The Ability to Pay and Willingness to Pay for LRT Bandung Raya Planning Babakansiliwangi Leuwipanjang

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Abstract. Population growth in Bandung Raya has led to an increase in the number of private vehicles and a decrease in the use of public transportation. The reason for this is the need for more quality and service of public transportation. Trans Metro buses cannot reach all areas, and more and more private cars are causing traffic jams. The solution is to build Bandung Raya LRT. However, assuring the LRT is affordable for people with different incomes is essential. This research would examined ATP and WTP and the relationship between them. ATP measurement used Travel Cost, while the WTP used the Fuzzy Mamdani. The analysis results showed that the average ATP is Rp 28,000, and the average WTP is Rp 2,530. Thus, this study showed that the prospective LRT users have a higher Ability to Pay (ATP) than Willingness to Pay (WTP) or called as Choice riders. This may be because they have not experience the LRT yet. The quality of the LRT service must be improved during its operation in order to increase the willingness to pay of the prospective users.

Keywords: The Ability to Pay (ATP), The Willingness to Pay (WTP), LRT, Travel Cost, Fuzzy Mamdani.

1 Introduction

Bandung Raya Metropolitan Area in West Java includes several cities [1]and has a population of 19,433,753 people [2], which grows yearly. Poor public transport and population growth have caused traffic congestion, and there is a need for urban rail services in the area, according to RIPNAS 2030 [3].

The development of Light Rail Transit can help reduce congestion [4]. Corridor 1 of Bandung Raya Light Rail Transit will be built in 2026 with 16 stations, while Corridor 2 will stretch from east to west with 21 stations [5]. This project aligns with Presidential Regulation Number 45 of 2018 concerning Spatial Plans for the Bandung Basin Urban Area [6].

The Bandung Raya LRT is expected to reduce congestion in Bandung Raya metropolitan area, based on the success of the LRT in reducing congestion in American cities [7] and Europe [8]. Operators must consider the purchasing power of potential users through factors such as income and prices [9]. Willingness and ability to pay

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impact how often people use transportation services, and fare planning is essential for business strategy [10]. Ideal tariff recommendations should be based on ATP and WTP [11]. A more complex train price structure can benefit consumers by providing more opportunities to choose costs, duration, convenience, and flexibility [12]. Further studies are needed to understand the purchasing power of potential users and the relationship between ATP and WTP.

2 Research Method

2.1 Ability to Pay

The calculation of the ability to pay (ATP) in this study uses the individual travel cost method. The ATP used based on individual travel costs is calculated by the following formula [13] :

$$ATP\ individual = \frac{Ic\ x\ \%TC}{D} \quad (1)$$

Where :

Ic : Income
%TC : Percentage of income for travel cost
D : Travel frequency

2.2 Willingness to Pay

The Willingness To Pay (WTP) is someone's willingness to pay for obtaining certain service in transportation. Fuzzy mamdani method was used to determine the willingness to pay of Bandung Raya LRT Prospective Users. The following is the definition of fuzzy set in the input variables of income and output variable of WTP.

a. Fuzzification, determines the fuzzy set through the degree of membership function and input and output variable;
b. Rules, the formation of fuzzy basic rules in line with input variable. Fuzzy Mamdani Method used the minimum implication and maximum rule composition (Min-Max Method);
c. Deffuzification, changing every result from rules into real number or original number. The defuzzification used was centroid method.

3 Results

3.1 Ability to Pay

The ATP value is counted from the respondents' data based on the travel cost approach. In this case, ATP value is differed based on six income categories which had been determined. This is because every individual has different income which will influence their ability to pay.

Table 1. The Result of ATP Calculation

Respondents	Income/ month (A)	Average transportation cost issued (B)	% Average allocation of transportation cost C=(B/A)* 100%	The travelling frequency /mongh (D)	ATP E=(A*C)/D
1	Rp 900,000	Rp 80,000	9%	5	Rp 16,000
2	Rp 900,000	Rp 200,000	22%	17	Rp 11,765
3	Rp 900,000	Rp 50,000	6%	13	Rp 3,846
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361	Rp 12,000,000	Rp 1,000,000	8%	17	Rp 58,824
362	Rp 12,000,000	Rp 650,000	5%	18	Rp 36,111

The data above still did not show certain pattern, until conducted the calculation of frequency distribution with the result as follows:

Total classes = 1+3,322 logn (2)
=1+log362
=10

Range =(Max value - Min value)/(total classes) (3)
=(269,231-556)/10
=26,868

Based on the calculation of total classes, the following is presented the data in the form of table concerning the distribution. Further, the distribution about ATP calculation is presented in the following graph:

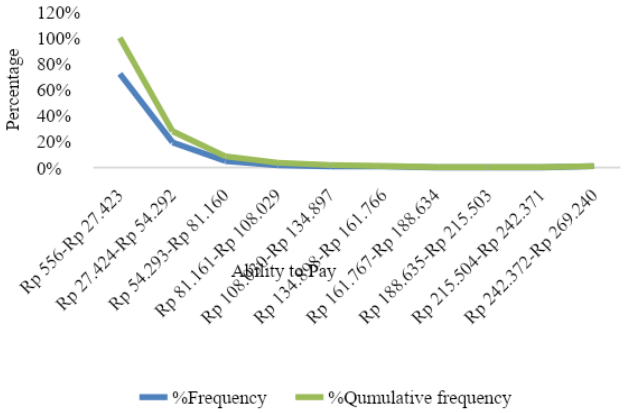

Fig. 1. ATP Distribution

Based on the result of ATP calculation which had been carried out, if the rate of Bandung Raya LRT is determined based on the respondents' ATP, then 100% respondents can pay in the range of Rp 556 – Rp 27,423 (rounded up to Rp 28,000)

3.2 The Willingness to Pay

1. Defining fuzzy variable

Table 2. Fuzzy variable

Function	Variable	Fuzzy set	Domain	Speaker's Universe
Input	Income	Very low Low Medium High Very high	[0 1000 2000 3000] [2000 3000 4000] [3000 4000 5000] [6000 7000 8000] [9000 10000 12000]	[0 12000]
Output	WTP	Low Medium High	[0 100 200] [200 300 300] [300 400 500]	[0 500]

2. Fuzzification

a. Income input variable

Income variable with speaker's universe [0 12000] is divided into 5 fuzzy sets namely very low, low, medium, high, and very high. The fuzzification result can be seen in Figure 2.

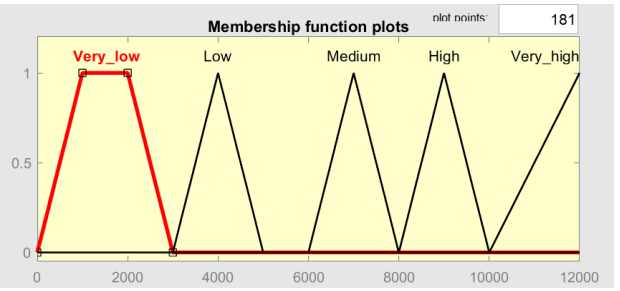

Fig. 2. Income Fuzzy Set

The membership function of income variable is formulated with the equation as follows:

$$\mu\text{Very low} = \{0 \rightarrow x \leq 0 \ \frac{(x-0)}{(1000-0)} \rightarrow 0 \leq x \leq 1000 \ 1 \rightarrow 1000 \leq x \leq 2000 \ \frac{3000-x}{3000-2000} \rightarrow 2000 \leq x \leq 3000 \ 0 > 3000$$

$$\mu\text{Low} = \{0 \rightarrow x \leq 2000 \ or \ x \geq 4000 \ \frac{(x-2000)}{(3000-2000)} \rightarrow 2000 < x \leq 3000 \ \frac{(4000-x)}{(4000-3000} \rightarrow 3000 < x < 4000$$

$$\mu\text{Medium} = \{0 \rightarrow x \leq 5000 \; or \geq 7000 \; \frac{(x-5000)}{(6000-5000)} \rightarrow 5000 < x \leq 6000 \; \frac{(7000-x)}{(7000-6000)} \rightarrow 6000 < x < 7000$$

$$\mu\text{High} = \{0 \rightarrow x \leq 6000 \; or \; x \geq 8000 \; \frac{(x-6000)}{(7000-6000)} \rightarrow 6000 < x \leq 7000 \; \frac{(8000-x)}{(8000-7000)} \rightarrow 7000 < x < 8000$$

$$\mu\text{Very high} = \{0 \rightarrow \leq 9000 \; or \; \geq 10000 \; \frac{(x-9000)}{(10000-9000)} \rightarrow 9000 < x \leq 10000 \; 1 \rightarrow x \geq 12000$$

b. WTP output variable
WTP output variable with the speaker's universe [0 500] is divided into three sets namely Low, Medium, and High. The fuzzification result of WTP output variable can be seen in Figure 3:

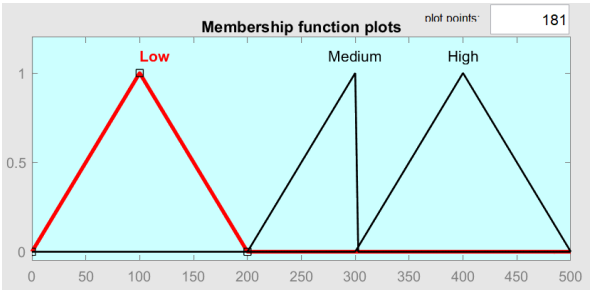

Fig. 3. WTP Fuzzy Sets

The membership function of WTP output variable can be seen in the following equation:

$$\mu\text{Low} = \{0 \rightarrow x \leq 0 \; or \; x \geq 200 \; \frac{(x-100)}{(200-100)} \rightarrow 100 \leq x \leq 200 \; \frac{(200-x)}{(200-100)} \rightarrow 200 < x < 100$$

$$\mu\text{Medium} = \{0 \rightarrow x \leq 200 \; or \; x \geq 300 \; \frac{(x-200)}{(300-200)} \rightarrow 200 < x \leq 300 \; \frac{(300-x)}{(300-300} \rightarrow 300 < x < 300$$

$$\mu\text{High} = \{0 \rightarrow x \leq 500 \; or \; x \geq 500 \; \frac{(x-300)}{(400-300)} \rightarrow 200 < x \leq 300 \; \frac{(500-x)}{(500-400} \rightarrow 400 < x < 500$$

3. Rules formation
The next stage is fuzzy rules formation based on the input evaluation which had been modified becomes the membership function degree or fuzzy rules to generate the output from each rule under the system.
The rules can be seen in Table 3.

