Feeder design for sustainable transportation using stated preference: case study in Gubug-Tegowanu, Grobogan City

by Sri Hartini

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Abstract. Bus Rapid Transit is mass transportation which was developed as a way to promote sustainable social mobility. To increase BRT effectiveness, it needs a feeder design that connects the region of the villages in Grobogan City, passed by the BRT Semarang-Gubug route. This research used the stated preference method to know passengers' responses to the offered design in Gubug – Tegowanu via Kapung. The questionnaires survey and interview started by determining the number of samples using purposive sampling technique and distribute it in 8 different scenarios to motorcycle users in Grobogan City. After the collected result is validated, the data is processed with multiple linear regression and binomial logit to get the probability of feeder choicer, the model predicts the probability of choosing between two modes of transportation based on cost, travel time, and waiting time attributes. The sensitivity analysis shows that the significant attribute which affects the modal shift is the waiting time/headway. The probability of modal shift passengers in optimist scenario is 0.8310 with travel cost is IDR 3,500, travel time is 15 minutes and waiting time/headway is 10 minutes maximum.

1. Introduction

Transportation is a movement of goods or people from origin to destination for certain purposes [1]. There is also mention that transportation is a servant of development and the formative power of regional development [2]. The increasing demand of transportation every year is evidence that transportation is an unseparated part in human life [3]. Many people use public transportation that has a big capacity for daily activities [4]. Bus Rapid Transit (BRT) is one of the forms of public transport that developed in this era. BRT is one way to promote social sustainable mobility [5] and it is recognized as capable of increasing urban mobility though intervention packages include busway improvement, efficiency operation, and increased urban environment [6]. BRT also can afford to comply with urban mobility and reduce global emissions [7].

BRT Trans Jawa Tengah is a Central Java Governor's superior program that connects agglomeration areas to support a modal shift from private to public transportation [8]. Agglomeration urban transport in corridor IV at Kedungsepur area is planned in 2021. To increase the effectiveness of BRT, integration can be implemented through informal cooperation with paratransit operators [9] or local bus services as feeders. Some authors stated that using non-motorized transportation increases effectiveness to improve service range [10].

Grobogan City is one city in Central Java that will be a development target of BRT Trans Jawa Tengah Corridor IV in 2021. The beginning survey that is held on December 2nd - 4th 2020 to 65 respondents dominated by village chief around corridor IV regions, shows that 90.8% of their community are welcome to the feeder and will move from motorcycle to feeder-BRT. The availability of feeder systems that connect trip generation for public transportation users with the main corridor makes it easier for accessibility towards the main corridor and can support trunk line operations. The

development of the feeder track as a support network for the trunk line system led to the creation of a public transport system that is integrated and efficient [11].

The potential feeder for integrated BRT corridor IV is the feeder that connects the Gubug-Tegowanu region. This research purposed to design some feeder scenarios. The stated preference method will be used and questionnaires will be spread to know the passengers' response to the designed scenario [12]. This method aims to see people's perspectives for the mode of choice trips compared with choice abide.

2. Literature Review

A literature review consists explanation of integration on public transportation, stated preference method, and sensitivity analysis.

2.1. Integration of Public Transportation

Bus Rapid Transit is mass transportation that offers speed and reliability of train, but has operational flexibility and is cheaper than conventional buses [13]. Whereas, the feeder is a small vehicle in the region with low density and shifts the passengers to buses with big capacity in the terminal. Feeders will be more efficient if operated with community characteristic requests. The integration between the feeder network with the trunk line hopes to optimize travel time and save travel cost [14] based on the paratransit function. Some researchers suggest using the paratransit as a feeder for intention of better urban transportation performance [15].

2.2. Stated Preference

Stated preference method was first time used for transportation research by Davidson, J.D. in 1973. Stated preference is a collection data method that is obtained by approaching the respondent to know their preference and alternative. The questionnaire contains a question for the community, what they want for one, and some hypothetical situations [16].

The conceptual framework is started by setting the alternatives design, set the factors that affect mode choice, and set the mode that will be used. After that, we do an observation survey and make a statistical model [17]. Stated preference using a discrete model which respondents can choose among the hypothesis alternative from attributes. Each attribute can provide two or more levels, and the combination would be different. This method enables researchers to manipulate the choice attribute with statistics efficiently [18] [19].

