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Elasticity of Travel Time and Travel Cost of Private Vehicles and Public Transportation in Bandung, Indonesia

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Abstract: Understanding mechanism of users in responding determinant variables to use mode of transport is beneficial to anticipate the effect of policy. This study aims to identify the elasticity value of travel time and travel cost of the users of private vehicles and public transportation. Using data from users of private vehicles and public transport in Bandung, Indonesia, the elasticity of travel time and travel cost was calculated based on estimated multinomial logit model (MNL) logit. The elasticity was calculated based on gasoline prices, parking fees, transfer fees, access times, travel times, and waiting times. Based on the results of the elasticity values for travel attribute, it was found that in access time and travel time, Trans Metro Bandung (TMB) Bus had the largest elasticity of -0,564 and -5,001, respectively, so TMB Bus was the most sensitive to changes in access time and travel time. In terms of waiting times and fixed costs/gasoline, conventional taxi has the highest elasticity values of -2,630 and -1,604, respectively, so conventional taxi is the most sensitive to changes in waiting time and fixed costs/gasoline.

Keywords: Public transportation; stated preference; travel time; travel cost; elasticity.

Introduction

Mode selection is part of the decision-making process in transportation, which includes identifying relevant transportation performance variables, selecting transportation modes, negotiating tariffs and service levels, and evaluating transportation mode performance [1]. Nowadays, people prefer modes by paying attention to comfort, safety, travel time, distance traveled, time reliability, or travel costs [2]. In choosing a travel mode, people prioritize the choice of a travel mode according to the purpose of the trip that must be fulfilled [3].

The problem with the choice of transportation mode is that people tend to use private vehicles because of their convenience, flexibility, more time saving, and also because people feel "in control", they can also decide when and where to go, so they assume that public transportation is not attractive enough [4]. Referring to 609,000 commuter residents of Greater Bandung, 95% of the commuter population traveled their activities using private vehicles or by foot and stated that they did not want to switch to using public transportation modes due to the long and impractical travel time [5].

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One of the main barriers to mode switching for private vehicle drivers is travel time [6] and travel costs [7]. Maduwanthi [8] found the reasons of the preference of people in Sri Lanka to private vehicles are time, safety, comfort, and purpose of travel based on the behavior of travelers. Johnson [9] also stated similarly that people in Sweden consider time and costs necessary for the choice of transportation mode (private vehicles, trains, and buses), but also show that preferences for flexibility and convenience are significant.

Travel costs are an essential factor in influencing the choice of transportation modes [10]. The low cost of public transportation has attracted interest in switching modes from private vehicles [11]. Moyano et al. [12] found that Spanish's society depends on the low cost factor in determining the transportation choice.

Thus, it is needed to have an indicator to evaluate the changes in people decision or behavior as result of the policy. Policy makers can predict how variables of transportation modes changes affect travel activities and revenues. The indicators of changes as a result of the change of the variables in transportation modes is also known as the elasticity of demand [13]. It can evaluate various transportation demand management policies or programs intended to change travel activity to achieve various planning objectives[14]. Many researchers on the elasticity of public transportation abroad not only analyzes based on vehicle attributes but also pays attention to the short-term and long-term demand [15,16], sociodemographic [17,18], and convenience [19]. Meanwhile, research on

elasticity in developing countries particularly Indonesia, is still limited to the vehicle attributes [20-23].

With this background, this study aims to analyze the elasticity value of private and public transport users. The elasticity value is analyzed by estimating Multinomial Logit Model (MNL) based on Stated Preference questionnaire distributed to users in Bandung, Indonesia. The elasticity values can be used to investigate the impact of such policy. It is also useful in enriching body of knowledge regarding behavior of users in developing countries

Method

Data Collection

The location of this study is Greater Bandung which includes Bandung Regency, West Bandung Regency, Sumedang Regency, Cimahi City, and Bandung City. Based on the results of the 2017 Bandung Raya commuter survey [24], the population of Greater Bandung has a population of 8.7 million people, which 7% of the total population are commuters.

The preliminary survey in this study was conducted to improve and refine the questionnaire that will be used during the primary survey. The preliminary survey was conducted one week from Monday, August 16, 2021, to Friday, August 20, 2021. The preliminary survey was conducted by distributing 3 out of 16 questionnaires to 30 respondents at random to find out the shortcomings of each narrative and question on the questionnaire. The preliminary survey aims to reduce respondents' misunderstanding when filling out the questionnaire. After one week, the preliminary survey was completed. The results were used to improve the questionnaire. The final questionnaire was distributed from Monday, October 18, 2021, to Sunday, October 24, 2021.

