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Mode Choice Analysis of Sustainable Public Transport in Bogor City of Indonesia

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Abstract
Public transport service scenarios must be well designed for public transport performance to be better and more sustainable. The aim of this study was to determine the percentage of the travelers move to public transportation in the Bogor City. The Stated Preference technique is used to know travelers responses to public transport service scenarios in utility functions. Furthermore, from the binomial logit model analysis obtained the probability of choice of public transportation mode. The results of the analysis have shown that the travelers responded positively to move to public transportation modes. In Corridor III, private car users and online-based motorcycle transport users choose the public transportation of non-economic medium bus type (scenario-2) with the greatest probabilities of 35.59 % and 61.02 %. In Corridor II, private car users choose the public transportation of non-economic big bus type (scenario-3) with the greatest probability of 36.31 %. Motorcycle users and online-based motorcycle transport users choose the public transportation of non-economic small bus type (scenario-1) with the greatest probabilities of 66.47 % and 70.64 %. The motorcycle users in Corridor II choose the public transportation in all scenarios with significant probabilities ranging from 62.03% to 66.47%.
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1. Introduction

The concept of sustainable transportation cannot be separated from the concept of sustainable development (WCED 1987). Moving on Sustainable Transportation explains that sustainable transportation aims to ensure that environmental, social and economic considerations are taken into account in decisions that affect transportation activities (Litman and Burwell 2006). Therefore, the public transportation services as an implementation of transportation development to meet the needs of mobility at this time, also may not sacrifice future generations related to mobility needs both in economic, social and environmental aspects.

The mobility of people in the Bogor City continuously increasing as seen from the high activity in the centers of socio-economic activity and the nodes of modal transfer of transportation such as the Bogor station and the bus terminal. BAPPENAS (2004) predicts that travel demand in the Jabodetabek area will increase by 26 million trips per day or 40% in 2020, also illustrating that as part of the Jabodetabek metropolitan area, Bogor City naturally experienced the same thing. The role of public transportation is very important to serve the increasing mobility of people continuously in the city of Bogor. However, the existing types of public transportation ("angkot") with a small capacity of 8 passengers including the driver (DEPHUB 2002) with poor performance are inefficient and cause economic losses.

Mass transit with Bus Transit System (Trans Pakuan) which has been developed in three corridors in the main route network (PEMKOT 2012), is still inadequate even two corridors have not operated in the last more than six months. The performance of public transportation services is less attractive to private transportation users because they do not provide the type of service they want. BAPPENAS (2004) also predicts that if appropriate action is not taken, the low performance of public transportation services will reduce the use of public transportation modes in the Jabodetabek area from 60 % in 2002 to 47 % in 2020. This also illustrates that the City of Bogor will naturally experience similar ones.

Regarding sustainable public transportation, proper policies and handling need to be done so that public transportation services become more sustainable. In addition to the performance of public transportation services, economic, social and environmental aspects must be considered in designing public transport service scenarios. However, the public transportation service scenario needs to see the response of the users or the travelers to find out what their choices are for the service scenario provided. For this reason, a study on mode choice analysis for sustainable public transport case in Bogor City of Indonesia is urgently needed. Previous studies related to the

choice of modes of public transportation or sustainable public transport have been carried out, but in addition to the focus of the study, different parameters and methods used in the study were also carried out in the scope of regions with different characteristics.

Some of these studies include Mansyur *et al.* (2009) related to the sustainable passenger public transport management model, Amoroso *et al.* (2011) related to sustainable urban public transport, Gregorc and Krivec (2012) related to urban public transport networks for sustainable mobility, Sabeen *et al.* (2012) related to sustainable public transport, Dirgahayani (2012) related to urban public transport policies for sustainable urban transportation, Bachok *et al.* (2014) about the perspective of passengers for the identification of sustainable public transport services, Ryley *et al.* (2014) related to Demand Responsive Transport (DRT) for the development of a sustainable public transportation system, Ponrahono *et al.* (2015) related to sustainable urban public transport systems, Bachok *et al.* (2015) related to sustainable public transport indicators, and Mupfumira and Wirjodirdjo (2015) related to an approach to a dynamic system of urban public transportation that is economically sustainable. Silitonga *et al.* (2011) related mode choice models in Indonesia to complete the use of private transport intended for public transportation use, and Ahern and Tapley (2008) related perceptions and preferences of inter-city train and bus passengers and their comparisons.