The technique to analyze stated preference is multiple linear regression [20]. Many people use this method as a rating choice for stated preference. Processing data to get quantitative relation among attribute and individual responses that started with linear regression and logit biner model that use to choose a model that can finish with regression linear model. The formula of multiple linear regression is:

$$Y = A + B_1X_1 + B_2X_2 + B_3X_3 + \cdots + B_nX_n \qquad (1)$$

Logit biner model is used to choose two modes and can finish by using multiple linear regression. Individual probability choose feeder is the difference utility among two modes by assuming that utility function. Logit biner model as follows [21].

$$P(f) = \frac{e^{Uf-Up}}{1+e^{Uf-Up}} \qquad (2)$$

$$P(p) = 1 - P(f) = \frac{1}{1+e^{Uf-Up}} \qquad (3)$$

The utility is a standard of a person in deciding the best alternative. The utility function is to measure community interest for every design or hypothesis that is given to the respondents. Combination linear of utility function as follows [22].

$$U_j = a_0 + b_1.x_1 + b_2.x_2 + b_n.x_n \qquad (4)$$

2.3. Sensitivity Analysis

Sensitivity Analysis aims to decide sensitive parameters in a created model. The sensitive parameters need to be observed because they will affect the research result. For insensitive parameters, sensitivity analysis aims to determine the range of parameters and not change optimal results [23]. On transportation, the sensitivity model is the purpose to conceive the change in the number of public transportation probability.

3. Study Area

A study area of this research is in Grobogan City, geographically located in the east and the middle of Central Java, Indonesia. The total area of this city is 2,022.25 km^2, consisting of 19 subdistricts with the capital city is in Purwodadi [24]. The most of population work as laborers and farm, they use private transportation to go to work because there isn't public transportation in the city. Figure 1 and Figure 2 show the Grobogan City location and feeder route plan.
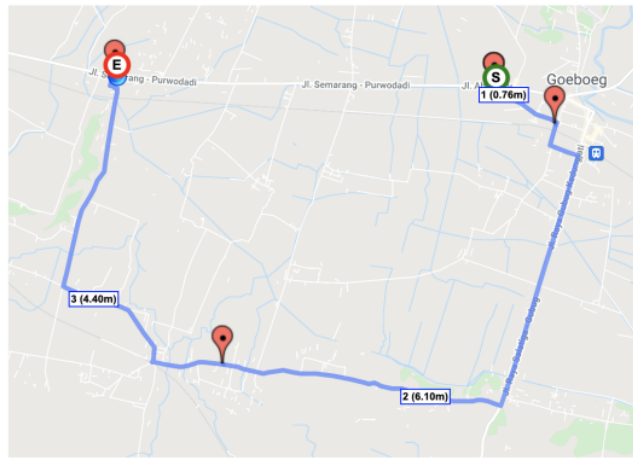

Figure 1. Grobogan City Location

Figure 2. Feeder Route Plan

Focus area of this research is in 3 subdistrics which passed by BRT Trans Jawa Tengah Koridor IV route from Penggaron Terminal to Gubug Terminal that are Gubug, Tanggungharjo, and Tegowanu subdistric. Based on BRT Trans Jawa Tengah Koridor IV operation socialization, the feeder route plan started from Gubug Terminal (S) – Kuwaron – Kapung Sugihmanik – Tanggungharjo – Tegowanu – Pasar Tegowanu (E), for round-trip.

4. Research Methodology

This research applied the Stated Preference (SP) method that is commonly used in conducting transportation research which approached respondents to determine their responses to the new mode (feeder) offered. SP method has the capability to measure preferences from alternative choices based on assumptions or hypothetical situations that are difficult to measure such as the environment and services or new products [25]. Conceptual framework can be shown in Figure 3.

Figure 3. Conceptual Framework

4.1. *Data Collection*

This study used a questionnaire and interview survey to collect the data. The questionnaires were spread to the Gubug-Tegowanu community in productive ages (17 - 64 years old) that using private transportation (motorcycles) for daily activities directly or using an online questionnaire (google form). A purposive sampling technique was adopted for selecting the potential respondents for one month.