The questionnaire in this study was divided into three parts, namely socio-demography, travel characteristics, and stated preference. Socio-demography in this study includes gender, age, last education, occupation, monthly income, private car and motorbike ownerships. Questions regarding travel characteristics include the purpose of the trip, departure time, travel time, travel costs, experience using public transportation, location of residence, distance traveled, use of transportation modes for the first mile, last mile, and the primary mode. The last part consists of a series of stated preference questions. In this study there are 16 sets of questionnaire, where each set consisted of 4 stated preference questions.

The minimum number of respondents (i.e. 400 respondents) needed in filling out this research questionnaire was calculated based on the Slovin formula[25]. A total of 540 respondents have filled out the questionnaire. However, there were 37 uncompleted respondents' responses, which were eliminated resulting 503 respondents for further analyses.

Design of Experiment

The experiment was designed to determine the effect of time and travel costs on selecting available transportation modes in the city of Bandung. Based on the variables of time and travel costs, the selection of attributes that are assumed to affect the choice of transportation modes is carried out.

The attributes used in selecting transportation modes in the Stated Preference questionnaire include: 1. Fixed costs (Gasoline/Tariffs); 2. Parking Fees; 3. Transfer Fees; 4. Travel Time; 5. Waiting Time; 6. Walking Time; 7. Number of Transits; 8. Delay. In general, the attributes used are divided into two parts, namely, travel time which is divided into travel time, walking time, and delays. The second is travel costs which are divided into fixed costs in the form of gasoline when using private vehicles and fares when using public transportation: parking fees, and transfer fees. The time and cost of the trip are also influenced by the number of transits, the intensity of the weather, and the purpose of the trip.

The determination of the combination is done because there are attributes and attribute levels used for the Stated Preference questionnaire. In this study, the combination is carried out to obtain a combination of attributes and attribute levels using NGENE Software. This division is carried out because each individual's short-term memory system stores information or stimuli for only about 30 seconds, and also, only about seven (7) chunks of information can be stored and maintained in the short-term memory system at a time[25]. In this study, there are seven attributes, with each having three levels. It should be noted that the explanatory variables for travel purposes and weather intensity were not included in the combination of the Stated Preference questionnaires to limit the Stated Preference questions to one questionnaire.

Discrete Choice Model

Mode selection behavior for public transportation is the key to public transportation planning [26]. The multinomial logit model (MNL) is the most widely used choice model in various fields. This model seeks to study choice decisions or perceived value of an event among a series of mutually exclusive alternatives [27]. The decision was made based on the

utility of the choices. Utility refers to the total satisfaction received by an individual when using a product or service [28]. The basic assumption embodied in the random utility approach is that the decision maker is a utility maximizer, i.e., given a set of alternatives, the decision maker will choose the alternative that maximizes his utility. The utility function contains alternatives and individual characteristics that describe the utility of individual assessments for each alternative [29]. The utility function can be systematically formulated as stated in equation 1.

$$U_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_i X_i + \varepsilon_i \quad (1)$$

where U_i is choice utility, β_0 is the constant influence of the choice characteristics that are not considered in the utility function, β_1 the resulting coefficient of an attribute to 1 (e.g. travel time), X_1 is attribute value of 1st choice (e.g. 20 minutes for travel time), and ε_i is error term.

Elasticity

To find out how significant changes in a demand variable that follow changes in transportation mode attributes are usually used elasticity of demand. Demand elasticity measures how sensitive changes in demand are due to changes in a determinant attribute [30]. Elasticity shows the effect of the percentage change of the dependent variable on the percentage change of the independent variable [13]. The percentage change value in the dependent variable depends on the utility value contained in Equation 1. The utility value is influenced by the respondent's choice of various attribute conditions contained in each type of available transportation mode where people will choose the mode of transportation that maximizes their utility or needs.

In transportation mode selection, elasticity represents information on the effect of changes in travel attributes such as travel time and cost on a dependent variable, namely the probability of choosing a transportation mode. Louviere et al. [31] explain direct elasticity to measure the percentage change in the likelihood of selecting a transportation mode due to the percentage change given to one attribute in the mode utility function.

$$E_{X_{ikq}}^{P_{iq}} = -\beta_{ik}\, x\, X_{ikq}\, x\, (1 - P_{iq}) \quad (2)$$

where $E_{X_{ikq}}^{P_{iq}}$ is the probability elasticity value of alternative i for individual q with the k-th attribute change in alternative i, $-\beta_{ik}$ is the coefficient of attribute value on alternative i for the k-th attribute, X_{ikq} is changes in the value of alternative i for the k-th attribute on individual q, and P_{iq} is alternative probability i for individual q.

