Mode Choice Analysis for Commuters in Metropolitan Region A-Case Study of Bogor City, Indonesia

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ABSTRACT

The congestion of Bogor City is increasingly alarming that it urgently needs policies on transportation system. This study used crosstab analysis and multinomial logistic regression to analyze the behavior of choice of commuter modes in Bogor City. This study had 588 respondents. The selected-by-subdistrict results showed that gender, total income, private car ownership, motorcycle ownership, trip cost, distance traveled, work commute and distance to the terminal affect the choices of Bogor's public transportation modes. As for the implications given in this study, the government is expected to add and renew infrastructure such as stations and shelters. The government is also expected to develop inexpensive public transportation that offers good quality of security and convenience.

Keywords: Implications, Mode Choice, Science, Multinomial Logistic Regression.

I. INTRODUCTION

Economic growth and transportation sector have a very close relationship. This is indicated by the role of transportation sector in economic growth which facilitates people's mobility in carrying out economic activities, such as work, school, recreation, shopping, and other economic activities. Adequate transportation can increase efficiency in the allocation of resources, improve accessibility, support economic activities and can streamline time (Maryanta 2005).

Transportation has a very important role, especially for urban communities and its impact on increasing consumption values, increasing labor productivity and access to employment. The city is considered as an engine of innovation, related to the number of jobs and social services provided by urban areas that it becomes an attraction for residents of rural areas (Baedeker et al 2014). Minal and Sekhar (2014) suggested that high industrialization triggers high economic growth, increased income and high demand for population mobility.

TABEL I

POPULATION DENSITY ACCORDING TO CITIES IN WEST JAVA PROVINCE

City	Population Density
Cimahi	15,127
Bandung	14,854
Bekasi	13,490
Depok	10,883
Bogor	8,985

Source: Statistics of West Java Province, 2017

Various big cities in Indonesia are in a very high stage of urbanization growth. High urbanization increases population density and influences transportation mode choices.

Bogor City is one of the urban areas in terms of various indicators. Based on Table I, the population density of Bogor City occupies the fifth largest in the West Java Province (Statistics Indonesia 2017) with a density level reaching 8,985 people/km2, after Depok City with a density level of 10,883 people/km2, which is caused by several things, namely, Bogor City has the fifth highest UMR (Regional Minimum Wage) in West Java Province, which is 3,557,146 (Governor Regulation of West Java 2018), its topographical position is in the middle of the industrial area, and it has a variety of adequate facilities. Bogor City also has a per capita GRDP that increases every year. Bogor City's GRDP has increased to almost 50 percent in 2010 until 2015. Rapid economic growth will increase the number of transactions and increase the population in Bogor City.

The increase in the number of population leads to the increasing demand for public facilities that are spreading throughout the Bogor City area, such as health, education, shopping center, and urban facilities; this will lead to high mobility between subdistricts, thus demand for transportation becomes high. The Government of Bogor City has provided various types of alternative transportation, such as city transportation (angkot), becak, motorcycle taxi or ojek (online ojek), and inter-city buses. In addition to public transportation modes, people also own private transportation, such as cars and motorcycles as alternative choices.

Based on the data from the Regional Development Planning Agency or Bappeda (2018), the number of vehicles, both public and private, in 2014 was 391,941 units and continued to increase to 2017 as many as 489,860 vehicles. This increase indicates that

the community is maximizing utility in carrying out activities, where they are directly confronted with the choices of various abilities and opportunities that they have (Maryanta 2005). With the development of various types of transportation, it is hoped that efficient transportation can be chosen in accordance with the possessed abilities and opportunities. Therefore, in the future good transportation will improve the economy of Bogor City.

The increase in the number of vehicles, if it is not balanced with an increase in infrastructure and an increase in policies regarding the transportation system in Bogor City, will only cause problems, namely traffic congestion. Bogor City ranks second out of the 5 most traffic-congested cities in the world (Waze 2016).

A large number of private transportation (private cars and motorcycles) also make traffic congestion worse, because because private transportation is deemed less effective, this type of mode can only accommodate about 1-5 people and also uses a quite large of road space.