The questionnaires consist of two main sections, the first section of questionnaires aim to collect socio-economics and travel characteristics data from the respondents such as gender, age, origin, last education, profession, and income. The second section aims to measure their responses about alternative scenarios of two modes (motorcycle, feeder) based on selected travel attributes. The choices using a schematic scale with rating point, ranging from 1 (Definitely Choose Feeder) to 5 (Definitely Choose Private Transportation). Another data was obtained from Development Planning Agency at the Sub-National Level (BAPPEDA) and Departement of Transportation in Grobogan City.

4.2. Variable / Attribute

The attributes are considered from previous studies and the beginning survey. The most influential attributes from the previous study are cost, travel time, access time, comfort, and waiting time. These five attributes were used in the beginning survey on this research with purposes to determine the sequential priorities attribute of the Gubug-Tegowanu community in choosing transportation mode, the result will be shown in Figure 4.
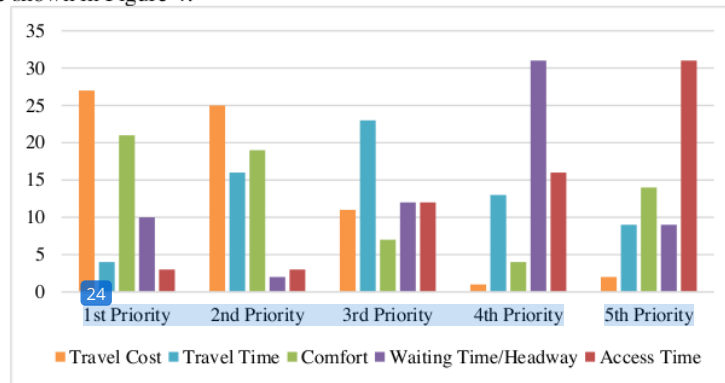

Figure 4. Attributes Result from The Beginning Survey

The number of attributes will affect the stated preference scenario design. Respondents will difficult to determine the choices if there are too many designs presented. This beginning survey will determine three important quantitative attributes [26] in Grobogan City. The chosen attributes are cost, travel time, and waiting time.

4.3. Experimental Design

There are several steps in making a stated preference questionnaire that is (a) Selected attribute levels and combinations for each alternative (b) Presented alternative designs (c) Choice specification obtained from respondents [27]. Factorial designs enable experimenters to study the effect of the design parameters on a response. According to the chosen variables with three attributes and two levels, there is an optimist (+) and pessimist (-) design, the design is called 2^3 factorial design, which generated 8 alternative combinations design.

- Cost Attribute

  The cost of the optimist level is IDR 3,000. Whereas, the pessimist level is IDR 5,000. The beginning survey shows that the dominant respondents choose the feeder cost below IDR 5,000. This accommodation fit with regulations in article 1, number 7 in 2015 that set the upper limit and the lower limit of transportation cost per kilometer. In general, by considering BRT cost, so average level is IDR 4,000.

- Travel Time Attribute

  The beginning survey shows that dominant respondents do travel for 20 minutes at the average level. So, design travel time in optimist levels is 15 minutes and pessimist level is 25 minutes.

- Waiting Time Attribute

  The beginning survey shows that dominant respondents tolerate the waiting time until 20 minutes so that the average level is 15 minutes, the optimist level is 10 minutes and the pessimist level is 20 minutes. This research provides eight scenarios for chosen, based on the design and analysis experiments book [28]. The choices and scenarios that were offered to the respondents are shown in Table 1. The rating point is in the schematic scale in qualitative but will get in quantitative.

Table 1. Attribute Scenarios and Chosen Level

Design	Code (IDR)	Travel Time (minutes)	Waiting Time / Headway (minutes)	CHOOSE YOUR ANSWER IN THIS COLUMN					
				Rating Point					
				Definitely Choose Feeder	May be Choose Feeder	Balanced	May be Choose Private Transportation	Choose Private Transportation	Definitely Choose Private Transportation
A	5,000	25	20	1	2	3	4	5	
B	5,000	15	20	1	2	3	4	5	
C	5,000	25	10	1	2	3	4	5	
D	5,000	15	10	1	2	3	4	5	
E	3,500	25	20	1	2	3	4	5	
F	3,500	15	20	1	2	3	4	5	
G	3,500	25	10	1	2	3	4	5	
H	3,500	15	10	1	2	3	4	5	

4.4. Data Processing Technique

This research uses multiple linear regression and logit biner for analyzing data, Cronbach's Alpha scores for reliability test, and Kolmogorov Smirnov scores for normality test. Data should be transformed to get a numeric scale for every choice. Table 2 shows the transformation from a schematic scale to a numerical scale [29].