Analysis

Descriptive Analysis

Based on the gender of the respondents, it was found that the majority who took part in the survey were women as many as 310 people (61.63%), living in the city of Bandung (410 respondents or 81.51%). They were in the age between 16 to 24 years (55.07%). Their highest education is senior high school (69.38%). Respondents were private employees (45.33%). They have a monthly income between three to five million IDR (45.73%), where the minimum wages standard in Bandung was around 3.5 million IDR. It is important to note that the respondents involved in this study do not have a private car (66.40%), but they have a personal motorbike (45.13%).

Travel Characteristic

The survey results show that the majority of respondents have a travel destination to work (55.67%). Majority of respondents depart from home to the activity location between 07.00 - 08.00 AM (48.91%). Most of respondents traveled less than five kilometers (49.50%). Respondents reported that they used conventional motorcycle taxis for less than one year (39.80%) and online motorcycle taxis for one to two years (36.58%). Around 43% of them reported for using online taxis for less than one year, as well as using city transportation for more than five years. Around 23% of them used Trans Metro Bandung (TMB) buses for less than one year (22.66%). Around 53% of respondents reported for having no experience using conventional taxis.

Model Estimation

The MNL model was estimated based on Stated Preference questionnaire. The dependent variables in this model alternative modes, namely private car, private motorcycles, public transport called *angkutan kota*, TMB Bus, conventional taxi, online motorcycle, and online taxi. The explanatory variables consisted of eight mode characteristics socio-demography variables. There are 54 estimated parameters for analyses, with a total of 2012 respondent' responses.

Model was estimated using biogeme software. For dependent variable, the alternative mode of transportation was coded with a number of one to seven. The private car is used as a reference mode. Table 1 shows the estimated model of mode choice.

Table 1. Estimated Model

Variables	Estimate	Rob. p-value
Angkutan Kota	1.62	0.000
Private Motorcycle	-1.83	0.000
Online Motorcycle	-0.056	0.625
Conventional Taxi	-0.351	0.159
TMB Bus	1.14	0.000
Online Taxi	0.836	0.000
Transportation Attribute		
Access Time	-0.816	0.000
Parking Cost	-0.019	0.336
Fixed/Gasoline Cost	-0.04	0.000
Transfer Cost	-0.014	0.732
Delay	-0.027	0.000
Transfer Amount	-0.141	0.126
Travel Time	-3.48	0.000
Waiting Time	-2.47	0.000
Socio demography		
Sex (Male = 1)	-0.078	0.519
Destination (Entertainment Places = 1)	0.339	0.065
Age		
16 - 24 Years	0.639	0.000
25 - 34 Years	0.298	0.049
> 34 Years	0.427	0.018
Car Ownership		
Own one or more car (1)	-0.039	0.778
Motorcycle Ownership		
Own one or more motorcycle (1)	-0.059	0.66
Weather		
Sunny	1.92	0.000
Drizzling	0.969	0.000
Moderate Rain	-0.954	0.000
Heavy Rain	-0.568	0.000
Last Formal Education		
Junior High School/Equivalent and Senior High School/Equivalent (1) D1/D2/D3 (Diploma) and above (0)	-0.046	0.747
Income per Month		
3 million IDR or below	0.443	0.003
Rp. 3.000.001 – Rp. 5.000.000	0.433	0.000
Rp. 5.000.001 – Rp. 10.000.000	0.304	0.034
10 million IDR or higher	0.183	0.285
Occupation		
Student/ College Student	0.207	0.181
Office Worker	0.279	0.024
Entrepreneur	0.43	0.005
PNS/TNI/Polri/BUMN and Others	0.448	0.008
Null Log Likelihood	-3915.171	
Final Log Likelihood	-3203.364	
Rho - Square Null Model	0.232	
Cox & Snell Rho - Square	0.594	
Nagelkerke Rho - Square	0.606	

Table 1 reported log-likelihood values for the base and final models. It can be seen that the log-likelihood value for the base model is -3915.171. After the independent variables were included, the log-likelihood value was reduced to -3203.364. Based on the results of the likelihood log, then the Rho – Square value is obtained which is 0.232. The value of Rho Square Cox & Snell can be calculated which produces a value of 0.594. The result with Nagelkerke Rho–square produces a value of 0.606.

