Mode choice analysis among motorcycle and Trans Koetaradja urban bus and its contributing factors using revealed preference (RP) data

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Abstract. The random utility maximization (RUM) is a widely used principle to study customer behaviors derived from econometric theory. The mode choice problem in transportation planning has been intensively studied to explore the choice behavior of travelers. In the demand analysis, market shares among transport modes are substantially used for public transport planning and operation. Therefore, this study is a preliminary analysis of the modeling complex mode choice behaviors among motorcycle and bus system so-called Trans Koetaradja by considering specific attributes of mode, households, and individual sociodemographic attributes. The developed mode model of mode choice is used to explore the effect of specific attributes of mode, households, and individual sociodemographic on traveler’s mode choice behaviors and its contributing factors. Using the Revealed Preference (RP) data collected in Banda Aceh, we formulate Binary Logit (BL) to identify and evaluate the effects specific attributes of mode, households, and individual sociodemographic on mode choice. These results confirm that there is a substantial contribution of the specific mode attributes of the individual in determining selected mode choice. The specific attribute of motorcycle mode preference such as travel time (TT) and distance of destination (DD).

Findings further confirm that individual sociodemographic variable including dummy young Age (DYA), dummy has elementary education background (DEB), dummy has low-medium income (DIN), dummy owned motorcycle (DOM) and dummy has driver license (DDL) have a statistically significant alert to the selecting mode choice of motorcycle.

1. Introduction
Public transport planning and operation become the major challenger of transport planners, particularly in developing country perspective. It is widely known that private modes such as cars and motorcycles are the most common mode used in emerging countries, including medium-big cities in Indonesia [1-3]. Thus, understanding the behavioral traveler, specifically related to the mode choice is a crucial issue in transit planning. Realizing the total market shares of the mode choice and its influencing factors is an essential problem for any investigation on the demand analysis.

In the context of the high demand for private mode usage, planning for public transport is crucial needs to be deliberate a policy that encourages public mode usage. One promising of transportation demand management (TDM) strategies aimed at alleviating private mode effects is promoting public transportation usage. In such a case, public transport (PT) such as the urban bus system is viewed as a
prospective policy aiming at achieving efficiency of infrastructure use. Several implementations of urban bus policy such as bus reform policy [4-5] and Bus Rapid Transit [6-7]. In Banda Aceh, the Trans Koetardja (TK) is a bus reform policy that has been operated to promote bus ridership. Previous studies by [4-5] explore that the TK is acceptable in a policy aiming at reducing congestion within the city center, but people somehow do not want to use the bus due to highly autos dependency. Regarding the demand of the TK users, forecasting the demand for bus ridership relates the choice behavior of travelers to the characteristics of private and TK mode. The accuracy of the mode share will provide the overall market shares among private mode and the bus TK, which are substantially used for the planning and operation of the bus.

The random utility maximization (RUM) is a widely used principle to study customer behaviors derived from econometric theory. The mode choice problem in transportation planning has been intensively studied to explore the choice behavior of travelers [8]. Further implementation BL model by [9-10] to explore travel behavior related to individual preferences in the voting congestion charging policy in Jakarta. Perhaps a more recent study by [8] conducted BL analysis to assess the effects of numerous factors and to identify the leading factor that exaggerated evacuation mode choice in Tohoku, Japan. In the demand analysis, market shares among transport modes are substantially used for public transport planning and operation. Therefore, this study is a preliminary analysis of the modeling complex mode choice behaviors among private (car and motorcycle) and public mode (Trans Koetaradja) by considering household and individual household and individual sociodemographic attributes. The developed model choice is used to explore the effect of household and individual household and individual sociodemographic attributes on traveler’s mode choice behaviors and its contributing factors. Using the Revealed Preference (RP) data collected in Banda Aceh, we formulate Binary Logit (BL) based on the RUM principle to identify and evaluate the effects of household and individual sociodemographic factors on individual mode choice. The rest of this paper is organized as follows.