The aim of this study was to determine the percentage of the travelers move to public transportation in the Bogor City, Indonesia.

2. Methodology

2.1 Method of collecting data

Preference from the travelers are needed to get the utility function of the choice of urban public transportation modes in Bogor City. Primary data of the preferences travelers obtained directly from the field through direct interview surveys with stated preference techniques. According to Kroes and Sheldon (1988), stated preference methods are techniques that use respondent statements individually about their preferences in a set of transportation choices to estimate utility functions. The choice is a description of the types of situations or transportation context developed by the researcher. By their nature, stated preferences require surveys that are designed with the aim of collecting data. The survey is to obtain data on the response of travelers from each alternative mode choice offered.

Data collection using stated preference techniques in this study was carried out on three segments of private car users, motorcycle users, and online-based motorcycle transportation users. The data collection to find out their response to intervention scenarios for more sustainable public transport and came up with probability of those switching to public transportation mode in each scenario. The current segment of public transport users ("angkot") is a captive user so it is assumed to continue to choose the public transportation provided. The number of respondents in the survey research with these stated preference techniques, Hensher (2003) stated that a minimum of 30 respondents and an optimal of 50 respondents, Ahern and Tapley (2008) used 40 questionnaires in a study of case mode selection models in Ireland. In this study interviews were conducted with 60 respondents for each segment.

Sustainability of public transportation in urban areas of Bogor City in terms of sustainable transportation indicators according to The World Bank (1996), Litman dan Burwell (2006), Schiller *et al.* (2010), Brotodewo (2010), Kennedy (2001), and Kumar (2014) and aspects of service performance. In accordance with the relevance of the conditions and characteristics of the service, the sustainability of public transportation can be viewed from: a) the mode share of the use of public transportation modes, b) savings in vehicle operating costs, c) savings in travel time value, d) savings in pollution value, e) public transportation facilities and services for users with disabilities, f) safety of public transport, g) availability of a mass transit system, h) consumption of fossil fuels for public transport, i) traffic noise level, k) emissions vehicle caused by traffic volume, l) headway, m) load factor, n) waiting time, and o) public transport operation performance. Intervention scenarios for variables and types of public transportation are developed so that public transportation is more sustainable. The scenarios are designed for public transport services on the main route network of Corridor III (Bubulak - Baranangsiang) and Corridor II (Baranangsiang - Ciawi). The scenarios use three types of public transportation services, namely scenario-1: non-economic small bus type, scenario-2: non-economic medium bus type, and scenario-3: non-economic big bus type. The service attributes and specifications of each scenario are grouped as Table 1 (Corridor III: Bubulak - Baranangsiang) and Table 2 (Corridor II: Baranangsiang - Ciawi). The attributes and specifications of each scenario are compared with public transportation types ("angkot") used today.

Table 1 Public transport service attributes and specifications (Corridor III: Bubulak - Baranangsiang)

Attributes	Public Transportation Services		
	Scenario-1	Scenario-2	Scenario-3
Atribut 1 (X_1) :			
- Travel time*	40 % shorter	60 % shorter	60 % shorter
- Duration of stops at bus stops or up and down facilities of passengers	≤ 1 minute	≤ 0.5 minute	≤ 0.5 minute
- Facilities for disability passengers	Not available	Available (1 seat priority)	Available (2 seat priority, 1 wheelchair space)
Atribut 2 (X_2) :			
- Service time	Every 3 minutes	Every 5 minutes	Every 8 minutes
- Fare	Rp 4.500	Rp 5.500	Rp 6.500
- Carried passengers	Sit all	75% sit + 25% stand up	62% sit + 38% stand up
Atribut 3 (X_3) :			
- Change mode	≤ 2 times	≤ 2 times	≤ 2 times
- Walking distance to public transportation	≤ 300 meters	≤ 300 meters	≤ 300 meters

* are compared with public transportation types ("angkot") used today

Table 2 Public transport service attributes and specifications (Corridor II : Baranangsiang - Ciawi)