Table 3. Rules.

Rules	Income	WTP	Rules	Income	WTP
R1	Very low	Low	R9	Medium	High

Rules	Income	WTP	Rules	Income	WTP
R2	Very low	Medium	R10	High	Low
R3	Very low	High	R11	High	Medium
R4	Low	Low	R12	High	High
R5	Low	Medium	R13	Very high	Low
R6	Low	High	R14	Very high	Medium
R7	Medium	Low	R15	Very high	High
R8	Medium	Medium			

4. Deffuzification

In this stage will be produced the output of fuzzy. Deffuzification method used was centroid. The result of this deffuzification was processed with the assistance of Matlab R2020a software device and obtained the result of each data. As an example the income Rp 900,000,- in input column is written [900] obtained output 254. In other words, if the income is Rp 900,000,- then the WTP is Rp 2,540. The deffuzification result can be seen in Figure 4 and Table 4.

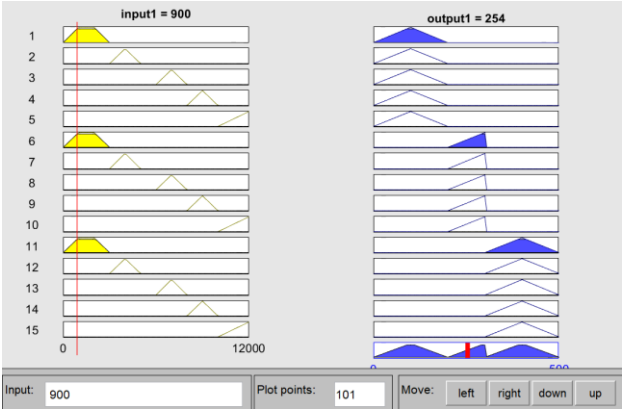

Fig. 4. Deffuzification of Fuzzy Mamdani Method

The following is presented some data the result of fuzzy mamdani by using Matlab R2020a.

Table 4. WTP Output

Income (Input)	WTP (Output)	Income (Input)	WTP (Output)
Rp 900,000	Rp 2540	Rp 6,500,000	Rp 2530
Rp 1,000,000	Rp 2540	Rp 9,000,000	Rp 2540
Rp 2,000,000	Rp 2540	Rp 10,000,000	Rp 2500
Rp 4,000,000	Rp 2540	Rp 12,000,000	Rp 2540
Rp 5,000,000	Rp 2500		

Based on the deffuzzification result of Matlab R2020a in Table 4 using fuzzy mamdani method obtained the result as in the table above. Then, the whole data were taken for their average and generated Rp 2,530 as WTP of the prospective users of Bandung Raya LRT.

3.3 The Correlation Between ATP and WTP

The graph below describes the correlation between ATP and WTP coming from the counted value:

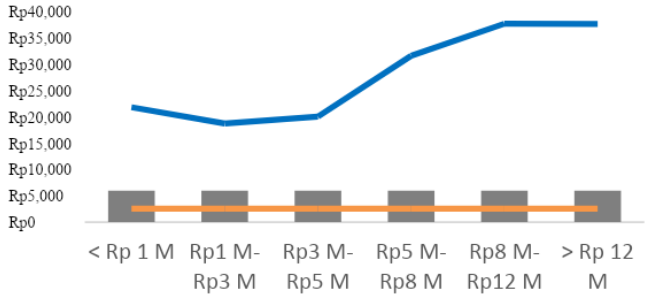

Fig. 5. Correlation Between ATP and WTP

The fare used is the rate from the Bandung Raya LRT Feasibility Study (FS) [14] results of Rp 6,000. The ATP produced by travel cost method had various range. The smaller WTP rate (Rp 6,000) of Bandung Raya LRT compared to the ATP (Rp 28,000) showed that LRT Prospective Users have higher income but the service satisfaction is lower (Choice riders). The respondents still do not feel LRT service because it hasn't been operated yet [15]. This is also reinforced by the fact that they prefer their private vehicle because of the low service quality of transportation in Bandung Raya.

4 Conclusion

1. The result of ATP data analysis using travel cost method, the average respondents can pay around Rp 28,000 and WTP data processing by using fuzzy method obtained the average amounted Rp 2,530.
2. The value of ATP > WTP. Until, the prospective users of Bandung Raya LRT are included in the preferred riders group.

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