Therefore, this study is a preliminary analysis of the modeling complex mode choice behaviors among motorcycle and bus system so-called Trans Koetaradja by considering specific attributes of mode, households, and individual sociodemographic attributes. The developed model of mode choice is used to explore the effect of specific attributes of mode, households, and individual sociodemographic attributes on traveler’s mode choice behaviors and its contributing factors. Using the Revealed Preference (RP) data collected in Banda Aceh, we formulate Binary Logit (BL) to identify and evaluate the effects specific attributes of mode, households, and individual sociodemographic on mode choice. In the next section gives a brief description of the RP survey, the distribution of the data, and describe the BL formulation. The finding, discussion, and conclusion of this work are presented at the end of this paper.

| Description                              | Detail                                      |
|------------------------------------------|---------------------------------------------|
| Time of survey                           | Juni 2020                                   |
| Target responden/location                | Citizen/Banda Aceh                          |
| Distribution methods                     | Online based questionnaire using google form |
| Number of questionnaires/valid samples   | 497/400 valid samples                       |

2. Study area
This preliminary study is focused on the TK bus lines located in the city of Banda Aceh, a capital province of Aceh. The city centers of Banda Aceh attract many visitors and are served by urban arterial roads that experience serious autos traffic. The target bus lines are within the city center of Banda Aceh, as illustrated in Figure 1. The questionnaires were distributed within a city of Banda Aceh to the individual who has experienced using both motorcycle and the TK bus as their mode. Among 497 samples, 400 samples were used for the analysis of mode choice among motorcycle and TK bus.
Figure 1. Map of the study area.

Table 2. Description of respondents’ socio-demographics.

| Item       | Category          | Share | Item       | Category          | Share |
|------------|-------------------|-------|------------|-------------------|-------|
| Gender     | Male              | 42%   | Monthly    | IDR 1 or less     | 14%   |
|            | Female            | 58%   | Income     | IDR 1 – 2.9       | 24%   |
| Age        | 17-19 years       | 15%   | (in million) | IDR 3 – 4.9       | 25%   |
|            | 20-29 years       | 76%   |            | IDR 5 – 6.9       | 19%   |
|            | 30-39 years       | 8%    |            | IDR 7 – 9.9       | 8%    |
|            | 40-49 years       | 1%    |            | More than IDR 10  | 10%   |
|            | 50-59 years       | 0%    |            |                   |       |
|            | 60 years or more  | 0%    |            |                   |       |
| Occupation | Working           | 17%   | Driver’s license | Has a driver’s license | 84%   |
|            | Student           | 61%   | license     | Has no driver’s license | 16%   |
|            | Unemployed        | 22%   |            |                   |       |

The respondents were asked general features of mode choice preference for their daily activities for both commuting and non-commuting by competing for motorcycle and TK bus as their mode preferences. Furthermore, the question related to a specific attribute of the selected mode, travel behavior attribute, individual socio-demographic characteristics such as gender, age, income, marital status, household membership, the number of a car owned, and the number of motorcycles owned. The questionnaires were distributed using the online system of google form as much as 480 samples were collected and a total of 400 samples valid and used in this study. The RP survey is summarized in Table 1, which gives the time of the surveys, target respondents/locations, distribution methods, number of samples, and valid samples.

Table 2 shows the distribution of respondent’s socio-demographics. It can be seen that young people (≤30 years) is dominated sample set, accounting for more than 90% of respondents. The gender distribution is slightly skewed toward females (58%). As regards employment status, our sample indicates 17% of employed respondents as workers, and less surprisingly more than 60% of the sample...
consists of students. As for the income, it is found that up to 49% has a medium monthly income. Additionally, the distribution of samples reveals that close to 85% of respondents are having a driving license.

3. Model formulation and variable setting
The RP questionnaire was employed to capture the effect of specific attributes of mode, households, and individual sociodemographic on mode choice on the mode preference among motorcycle and TK bus. The dependent variable is set as the preference of the mode choices used by respondents for their daily traveling. Two choices of the mode are offered to the respondent to select one between two choices (i.e., motorcycle and TK bus).

| Table 3. Distribution of the dependence variable (mode choice for daily traveling). |
|-----------------------------------------------|
| Variable | Mode Choice Set | Observed Mode Choice Preference |
|----------|-----------------|---------------------------------|
|          | 80%             | Motorcycle                      |
|          | 20%             | Trans Koertardja (Bus)           |

Table 3 depicts that the dependent variable looks like to be normally distributed. A Kolmogorov-Smirnov test is conducted to ensure the data normally distributed with a 5% significant level of error. The mean of selecting a motorcycle as a preferred mode in the dataset was 0.80 (SD = 0.402). It depicts that people in Banca Aceh have a strong preference to use a motorcycle for their daily travel.