Table 2. Scale Transformation

Rating	Probability Scale	Numeric Scale $Ln\left(\dfrac{P}{1-P}\right)$
1	0.9	2.1972
2	0.7	0.8473
3	0.5	0
4	0.3	-0.8473
5	0.1	-2.1972

Multiple linear regression analysis purposed to get the model parameters alternatives between existing and what the community's expected. Coefficient determination aims to whether a hypothetical model that made is close to the actual, F-test is to determine independent variable ability towards dependent variable and t-test is to determine the effect of the independent variable on the dependent variable. Utility equation generated from multiple linear regression will determine people's preference for choosing two modes and get the estimated deviation of individual choice. Continued to logit binary model analysis that will determine an individual probability for choosing feeder or private transportation in the pessimist, average, and optimist scenarios.

5. Result and Discussion
Result and discussion consist of descriptive analysis of respondents and data processing.

5.1. Respondents characteristic: socio-economy and travel
There are 104 respondents whose questionnaires were valid and can be used for further data processing. The questionnaire results of socio-economics and travel characteristics can be seen in Figure 5 until Figure 16.
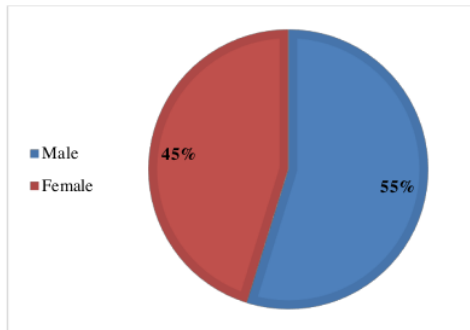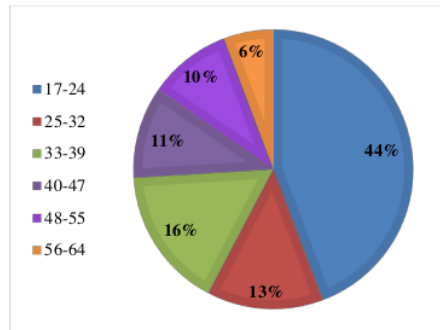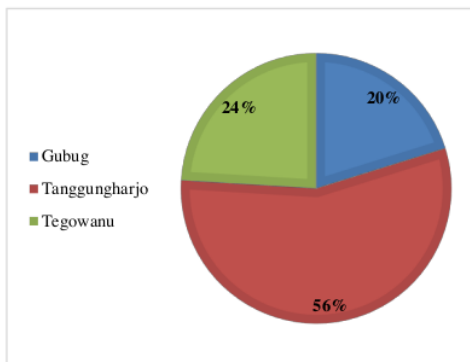