Atribut	Public Transportation Services		
	Scenario-1	Scenario-2	Scenario-3
Atribut 1 (X_1) :			
- Travel time*	20 % shorter	45 % shorter	45 % shorter
- Duration of stops at bus stops or up and down facilities of passengers	≤ 1 minute	≤ 0.5 minutes	≤ 0.5 minutes
- Facilities for disability passengers	Not available	Available (1 seat priority)	Available (2 seat priority, 1 wheelchair space)
Atribut 2 (X_2) :			
- Service time	Every 5 minutes	Every 8 minutes	Every 10 minutes
- Fare	Rp 4.000	Rp 5.000	Rp 6.000
- Carried passengers	Sit all	75% sit + 25% stand up	62% sit + 38% stand up
Atribut 3 (X_3) :			
- Change mode	≤ 2 times	≤ 2 times	≤ 2 times
- Walking distance to public transportation	≤ 300 meters	≤ 300 meters	≤ 300 meters

* are compared with public transportation types ("angkot") used today

Based on the public transportation service attributes and specifications of each scenario as Table 1 and Table 2 an experimental design was made to obtain preferences from the travelers and further analysis as in Table 3.

Table 3 Experimental design of public transport service level of each attribute

Scenarios	Attributes Level of Public Transport Services			Choice*
	X_1	X_2	X_3	
Corridor III : Bubulak – Baranangsiang :				
Scenario-1	0	2	1	0 / 1
Scenario-2	1	1	1	0 / 1
Scenario-3	1	0	1	0 / 1
Corridor II : Baranangsiang – Ciawi :				
Scenario-1	0	2	1	0 / 1
Scenario-2	1	1	1	0 / 1
Scenario-3	1	0	1	0 / 1

* 0 = not choosing public transportation; 1 = choosing public transportation

2.2 Data analysis method

The analysis was carried out to obtain the utility function and the probability of choice of modes of public

transportation in the city of Bogor in each segment of the travelers. According to Pearmain and Swanson (1991) that utility is the satisfaction of someone spending their limited funds for something different. Utility is the value given to a product and is assumed to be the maximum utility. This study uses the utility function as stated by Kroes and Sheldon (1988) and Pearmain and Swanson (1991) with a linear model that is : $U_{PT} = a_0 + a_1.x_1 + a_2.x_2 + a_3.x_3$ with U_{PT} is utility of public transport option, a_0 is model constant, a_1, a_2 dan a_3 are model coefficients of public transport attributes, and x_1, x_2 and x_3 are public transport attributes.

The probability of choice of public transport modes uses discrete choice models as probabilistic models Pearmain and Swanson (1991). Discrete choice models are probabilistic models that the value of each choice of respondents relates to other choices in a set of alternatives offered Pearmain and Swanson (1991). The most common form of this model is the logit function. The most popular analysis technique for this method is logit analysis. The probability of choice of public transport modes in this study uses discrete choice models with the Binominal Logit Model that is : $P_{PT} = 1 / (1 + \exp(U_C - U_{PT}))$ with P_{PT} is probability of choosing public transport, U_{PT} is utility of public transport, and U_C is utility of non public transport.

3. Results And Discussion

Analysis was carried out on several alternative scenarios of public transportation services in the main route network within the Bogor City area Corridor III (Bubulak - Baranangsiang) and Corridor II (Baranangsiang - Ciawi). The mode choice model of urban public transportation, namely the utility function and binomial logit model, was developed based on the preferences of the travelers. The results of the analysis using the binomial logit model obtained utility functions and logit models for private car users (PCU), motorcycle users (MCU), and online-based motorcycle transport users (OMCU).

