normal	Normal	Normal
15	R15	Medium	Normal	High	Able
16	R16	Wide	Normal	Low	Insufficient
17	R17	Wide	Normal	Normal	Normal
18	R18	Wide	Normal	High	Able
19	R19	Narrow	Oftern	Low	Insufficient
20	R20	Narrow	Oftern	Normal	Normal
21	R21	Narrow	Oftern	High	Able
22	R22	Medium	Oftern	Low	Insufficient
23	R23	Medium	Oftern	Normal	Normal
24	R24	Medium	Oftern	High	Able
25	R25	Wide	Oftern	Low	Insufficient
26	R26	Wide	Oftern	Normal	Normal
27	R27	Wide	Oftern	High	Able

After the fuzzy implication rules were determined, fuzzy output was then prescribed using the Sugeno Orde-One Fuzzy Inference System method as follows.

$$\text{IF } (x_1 \text{ is } A_1) \cap \ldots \cap (x_N \text{ is } A_N) \text{ THEN z} = p_1 * x_1 + \cdots + p_N * x_N + q$$

x_N = n-th input variable
A_N = Fuzzy set
z = contract value percentage × revenue

In this study, the minimum implication function was used, namely by looking for the smallest i rule as follows.

$$\alpha_i = \min\{\mu_{Ai}(x), \mu_{Bi}(x)\}$$

Where :

α_i= minimum value of fuzzy set A and B from i-rule
$\mu_{Ai}(x)$ = the degree of membership x of the fuzzy set A in the i-rule
$\mu_{Bi}(x)$ = the degree of membership x of the fuzzy set B in the i-rule

4. Composition of rules

In this study, the maximum composition of the rule would be used, which was by selecting the highest value of the membership degree for the results of the same implication function.

$$\mu_{sf}[x_i] = \max(\mu_{sf}[x_i], \mu_{kf}[x_i])$$

Where :
$\mu_{sf}[x_i]$: the membership value of fuzzy solutions to the i-rule
$\mu_{kf}[x_i]$: consequent fuzzy membership value to the i-rule

5. Deffuzification

In the Sugeno Method, defuzzification is conducted by finding the weighted average as follows.

$$z = \frac{\sum_{i=1}^{n} a_i z_i}{\sum_{i=1}^{n} a_i}$$

Where,
$a_i = a$ predicate on the i-rule
z_i = output on the i-rule

6. Examples of parking retribution revenue determination with the Fuzzy Sugeno Order-One Method

The following example is the determination of the revenue in the Restaurant A parking lot with a parking area of 35 m², the average interarrival time of 12.87 minutes, and revenues of IDR 1,724,000.

- Determine the fuzzy set of each variable

1. Parking lot area

$$\mu_{Narrow}[35] = \frac{50{,}5 - 35}{15{,}75} = 0{,}98$$

$$\mu_{Medium}[35] = \frac{35 - 34{,}75}{15{,}75}$$

$= 0{,}02$

$$\mu_{Wide}[35] = 0$$

The parking lot of Restaurant A could be considered as narrow with a membership degree of 0.98 (with 98% confidence that the area is narrow) and could be said to be medium with a membership level of 0.02 (with a belief of 2% that the area is medium).

2. Inter-arrival time

$$\mu_{often}[12{,}87] = \frac{15 - 12{,}87}{4{,}19} = 0{,}51$$

$$\mu_{Normal}[12{,}87] = \frac{12{,}87 - 10{,}81}{4{,}19} = 0{,}49$$

$$\mu_{rare}[12{,}87] = 0$$

The time between arrivals at the Restaurant A parking lot could be said as often with a membership degree of 0.51 (with 51% confidence that the time between arrivals is often) and could be said as Normal with a membership level of 0.49 (with a 49% confidence that the time of arrival).

3. Revenue

$$\mu_{low}[1724000] = 1$$

$$\mu_{Normal}[1724000] = 0$$

$$\mu_{high}[1724000] = 0$$

So, the revenue at the parking location of Restaurant A could be said as Low with 1 membership degree (with 100% confidence that parking revenue is low).