The trips and mode selection patterns affect the level of traffic congestion, so transportation policies must be established (Sugiyanto 2013). Mode selection is very important and influential in the analysis of transportation policies and decision making. The people of Bogor City on average make a transportation mode choice in order to maximize their utility by considering internal and external factors, therefore they know which transportation mode is appropriate in carrying out activities, both social and economic activities. The estimation factor of the transportation mode selection includes internal factors consisting of age, gender, education, employment status, total income, number of children, number of vehicles and external factors which consist of distance, trip time and transportation cost that must be incurred by

the community. These factors will later influence the community in choosing a particular mode of transportation, therefore mode choice can provide solution to transportation problems in an area (Setyodhono 2017).

Studies related to transportation demand have been carried out in Indonesia, such as the study conducted by Indra and Sukarman (2014) on the transportation mode choices in Palembang, and the same study was also researched by Sugiyanto (2013) with case studies of Yogyakarta and Philippines. However, no research has been conducted on the transportation mode selection in Bogor City with many mode choices, such as private vehicles, travel by foot, and public transportation. The urgency in this study is to solve the problems in the field of transportation in Bogor City by examining the diversity of transportation modes and analyzing the factors that influence transportation mode choices, so that it can be used as a reference in policies in the transportation sector.

II. METHODS AND MATERIAL

The main data used in this study are secondary data from the survey of energy and transportation consumption in the city of Bogor in 2018 conducted by IGES (Environmental Strategy Institute) which uses IPB (Bogor Agricultural Institute). The type of data in this study is cross-sectional data that provides information about the respondent's household characteristics and the characteristics of the respondent's trip. Based on secondary data, the number of data used was 588 respondents taken from all sub-districts in Bogor City (Bogor Utara sub-district, South Bogor, East Bogor, West Bogor, Central Bogor, Tanah Sareal).

This study used descriptive and quantitative analysis methods. Descriptive analysis was used to assess the diversity of transportation modes chosen by

respondents based on characteristics. Quantitative analysis was used to analyze the factors that influence individual decision in choosing the transportation mode used by the people of Bogor City.

A. Descriptive Analysis

The approach taken to assess the diversity of transportation modes used descriptive methods, especially cross tabulation (crosstab), to study a state of a group of people, objects, condition set, thought system or a class of event in the present as well as to obtain information about the profile of the respondents about the chosen transportation modes. It was done using the STATA 14 analysis tool.

B. Analysis of Factors Influencing the Transportation Mode Choices

The model used in quantitative analysis was multinomial logit regression. According to Nachrowi and Usman (2002), multinomial logit regression is a logistic model whose dependent variables are not dichotomy choices (yes or no), but multiple choices (more than two). This model is a development of a binary logit model that is used to analyze the choices on the transportation types used in traveling. The advantage of multinomial logit regression analysis tool is that it can explain simultaneously the influence of independent variables on the probability to choose (Maryanta 2005). The general model of the multinomial logit mentioned by Pindyck and Rubinfeld (1991) mathematically can be formulated as follows:

$$g_1(x) = Ln\left|\frac{F(y=1|x)}{F(y=0|x)}\right| = \beta_{10} + \beta_{11}X_1 + \beta_{12}X_{2+} \ldots + \beta_{1p}X_p$$

Where $F(y = 1|x)$ = probability conjecture of the occurrence of selecting the 1st mode; $F(y = 0|x)$ = probability conjecture of an individual to choose the 0th mode; β_{10} = intercept function of the

comparison between the 1st alternative probability and the 0th alternative probability; β_{11} = regression coefficient of probability comparison function in choosing the 1th mode alternative and the jth alternative for independent variable X_p ; X_p .= independent variable(influence variable) to p; P = gender variable up to d_station.

Public transportation (angkot, becak and online ojek), private cars, travel by foot, and motorcycles are variables that have categorical and discrete properties, hence these variables have been designed for multinomial logit model. In this model, the dependent variables are 1 for public transportation, 2 for private cars, 3 for travel by foot, and 4 for motorcycles. In accordance with the above explanation on multinomial logit model, the model equation is thus compiled by including the following dependent and independent variable elements:

$$Ln\frac{\pi 1(x)}{\pi j(x)} = \quad \beta 0 \quad + \quad \beta jgenderGender \quad +$$
$\beta jincomehhIncomeHH$ + βjnm_kids Nm_kids + $\beta jvehicle\_carhhVechile\_carHH$ + $\beta jvehicle\_motorhhVechile\_motorHH$ + $\beta jtrip\_timeTrip\_time$ + $\beta jtripcostTripcost$ + $\beta jlntrip\_distanceLntrip\_distance$ + βjp_workP_work + $\beta jp\_schoolP\_school$ + $\beta jd\_terminalD\_terminal$