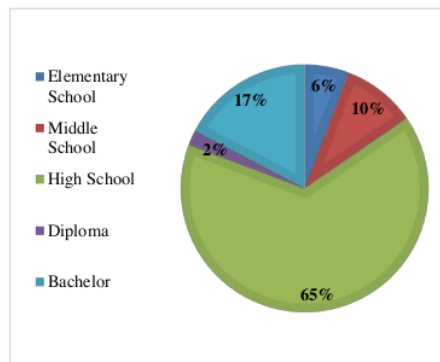**Figure 5.** Gender

Figure 6. Age

Figure 7. Origin Respondents

Figure 8. Last Education
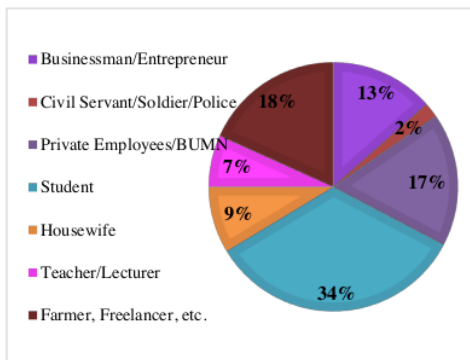
Figure 9. Profession
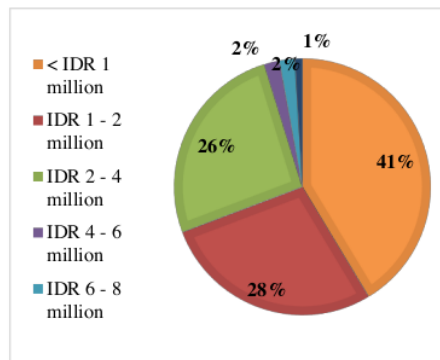
Figure 10. Income per month
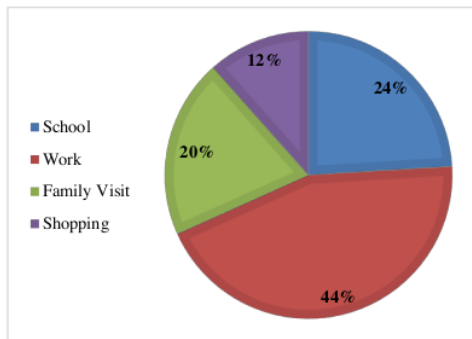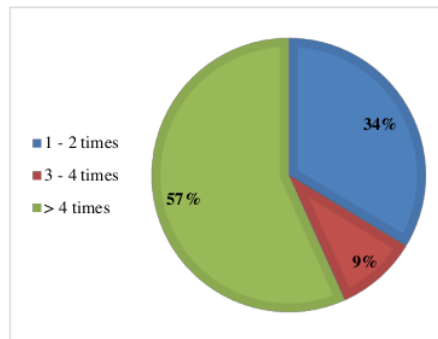
Figure 11. Travel Purposes

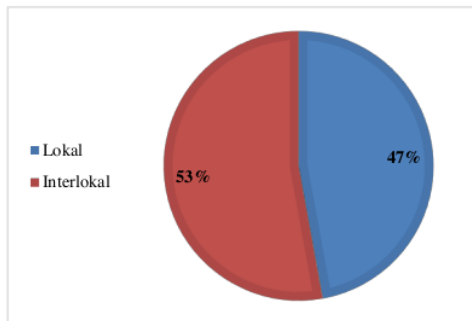**Figure 12.** Travel Frequency
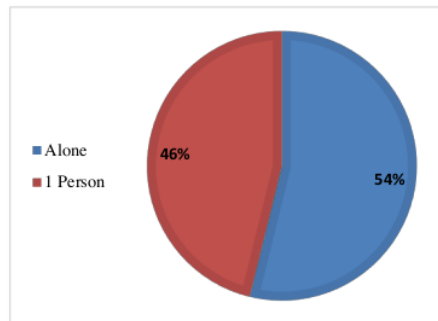

Figure 13. Travel Destination

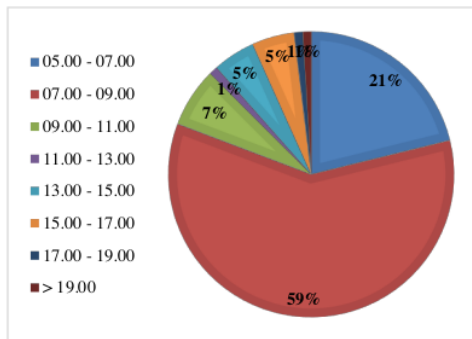**Figure 14.** Travel Friend

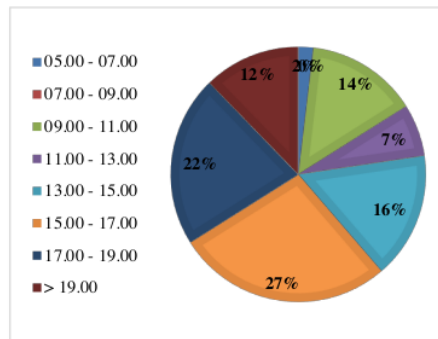**Figure 15.** Departure Time

Figure 16. Return Time

As seen in the figure above, the majority of the respondent was male (55%). Most of them were 17 to 24 years old (44%). The majority of the respondent had graduated at senior high school level (65%) and reported having an annual income of less than 1 Million. The profession of the majority of the respondent was a student (34%). Many respondents use transportation to go to work (44%) more than 4 times (57%). The majority person goes to interlocal (53%) and alone (54%). Activities in departure at 07.00 – 09.00 (59%) and for return at 15.00 – 17.00 (27%). By looking at socio-economic and travel characteristics, it can be seen that public transportation must be in accordance with the interests of users because it affects the choice of modes.