- Application of function implications

[R10] α – predicate 10

$\mu_{parking\ lot\ area\_narrow} \cap \mu_{inter-arrival\ time\ \_normal} \cap \mu_{parking\ revenue\_low}$=min ($\mu_{parking\ lot\ area\_narrow}$, $\mu_{inter-arrival\ time\ \_normal}$, $\mu_{parking\ revenue\_low}$)min (0,98, 0,49, 1) = 0,49 (parking retribution deposit is insufficient with a deposit of 15% of parking revenue)

[R13] α – predicate13

$\mu_{parking\ lot\ area\ \_medium} \cap \mu_{inter-arrival\ time\ \_normal} \cap \mu_{parking\ revenu\_low}$=min($\mu_{parking\ lot\ area\ \_medium}$, $\mu_{inter-arrival\ time\ \_normal}$, $\mu_{parking\ revenu\_low}$)= min (0,02, 0,49, 1) = 0,02 (parking retribution deposit is insufficient with a deposit of 15% of parking revenue)

[R19] α – predicate 19

$\mu_{parking\ lot\ area\_narrow} \cap \mu_{inter-arrival\ time\ \_often} \cap \mu_{parking\ revenue\_low}$=min($\mu_{parking\ lot\ area\_narrow}$, $\mu_{inter-arrival\ time\ \_often}$, $\mu_{parking\ revenue\_low}$ = min (0,98, 0,51, 1) = 0,51 (parking retribution deposit is insufficient with a deposit of 15% of parking revenue)

[R22] α – predicate22

$\mu_{parking\ lot\ area\_medium} \cap \mu_{inter-arrival\ time\ \_often} \cap \mu_{parking\ revenue\_low}$=min($\mu_{parking\ lot\ area\_medium}$, $\mu_{inter-arrival\ time\ \_often}$, $\mu_{parking\ revenue\_low}$= min (0,02, 0,51, 1) = 0,02 (parking retribution deposit is insufficient with a deposit of 15% of parking revenue)

Rule composition
15% of parking revenue = max(0,02, 0,49, 0,51) = 0,51
20% of parking revenue = max(0) = 0
25% of parking revenue = max(0) = 0

- Defuzzification

$$z = \frac{\sum_{i=1}^{n} a_i z_i}{\sum_{i=1}^{n} a_i}$$

$$z = \frac{0{,}51(15\% * Revenue) + 0(20\% * Revenue) + 0(25\% * Revenue)}{0{,}51 + 0 + 0}$$

$$z = \frac{0{,}51(15\% \times 1724000) + 0(20\% \times 1724000) + 0(25\% \times 1724000)}{0{,}51}$$

$= 258600$

Based on the calculations using the Fuzzy Sugeno Order-One Method, it could be determined that the parking retribution deposit at the parking location of Restaurant A was 15% parking revenue, or equal to IDR 258,600. This result was less than the retribution deposit determined in the contract, which was IDR 300,000. This condition was influenced by the time between arrivals and income obtained by Restaurant A at the end of the month. The arrival time showed how many vehicles were parked for one month. During that period, the time between arrivals at that location was observed so rarely that the number of vehicles parked was small. Besides, a large number of vehicles also affected the income earned during a period. During this period, parking revenue at the location was relatively low. Based on this explanation, the program created was also able to correct the parking retribution deposit results so that the results would be following the conditions in the specified period. Using the same method, the calculation of contract value for all locations in this study was obtained as follows.

Table 8. Parking retribution revenue for all location

No	Location	Contract Value (IDR)	Revenue Based on fuzzy rules (IDR)
1	Restaurant A	300.000	258.600
2	Restaurant B	Unregistered	306.150
3	Restaurant C	500.000	1.269.000
4	Restaurant D	Unregistered	840.922
5	Grocery	Unregistered	1.030.420
6	Print Service	Unregistered	550.383
7	Electrical Store	300.000	282.300
8	Phone Counter	300.000	213.300
9	Restaurant E	400.000	421.527

4 CONCLUSIONS

Based on the results of data processing and analysis that had been conducted, it could be concluded that the results of parking revenue deposit calculations using the Fuzzy Sugeno method showed results that were slightly different from the established contracts. This was due to fuzzy calculations based on the condition of the parking location at the end of the period so that the number of deposits per period was not fixed. Therefore, this method of calculation is considered effective because the amount of parking revenue deposits can adjust the revenue of the parking officer.

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