4. Binary logistic model
A modeling approach of a discrete choice model based on the random utility maximization (RUM) is used to explore the effect of specific attributes of mode, households, and individual sociodemographic on mode choice on the mode preference among motorcycle and TK bus. A simple formulation of binary logistic (BL) regression of the odds ratio is used to delve more deeply related respondent’s intentions to choose their mode for their daily travel.

The modeling BL choice behavior is formulated for the following choices: respondents to select one between two choices among motorcycle and TK bus for their travel. The probability that an individual i chooses motorcycle $\pi_i$ is modeled based on the RUM theory as shown in Equation (1) and (2). More advance and detail of the binary choice and maximum likelihood estimator (MLE) can be referred to [8-10]. In this study, unknown parameters are estimated using MLE and implemented in NLogit 5.

$$\begin{align*}
\text{logit}(\pi_i) &= \log\left(\frac{\pi_i}{1-\pi_i}\right) = \beta x_i \\
\pi_i &= Pr(Y_i = 1|x_i) = \frac{exp(\beta x_i)}{1+exp(\beta x_i)}
\end{align*}$$

The BL regression is a conventional method to determine the best fit model among dependence variables and predictors using the calibration data set as described in Table 3. The exogenous variables were set as binary choice as $Y_i = \{1: \text{used motorcycle}, 0: \text{used TK bus}\}$. According to the equation (2), Y represents response variables, and $x_i$ is a vector of explanatory variables namely Travel Time (TT), Distance of Destination (DD), Age (dummy young AG), Academic Background (dummy elementary education AB), Income (dummy low-medium income INC), Motorcycle Owned (dummy has motorcycle MO), and Driver's license (dummy has driver license DL). Variable notation, definition, and empirical settings for both response and regressor used in BL calibration of mode choice model are summarized in Table 4.
Table 4. Distribution of the dependence variable (mode choice calibration).

| Variable                        | The setting of variables (parameter coding)                                                                 |
|---------------------------------|-------------------------------------------------------------------------------------------------------------|
| Mode Choice (MC)                | Binary choices: 1 used motorcycle; 0 used TK bus                                                                |
| Travel Time (TT)                | Dummy variable of Travel Time: 1 if <30 minute; 0 if more >30 minute                                           |
| Distance of Destination (DD)    | 1 if < 4 km or less; 2 if 4-6.9 km; 3 if 7-9.9 km; 4 if 10-12.9 km; 5 if > 12 km or more                   |
| Dummy Young Age (DYA)           | Dummy variable of Age: 1 if has < 30 years; 0 if has more >30 years                                           |
| Dummy has elementary education background (DEB) | Dummy variable of academic background: 1 if elementary education; 0 Otherwise                             |
| Dummy has low-medium income (DIN) | Dummy variable of monthly household’ income: 1 if low-income household (income < 5 million IDR/month); 0 Otherwise |
| Dummy owned motorcycle (DOM)    | Dummy of having a motorcycle within the household: 1 if has a motorcycle; 0 otherwise                       |
| Dummy has a driver license (DDL) | Dummy has a driver license: 1 if has driver’s license; 0 if no driver’s license                             |

5. Result and Discussion

The stepwise calibration method is used to select the best fit of the model. The maximum likelihood estimator (MLE) is implemented to calibrated BL parameters. To ensure our model is statistically acceptable the 5 % level of error is applied for t-test significantly. However, several variables still are selected within a 10% level of error as it is for behavioral analysis rather than for the predicted model. The result of the calibrated parameters and its significant level can be seen in Table 5 including the Goodness of Fit (GoF) calibrated model.

Table 5. Calibrated parameters and goodness of fit of mode choice model.

| Predictors                        | Coefficient (β) | Odds Ratio (exp β) | T-value | P-Value |
|-----------------------------------|-----------------|--------------------|---------|---------|
| Travel Time (TT)                  | 0.911           | 1.140              | 3.03    | 0.002   |
| Distance of Destination (DD)      | 0.131           | 2.487              | 1.26    | 0.209   |
| Dummy Young Age (DYA)             | 2.433           | 11.394             | 5.36    | 0.000   |
| Dummy has elementary education background (DEB) | 0.795           | 2.214              | 4.92    | 0.000   |
| Dummy has low-medium income (DIN) | 0.356           | 1.428              | 3.18    | 0.001   |
| Dummy owned motorcycle (DOM)      | 0.312           | 1.366              | 2.23    | 0.026   |
| Dummy has a driver license (DDL)  | 0.925           | 2.520              | 2.63    | 0.009   |
| Dependent Variable                | MC              |                    |         |         |
| Number of Samples                 | 400             |                    |         |         |
| LL (0)                            | -201.53         |                    |         |         |
| LL(β)                             | -165.69         |                    |         |         |
| χ² (5df)/χ² Significance level    | 71.82/0.00      |                    |         |         |
| McFadden Pseudo R-Squared         | 0.19            |                    |         |         |
| A Receiver Operating Characteristic Curve (ROC) | 0.79            |                    |         |         |