5.2. Multiple Linear Regression

Table 3 shows the output of multiple linear regression analysis. According to the result using Microsoft Excel, the value of coefficient determination is 0.28056. This value means that the effect of all attributes in this model on mode selection is 28%. Another impact is 72% not calculated in this model. F-test result is 7.60635 which means these are proved that the three attributes give an effect on mode choice. A utility of feeder (U_F) or private transportation (U_P) is:

$$U_{F-P} = 2.17834 - 0.00036\ (\text{Cost}) - 0.09478\ (\text{Travel Time}) - 0{,}12403\ (\text{Waiting Time})$$

This equation shows that if someone chooses a mode, it will consider the difference between all the attributes of the mode to be selected.

Table 3. Output Multiple Linear Regression

Attribute	Coefficient	t-stat
Intercept	2.178341747	14.8977349
Cost	-0.000361627	-5.898143089
Travel Time	-0.094788702	-10.30671459
Waiting Time	-0.124032933	-13.4865444
R *square*	0.28056	
F-*test*	7.60635	

5.3. Binomial Logit

The binomial logit or binary logit aims to estimate the probability of choosing a mode by looking at the difference in utility between the two modes being compared. Utility describes the level of satisfaction that a person gets when using goods or services. The utility function shows a person's level of satisfaction in choosing a mode by considering fares, travel times, and waiting times. The calculation of the probability utility for the pessimistic, average, and optimistic scenarios shows in Table 4 below.

Table 4. Probability and Utility Scenarios

		Cost (IDR)	Travel Time (minutes)	Waiting Time (minutes)	$U_{(F-P)}$	P(F)	P(P)
Optimistic Scenario							
Feeder Level		5,000	25	20			
Private Level		4,000	20	0	-1.138	0.2427	0.7573
Deviation		1,000	5	20			
Constanta	2.1783	-0.0004	-0.0948	-0.124			
Average Scenario							
Feeder Level		4,000	20	15			
Private Level		4,000	20	0	0.318	0.5788	0.4212
Deviation		0	0	15			
Constanta	2.1783	-0.0004	-0.0948	-0.124			
Pessimistic Scenario							
		Cost (IDR)	Travel Time (minutes)	Waiting Time (minutes)	$U_{(F-P)}$	P(F)	P(P)

Feeder Level		3,500	15	10			
Private Level		4,000	20	0	1.593	0.831	0.169
Deviation		-500	-5	10			
Constanta	2.1783	-0.0004	-0.0948	-0.124			

5.4. Sensitivity Analysis

The cost sensitivity is shown in Figure 17. The graph has a slope towards the negative line which is not too sharp. It means that the cost attribute is slightly sensitive and it can be interpreted that the expensive cost will increase the probability of passengers choosing private transportation.

The travel time sensitivity is shown in Figure 18. The graph has a sharp slope to the negative line. It means that the travel time attribute is quite sensitive attributes and it can be interpreted that a greater travel time will increase the probability of passengers choosing private transportation.
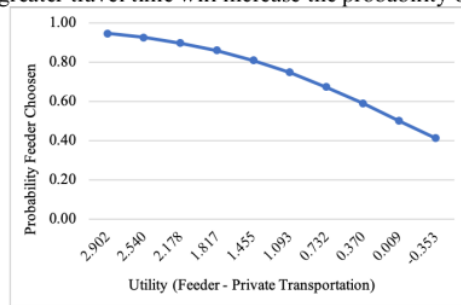