Based on the results of the log-likelihood value, there are differences before and after the independent variables are entered for analysis. The smaller the log-likelihood value, the more accurate the model will be. So with the independent variables included in the analysis, the model has higher accuracy than the base model. Based on the parameters for the independent and dependent variables in Table 3, several insignificant variables can be seen based on the p-value, which is 5% and 10%. Based on the table, some variables significantly affect transportation mode choice.

The parameter estimation results from the existing alternatives show that city transportation, private motorbikes, TMB buses, and online taxi affect the choice of mode by private car. Suppose all variables are considered to have the same value (all else equals), people tend to choose city transportation, private motorbikes, TMB buses, and online taxis in traveling. The results of the trip attribute show that access time, waiting time, travel time, fixed costs/ gasoline, and the possibility of delays have a significant influence on the choice of transportation mode, where people tend to use transportation with minimal time, cost, and possible delays.

Based on the age category, all variables in the age category significantly influence the choice of transportation mode, where the three age variables tend to use private cars compared to other transportation. Based on weather category, all weather conditions significantly influence the choice of transportation mode. In sunny and drizzling weather, people tend to use private cars. Meanwhile, people tend to use other transportation in moderate and heavy rains instead of private cars.

Based on the income category in the family, three variables significantly affect the choice of transportation mode, namely for income below the minimum wage, Rp. 3,000,000 – Rp. 5,000,000, and Rp. 5,000,000 – Rp. 10,000,000. People who have income in these three variables tend to use private cars to travel. Based on the job category, three job variables significantly influence the choice of transportation mode, namely office workers, entrepreneurs, and *PNS/TNI/Polri/BUMN* and others (housewife, unemployed, and others). People with these jobs tend to use private cars to travel.

Table 2. Elasticity Value

Transportation Mode	Probability (%)	Elasticity					
		Travel Time	Access Time	Waiting Time	Fixed/Gasoline Cost	Transfer Cost	Parking Cost
Private Car	10.751	-1.118	-	-	-0.098	-	-
Private Motorcycle	28.471	-2.083	-	-	-0.099	-	-
Angkutan Kota	17.275	-4.436	-0.528	-2.437	-0.211	-0.048	-
TMB Bus	10.922	-5.001	-0.564	-2.399	-0.176	-0.078	-
Conventional Taxi	2.241	-4.833	-0.219	-2.630	-1.604	-	-
Online Taxi	11.767	-4.379	-0.197	-2.150	-1.228	-	-0.025
Online Motorcycle	18.573	-3.768	-0.06	-1.724	-0.670	-	-0.024

Table 2 shows that private motorbikes with the highest probability for choosing (28.471%). In contrast, public transportation, namely online motorcycle taxi, is the first choice. In contrast, the minor choice is conventional taxi. Meanwhile, the TMB Bus has a probability of 10.922%. This value is still lower than the city transportation with 17.275%, which means that people still prefer city transportation to the TMB Bus. To increase the probability of selecting the TMB Bus, it is necessary to increase the travel attributes. Improving the quality of travel attributes in this study can be done on travel time, access time, waiting time, fixed costs/gasoline, transfer fees, and parking costs by looking at the elasticity values, which are also in Table 2.

The increase or decrease in transportation use can be seen based on the elasticity value in Table 3. For example, increasing the use of the TMB Bus can be done by reducing travel time and costs. By reducing access time, waiting time, travel time, fixed costs/ gasoline, and transfer fees on the TMB Bus by 10%, it will increase the probability of the TMB Bus by 5.64%, 23.99%, 50.01%, 1.76%, and 0.78%, respectively. The most considerable attribute effect is reducing the TMB Bus's travel time. This is also a problem where the travel time on the TMB Bus takes a long time. The same explanation can be applied to the other six modes of transportation to increase or decrease the probability of selecting a transport.

In private vehicles, travel attributes only affect travel time. In contrast, parking fees and fixed costs/petrol only affect the selection of private vehicles below 1%. The elasticity value of a private car for travel time only affects 11.18% for a 10% decrease in travel time. This is because many people also prefer to use private cars rather than public transportation, decreasing the probability of choosing the shortest travel time compared to other modes of transportation.

Based on the results of the elasticity value, for example, in travel time, if the travel time for each mode of transportation is assumed to have the same value, people will be more inclined to use private vehicles than public transportation. Likewise, with fixed costs/gasoline, people are more likely to use private vehicles than private transportation.