The purpose of using the multinomial logit model in this study was because this model is able to predict the probability of individuals in choosing each of the several alternatives available on the opportunity of choices. Each individual has the probability to choose events 1,2,3,4 that are in accordance with the logit functions, namely travelling by public transportation, private car, foot, or motorcycle. The software program to help the data processing of this study used STATA 14.

III. RESULTS AND DISCUSSION

A. Transportation Mode Diversity Study

Bogor City has a variety of activities facilitated by various types of public services, such as health services, shopping centers, education, offices, and recreation centers spread across 6 sub-districts, this indicates that the people of Bogor City have a high level of mobility between sub-districts. Respondents have a variety of alternative transportation modes based on the characteristics of respondents and travel in determining the mode.

The routes describes which subdistrict has the highest number of routes in each subdistrict in Bogor City. Respondents have a variety of alternative transportation modes based on several characteristics of the respondents and trips in determining the mode. Table II shows that 43 percent of respondents prefer to use motorcycle transportation for mobility, followed by 32 percent of respondents using private car transportation, then 10 percent of respondents choose to travel by foot, and the remaining 15 percent of respondents choose to use public transportation.

The route describes which sub-districts have the highest number of routes in each sub-district in Bogor City. Respondents have a variety of alternative transportation modes based on the characteristics of respondents and travel in determining the mode. Table II shows that the use of public transportation modes is relatively small compared to other modes of transportation (private cars, motorbikes and walking). motorcycle is dominantly used by male and female respondents. respondents with middle and lower income groups were more likely to choose to use motorbikes; while the dominant car is used by respondents in the high income group.

The use of private cars more and more when the costs are higher, the distance is getting farther, the travel time is longer and the purpose of the school; while for motorbike use, the less use of car ownership, the higher the cost, the further the distance, the destination does not work and the destination is not going to school. In the use of public transportation, men tend to use public transportation compared to women. The small choice of public transportation modes for both women and men is due to uncomfortable problems and relatively long travel times.

TABLE II. TRANSPORTATION MODE CHOICE BASED ON THE CHARACTERISTICS OF RESPONDENTS

Variable	Category	By foot (%)	Private car (%)	Public transportation (%)	Motorcycle (%)
Gender	Male	16	28	17	39
	Female	5	35	13	47
IncomeHH	Low MediuHigh	20	10	16	54
		7	33	17	43
		9	53	7	31
KidHH	≤2	10	30	16	44
	>2	14	37	10	39
Vehicle_carHH	0	12	0	20	68
	>1	9	54	12	26
Vehicle_motorHH	0	13	62	24	0
	>1	10	25	13	52
Trip_time	>30 minute	1	46	18	35
	<30 minute	12	29	14	45
Tripcost	<10000	14	22	14	50
	11000-24000	0	50	18	32
	25000-49000	0	59	15	26
	50000-74000	0	90	0	10
	≥75000	0	80	16	4
Lntrip_distance	1-10 Km	12	27	16	46
	11-20 Km	0	46	9	45
	21-30 Km	0	61	22	17
	>40 Km	0	62	8	29
P_Work	Unemployed	15	33	15	37
	Employed	6	31	15	48
P_school	Not going to school	11	31	16	42
	Going to school	2	44	0	53
D_station	0-5 Km	11	33	18	38
	6-10 Km	80	21	9	30
	11-15 Km	7	33	9	51
	>16 Km	0	38	12	50
Total		588	10 %	32%	15%	43%

A. Analysis of Factors Influencing Transportation Mode Choices

Multinomial logit regression analysis was conducted to determine the respondents' transportation mode choices in Bogor City. This model uses base category to facilitate interpreting estimation results. This study used public transportation mode as the base category. Base category is regarded as fixed category and can be used as a comparison with other categories (Probokawuryan 2015). The value of goodness of fit in Table 5 is shown by the value of pseudo R2, which is equal to 0.394, meaning that 39.4 percent is percentage of variation can be explained by the model.