Table 4 exhibits the parameter results of the estimation of mode choice model considering explanatory variables such as Travel Time (TT), Distance of Destination (DD), Dummy Young Age (DYA), Dummy has elementary education background (DEB), Dummy has low-medium income (DIN), Dummy owned motorcycle (DOM), and Dummy has driver license (DDL). Calculated indicates of
model performance include log-likelihood at convergence (LL (β)) and McFadden Pseudo R-Squared, and a receiver operating characteristic curve (ROC). The values of several goodness of fit indices as shown in the bottom of Table 4 show that the LL0 (-201.53), LLβ (-165.69), $\chi^2$ (5df)/$\chi^2$ Significance level (71.82 at sig. 0.000), McFadden Pseudo R-Squared (0.19), and a Receiver Operating Characteristic Curve (0.79). These indices depict substantially the best fit for the calibrated model in Table 4.

![Figure 2. The ROC curve.](image)

Examining the calibrated parameter results presented in Table 5, the parameters of the specific attribute of motorcycle mode preference such as travel time (TT) and distance of destination (DD) have shown a significant positive correlation to the selected motorcycle mode choice. The odds ratio (exp β) indicates that 1.14 and 2.48 for travel time (TT) and distance of destination (DD), respectively, meaning that increasing 0.9 minutes of travel time will lead to an increase in the probability of selecting a motorcycle 1.4 times compared to the probability of selecting bus Trans Koetaradja. Furthermore, the probability of selecting a motorcycle will increase 2.48 times compared to the probability of selecting bus Trans Koetaradja as a distance increase of 0.13 km travel. These results confirm that there is a substantial contribution of the specific mode attributes of the individual in determining selected mode choice.

Pertaining the individual sociodemographic on selecting mode choice, all the variables including dummy young Age (DYA), dummy has elementary education background (DEB), dummy has low-medium income (DIN), dummy owned motorcycle (DOM) and dummy has driver license (DDL) have a statistically significant alert to the selecting mode choice of motorcycle. The variables of dummy young age, dummy has an elementary education background and dummy has low-income have shown the most significant contributing factors. For instance, it seems that young age respondents tend to use motorcycle compared to Trans Koetaradja as the value of odds ratio (exp β) 11.3 times compared to the probability of selecting Trans Koetaradja. This indicates that young people play a crucial role in influencing the used of motorcycle mode in Banda Aceh. Moreover, a positive correlation also linked to other individual’s socio-demographic attributes of low-income households and has an education background. It appears that low-income households tend to be used motorcycles to transport as they may feel a motorcycle is a convenient mode and easy to use.
6. Conclusion

This work investigates how individual choice behavior relating to the mode choice used for daily travel by considering revealed preference (RP) data collected in Banda Aceh. A binary choice based on logistic distribution formulated according to random utility maximization theory to explore individual choice behavior of the mode choices among motorcycle and Trans Koetaradja bus system. The effect of specific attributes of mode, households, and individual sociodemographic attributes on traveler’s mode choice behaviors and its contributing factors then revealed using developed mode choice model in this study. These results confirm that there is a substantial contribution of the specific mode attributes of the individual in determining selected mode choice. The specific attribute of motorcycle mode preference such as travel time (TT) and distance of destination (DD) have shown a significant positive correlation to the selected motorcycle mode choice. Findings further confirm that individual sociodemographic variable including dummy young Age (DYA), dummy has elementary education background (DEB), dummy has low-medium income (DIN), dummy owned motorcycle (DOM) and dummy has driver license (DDL) have a statistically significant alert to the selecting mode choice of motorcycle. The variables of dummy young age, dummy has an elementary education background and dummy has low-income appears as the most significant contributing factors. These empirical findings may present broad assistance in efforts to the government for the suggested establishment of the Trans Koetaradja bus policy as previous work done by [11-12]. Furthermore, this transport-related policy to mitigate motorcycle dependency and promote Trans Koetardja bus system ridership.

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