Discussion

Compared to other studies, such as the study conducted by Sugiyanto [23], the results of the elasticity in this study for travel time are larger, while travel costs are smaller. Then research by Wulansari [22] on private vehicles with monorails resulted in elasticity values for travel times having smaller values than elasticity in this study and elasticity value for travel costs having a higher value than elasticity in this study. A study by Espino et al. [19] shows that the elasticity value of BRT with private vehicles is smaller at the time of travel, and the cost of travel has almost the same elasticity value. The difference in the elasticity value can occur due to several things, for example, the level value on the attribute, the type of mode chosen, the research location, community characteristics, research time, and so on.

Based on the elasticity value for public transportation, especially the TMB Bus, access time and travel time are attributes that have a large impact if there is a change in the value of these two attributes. It means that policymakers can focus on improving the quality of access times and travel times to increase the use of TMB Bus. Improving the quality of access time and travel time can be done by reducing the time values. Reducing travel time can be done by making special lanes for TMB Buses, prioritizing signalized intersections, and reconstructing bus service routes to increase the scope of bus network services to various destinations such as shopping centers, schools/college places, workplaces, and increase connectivity with other public transportation. Connectivity with others transportation can make it easier for people to travel in terms of payment, access to public transportation, and can shorten travel time [32].

Based on the results of the elasticity of private vehicles on travel time, reducing the use of private vehicles can be done by increasing the travel time of private vehicles. For example, by way of policymakers restricting the use or ownership of private vehicles.

Restrictions on the use of private vehicles can be done, for example, by implementing an odd-even system. Based on Fadhli and Widodo's [33] research, implementing the odd-even system resulted in a shift from private vehicles to public transportation by 45%.

The waiting time attribute has the largest influence on *angkutan kota*. If the waiting time for *angkutan kota* is reduced, there will be an increase in the use of *angkutan kota*. It means that the main problem in *angkutan kota* is due to uncertain waiting times. This is because *angkutan kota* is a paratransit mode, so it does not have a fixed time frame for its operation [34]. Meanwhile, the elasticity for fixed/gasoline costs show that the biggest impact on changes in the value of fixed/gasoline costs is in conventional taxis, followed by online taxis. Meanwhile, TMB buses, *angkutan kota*, and private vehicles do not have a large impact. Both the elastic value of parking fees and transfer fees do not have a big impact on public transportation (TMB bus and *angkutan kota*), and private vehicles, if there is a change in the value of both attributes.

Each research location can certainly produce different elasticity values depending on the characteristics of the community in the research area. In this study, the resulting elasticity value explicitly explains the effect of time and travel costs in the city of Bandung. The results of the elasticity value in this study are expected to be used as a basis for improving the quality of travel in the use of public transportation in Bandung.

Conclusion

This article shows that the choice of transportation mode can be predicted based on the travel attributes of each mode of transportation but can also be predicted by including sociodemographic and travel characteristics in the model.

Based on the parameter estimate modeling, it was found that the travel attributes, both time and travel costs, have a significant impact on the choice of transportation mode. This can be explained further by looking at the elasticity value of the travel attributes, namely travel time and travel costs. Compared with previous studies, the elasticity value of travel time in this study has a higher value than the previous one. In comparison, travel costs have a lower value than in the previous study. This difference can also be interpreted that travel times are getting higher due to traffic density, increased use of private vehicles, and so on. In contrast, travel costs on public transportation are quite affordable for every economic group.

It was found that the TMB Bus can attract more users by considering the travel time and access time on that mode. With decreasing travel time and access time on the TMB Bus, the probability of selecting the TMB Bus also increases significantly. In addition, there is a considerable impact on private vehicles if the travel time increases. It can be concluded that reducing the travel time on public transportation, especially the TMB Bus, and increasing the travel time on private vehicles will have a high possibility to attract people to use public transportation, especially the TMB Bus. To make it a reality, it is necessary to increase the facilities and infrastructure for the TMB Bus which will reduce the travel time. It may be made by providing exclusive bus lanes for TMB Buses, prioritizing TMB Buses at intersections, creating an integrated transportation system, or reducing private vehicles, for example, with an odd-even system.

The elasticity of fixed costs/gasoline shows that these attributes do not significantly affect TMB buses or private vehicles. It can be seen that the biggest influence is on conventional taxis and online taxis. This is probably because the travel costs for the TMB Bus are still cheap but have a long travel time, while for private vehicles, the costs incurred are cheap and have a much faster travel time than public transportation. Therefore, the impact given by fixed costs/gasoline is not significant enough for both TMB buses and private vehicles.

Further studies are needed as a continuation of this study. Study with incorporating psychological attributes are needed to find the most sensitive psychological attribute, since human is the main actor in transportation decision. Further study is also needed to have a knowledge regarding how people will react to a specific kind of policy and how the policy was delivered.

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