TABLE III. THE DETERMINANTS OF TRANSPORTATION MODE CHOICE

Variable	By Foot		Private Car		Motorcycle	
	Coef	RRR	Coef	RRR	Coef	RRR
Gender	0,68	1,98	-0,79*	0,45	-0,60*	0,54
IncomeHH	-0,29*	0,74	0,32***	1,38	0,02	1,00
KidHH	0,13	1,14	0,22	1,24	0,02	0,97
Vehicle_carHH	0,99*	2,70	2,16***	8,69	-0,13	0,87
Vehicle_motorHH	0,14	1,15	-0,30	0,73	0,74***	2,10
Trip_time	0,01	1,01	-0,005	0,99	-0,002	1,00
Tripcost	-1,70	5,11	0,16	1,18	-0,56*	0,56
Lntrip_distance	-2,02***	0,13	0,22	1,25	-,10	-0,90
P_Work	-0,06	0,93	-0,469	0,62	0,69*	2,00
P_School	13,88	1,071	16,76	1,91	17,39	3,58
D_Station	0,29	1,33	0,43*	1,54	0,56**	1,75
_Cons	27,87	1,28	-5,04	0,006	0,63	1,88
No. of Obs	588					
Pseudo R^2	0,394					
Log likelihood	-443,24					
Prob>X^2	0,000					
LR X^2	576,27					

Description : *** significant at 1%, ** significant at 5%, * significant at 10% Note : Base category is public transportation

The likelihood ratio test was carried out to test the parameters simultaneously so that the conclusion that the logit model used as a whole is able to explain qualitative choice decision (Y) can be obtained. Based on Table III, the value of the likelihood ratio (LR) is equal to 576.27 with a p- value of 0.000 where the LR value is significant at $\alpha < 5$ percent, which means that all variables jointly influence the decision of respondents in choosing transportation modes.

Finding the probability values in the multinomial logit model was done by looking for the values of RRR (Risk Relative Ratio). RRR is a comparison of probabilities of event occurrences; RRR in this study is the same as the odds ratio in the binary logistics that compares with the base category. If RRR value is greater than one, then the probability of traveling by foot, private cars, or motorcycles being selected will also be greater (Probokawuryan 2015).

Based on the literature review, several variables were used into the model to identify factors that influence the people of Bogor City in choosing transportation modes (by foot, private cars, public transportation and motorcycles). The estimation results in this model are significant to dependent variables with direction (+) or (-). A summary of the results of the multinomial logit regression estimation is shown in Table 5.

Based on Table 5, gender variable has a significant influence on the private car and motorcycle mode

choices with negative direction. The probability for male respondents to choose to use private car mode is greater at 0.45 times and the probability to use motorcycles is at 0.54 times. Based on field and interview results at the time of the study, male respondents found it easier to use public transportation and more female respondents chose to use private cars and motorcycles because of comfort and safety factors.

In the model, the total income variable (IncomeHH) significantly influences the transportation mode choices, namely in choosing to travel by foot in a negative direction and choosing a private car in a positive direction. The negative sign indicates that the increase in the income of the respondents leads to the probability to choose traveling by foot lower by 0.74 compared to using public transportation. The same issue was also studied by McDonald (2008) who said that increasing household income would cause a decrease in the travel by foot choice. Meanwhile, the positive sign on the private car mode choice indicates that respondents' higher income leads to the probability to choose using private cars 1.38 times greater than using public transportation. According to Anderson and Karen (2010), Kamba et al. (2007), and Ashalatha et al. (2013), people with lower income will choose to use public transportation.

The estimated result of the number of private car ownership variable (Vehicle_carHH) significantly influences choices with positive direction for travel by foot and private cars, where the increase number of private cars leads to the probability to choose to travel by foot 2.70 times greater than using public transportation. Based on the results of the observations in the field, on average the trip destinations of the respondents are close to their place of residence, this makes more people decide to travel by foot than to use public transportation. A positive sign is also shown in the private car mode choice, where the increase number of private cars leads to the probability to choose private cars 8.69 times greater

than using public transportation. The results of this study are similar to the research conducted by Ashalatha et al. (2013) and Nurdeen et al. (2007) where private car ownership has a significant influence on the selection of private cars compared to using public transportation.