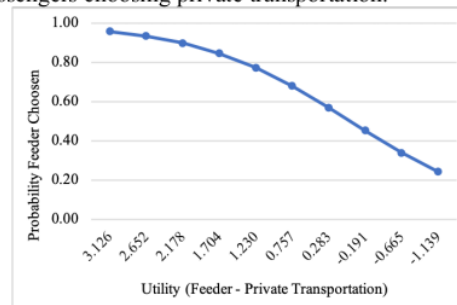**Figure 17.** Cost Sensitivity Graphic

Figure 18. Travel Time Sensitivity Graphic

The waiting time sensitivity is shown in Figure 19 below. The graph has a very sharp slope to the negative line. It means that the waiting time attribute is very sensitive and it can be interpreted that a greater waiting time will increase the probability of passengers choosing private transportation.
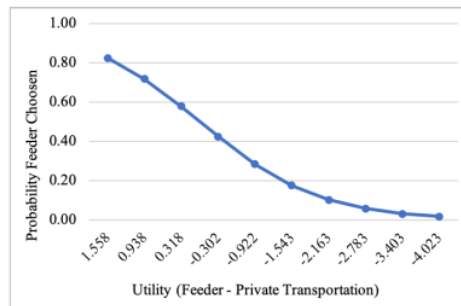

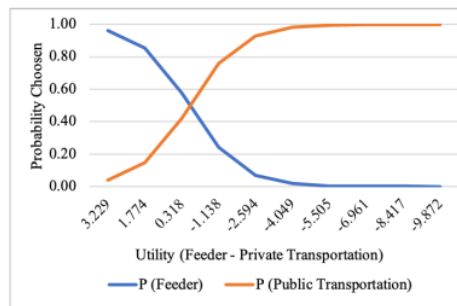**Figure 19.** Waiting Time Sensitivity Graphic

Figure 20. Feeder or Private Transportation Mode Choice Graphic

Figure 20 shows a graph of mode choice of feeder and private transportation in combined attributes by changing every attribute value. It can be seen that the critical point between feeder and private transportation is in the cost deviation IDR 0, has the same travel time as private transportation, and has a maximum waiting time is 15 minutes. Table 5 shows, the utility and probability of choosing feeder or private transportation, the higher value of attributes caused the probability a person choose feeder will decrease. It is found that the value of maximum utility is 3.2293 with a feeder probability is 0.9619.

Table 5. Probability and Utility Model of Feeder and Private Transportation

No	Deviation			Utility (F-P)	P(F)	P(P)
	Cost (IDR)	Travel Cost (minutes)	Waiting Time (minutes)			
1	-2,000	-10	5	3.2293	0.9619	0.0381
2	-1,000	-5	10	1.7736	0.8549	0.1451
3	0	0	15	0.3178	0.5788	0.4212
4	1,000	5	20	-1.1379	0.2427	0.7573
5	2,000	10	25	-2.5936	0.0696	0.9304
6	3,000	15	30	-4.0494	0.0171	0.9829
7	4,000	20	35	-5.5051	0.0040	0.9960
8	5,000	25	40	-6.9608	0.0009	0.9991
9	6,000	30	45	-8.4166	0.0002	0.9998
10	7,000	35	50	-9.8723	0.0001	0.9999

6. Conclusion

The research succeeded in developing 8 alternative scenarios based on three selected attributes with two levels which are cost, travel time, and waiting time. Each attribute having an optimist and pessimist level. The utility model obtained from multiple linear regression, generates the intercept value is 2.1783, a coefficient for cost is -0.00036, for travel time is 0.0948, and for waiting time is -0.1240. The binomial logit model shows that the utility of the optimistic scenario is 1.593 with a feeder probability is 0.8310, the average scenario utility is 0.318 with a feeder probability is 0.5788 and the pessimistic scenario utility is -1.138 with a feeder probability is 0.2427. The passenger willingness to pay is IDR 3,500, 15 minutes for travel time, and 10 minutes tolerable for waiting time. The waiting time has a very significant impact on the mode choice, high number of waiting time wouldn't make the passenger shift mode to the feeder. If the cost and travel time of the feeder are the same as the motorcycle, some passengers will shift mode to the feeder. This study is limited to measure a shifting level of motorcycle users towards feeder at the Gubug-Tanggungharjo-Tegowanu route, based on the selected attributes. Further research is needed to determine the number of potential demands that can be caught using multi-criteria decision-making. It is also important to study the feasibility aspect from the operator's perspective who will drive the feeder.

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