Corridor III : Bubulak – Baranangsiang :

a. For private car users (PCU):
   $U_{PT} = -4.22552 + 2.83922*X_1 + 0.79323*X_2$;
   $P_{PT} = 1 / (1 + \exp(-(-4.22552 + 2.83922*X_1 + 0.79323*X_2)))$
b. For motorcycle users (MCU):
   $U_{PT} = -1.85238-22.78519*X_2$; $P_{PT} = 1 / (1 + \exp(-(-1.85238-22.78519*X_2)))$
c. For online-based motorcycle transport users (OMCU):
   $U_{PT} = -2.32238 + 1.47508*X_1 + 1.29532*X_2$;
   $P_{PT} = 1 / (1 + \exp(-(-2.32238 + 1.47508*X_1 + 1.29532*X_2)))$

Corridor II : Baranangsiang – Ciawi :

a. For private car users (PCU):
   $U_{PT} = -0.56194-0.07365*X_2$; $P_{PT} = 1 / (1 + \exp(-(-0.56194-0.07365*X_2)))$
b. For motorcycle users (MCU):
   $U_{PT} = + 0.49071 + 0.09677*X_2)$; $P_{PT} = 1 / (1 + \exp(-(+0.49071 + 0.09677*X_2)))$
c. For online-based motorcycle transport users (OMCU):
   $U_{PT} = + 0.69687 + (0.09047*X_2)$; $P_{PT} = 1 / (1 + \exp(-(+0.69687 + 0.09047*X_2)))$

The model is used to predict the choice probability of travelers for urban public transport service scenarios. Based on the results of calculations using the model, the choice probability of public transportation modes in each scenario for each segment of the travelers are as shown in Table 4.

Table 4 The choice probability of public transportation modes based on scenarios and segments of the travelers

The scenarios of public transportation service	Segments of the travelers					
	Corridor III			Corridor II		
	PCU	MCU	OMCU	PCU	MCU	OMCU
Scenario-1	6.67 %	0.00 %	56.67 %	32.98 %	66.47 %	70.64 %
Scenario-2	35.59 %	0.00 %	61.02 %	34.62 %	64.28 %	68.73 %
Scenario-3	20.00 %	13.56 %	30.00 %	36.31 %	62.03 %	66.75 %

The choice of public transportation modes as Table 4 shows that in general there are travelers who move to public transportation modes in each scenario. In Corridor III, PCU and OMCU are willing to choose public transportation scenario-2 with the highest probability, namely 35.59 % and 61.02 %, respectively. The MCU are willing to choose public transportation only scenario-3 with a probability of 13.56 %. In Corridor II, PCU willing to choose public transportation scenario-3 with the largest probability of 36.31%. As for MCU and OMCU, they are willing to choose public transportation scenario-1 with the highest probability, namely 66.47% and 70.64, respectively. MCU in Corridor II are willing to choose public transportation in all scenarios with a significant probability ranging from 62.03% to 66.47%. This is different from Corridor III, which is only willing to choose scenario-3 with a less large probability.

A positive response to the move of travelers to public transportation can encourage the sustainability of public transportation. This public transportation service scenarios as a policy intervention can increase public transport share modes, disability user facilities, public transport security, the existence of a mass public transport

system, load factor of public transport, and public transport service performance which are indicators of sustainable public transportation. In addition, these policy interventions can reduce vehicle operating costs, travel time values, and motor vehicle emissions which are also indicators of sustainable public transport.

4. Conclusion

A policy scenario is needed so that urban public transportation in Bogor City becomes more sustainable. Several public transportation service scenarios can be used to intervene indicators that can be a lever for the sustainability of public transportation. These scenarios are public transport services using non-economic small bus type (scenario-1), non-economic medium bus type (scenario-2), and non-economic big bus type (scenario-3). However, to the extent that these scenarios are acceptable to the travelers so that they will move to using public transportation, it is necessary to analyze their preferences for the given scenarios. In general, the travelers gave a positive response to the scenarios of public transport services both in the case of Corridor III and Corridor II. This can be seen from the preference of those who are willing to move to public transportation modes. In Corridor III, PCU and OMCU choose public transportation of non-economic medium bus type (scenario-2) with the greatest probability of 35.59 % and 61.02 %, respectively. In Corridor II, PCU choose public transportation of non-economic big bus type (scenario-3) with the greatest probability of 36.31 %. MCU and OMCU choose public transportation of non-economic small bus type (scenario-1) with the greatest probability of 66.47 % and 70.64 %, respectively. The MCU in Corridor II choose public transportation in all scenarios with a significant probability ranging from 62.03 % to 66.47 %.

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