The number of motorcycle ownership variable (vehicle_motorHH) significantly affects the choosing of motorcycle mode with a positive direction, meaning that the increasing number of motorcycles respondents leads a greater chance of respondents to choose motorcycles than using public transportation by 2.10 times. Respondents who own motorcycles prefer to use motorcycles instead of having to use public transportation because Bogor City ranks second in the world's most traffic-congested cities (Waze 2016). This is similar to the study done by Ashalatha et al. (2013) that stated that those who own motorcycles show the transition trend from bus to motorcycle because Calicut City is one of the world's most traffic-congested cities. Even the cost of using a motorcycle is cheaper than that of using public transportation.

The trip cost variable (Tripcost) also affects the motorcycle mode choice with a negative direction, which means that greater trip cost leads to lower probability of respondents in selecting motorcycles compared to using public transportation by 0.56 times. This is supported by the Meteorology, Climatology and Geophysics Agency (BMKG of West Java Province 2018) which stated that Bogor City in the months of study period, namely February and March 2018, experienced 123 mm precipitation, therefore respondents preferred to use public transportation.

The distance variable (Lntrip_distance) significantly affects the selection of travel-by-foot mode with negative direction, which indicates that the more distance the respondents travel, the lower the probability to choose walking compared to using public transportation is by 0.13 times. A similar study

examined by McDonald (2018) stated that farther distance traveled to school has led to the decision in using the school bus. In addition, Ewing et al. (2004) also stated that short distances make people choose to walk rather than using public transportation.

Work commute variable (p_work) significantly influences the motorcycle mode choice with a positive direction which means that the respondents with the travel destination of going to work have the probability to select using motorcycles 2.00 times greater than the ones whose destination is not to go to work. The limited number of stations and shelters in each subdistrict of Bogor City makes using motorcycles more efficient for work purposes. The results of this study are in line with the findings made by Salarvandian et al. (2017) who said that users of public transportation are far lower than those of private vehicles for work trips.

The distance to station variable (d_station) with a positive sign has a significant effect on choosing private cars and motorcycles. This indicates that farther distance to station leads to the greater probabilities of respondents in choosing to use private cars and motorcycles than using public transportation by 1.54 times and 1.75 times, respectively. These findings are supported by the results of the study conducted by Anderson and Karen (2010) who found a similar thing, namely at any distance to the train station, the community is more dominated by private cars compared to using buses. In addition, Wibowo and Rudiarto (2017) also stated that the farther the respondents' residence to the airport, the greater the probability of private vehicles to be chosen to go to Kulonprogo Airport.

IV. CONCLUSION AND RECOMMENDATIONS

The results of the analysis show that the choice of public transportation modes is relatively small compared to other modes of transportation (private cars and motorbikes and walking), which are dominated by private modes of car and motorcycle transportation. Dominant motorbikes are used by respondents in the middle and lower income groups; while the dominant car is used by respondents in the high income group. The use of private cars more and more when the costs are higher, the distance is getting farther, the travel time is longer and the purpose of the school; while for motorbike use, the less use of car ownership, the higher the cost, the further the distance, the destination does not work and the destination is not going to school. In the use of public transportation, In the use of public transportation, men tend to use public transportation compared to women. The small choice of public transportation modes for both women and men is due to uncomfortable problems and relatively long travel times.

The results of the multinomial logit analysis show that the factors that significantly influence the choice of walking rather than public transportation are the relatively high total income and relatively far distance. The factors that influence the choice of private cars from using public transportation significantly are female sex, relatively large number of private car ownership, relatively high total income and the distance to the terminal which is relatively far away. The factors that influence the choice of motorbikes from using public transportation significantly are the female respondents, the relatively large number of motorbike ownership, the cost of a relatively cheap trip, the purpose of the trip to work, and the distance to the terminal which is relatively far away.

Based on the results of the analysis, the policy implications in encouraging increased public transport use and reducing the level of traffic congestion in the city of Bogor are to add and renew terminals or stops; develop modes of transportation that are safe, comfortable, and have a lot of operating time with relatively cheap rates.

V. ACKNOWLEDGMENTS

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