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ORIGINAL ARTICLE

Investigation of the Effects of Traffic Safety and In-vehicle Criminality on Commuter's Mode Choice Behaviour

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***Abstract*:** This research investigates the effect of traffic safety and in-vehicle criminality on the commuter's mode choice preference. Modelling the mode choice behaviours of travellers is a key to design effective transport management policies, particularly in shifting travellers to public transport. Abundant studies have analysed the impact of level of services, such as travel time, fare, waiting time and delays, on mode choice preferences, but the effects of safety aspect have been overlooked. In Jogjakarta, Indonesia, majority of travellers choose private vehicle, such as motorbikes, for their daily travel, which increases traffic congestion levels and traffic accident risks. A mass transit system, Transjogja Bus, has been in operation for nine years, intending to shift the travellers from motorbikes by offering the safer and more reliable transportation mode. Nevertheless, people tend to choose motorbikes due to the criminality issues, like thieves in the public transport. This research aims to quantitatively evaluate the impact of the road traffic safety and the in-vehicle criminality on choosing the transportation modes. The study is performed in two cities for comparison: Jogjakarta in Indonesia and Matsuyama in Japan. A stated preference (SP) survey is conducted, in which respondents choose Bike or Bus under hypothetical situations. The scenarios consider the frequency of traffic accidents and in-vehicle criminality as the factors in addition to general factors, such as travel time, travel cost, average waiting time, maximum delay time and access time. A binary logit model is applied to the data from the SP survey. The results revealed that travellers involved in traffic accidents prefer the safer transportation modes – Bus in both cities. In Jogjakarta, experience of the in-vehicle criminality also affects the preference of the passengers. The findings suggest that ensuring the in-vehicle public safety is essential to attract travellers to mass transit systems in developing countries.

Keywords: public transportation, mode choice, binary logit, safety, criminality

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1. Introduction

1.1 Background

Many modern cities are facing traffic problems due to rapid urbanisation. Increasing population induces increasing number of mobility demand, which results in problems in transportation. Particularly in developing Asian cities, the traffic problems have existed for many years. Growing economies have enabled the residents to own private vehicles, such as motorbikes and cars. This change makes the individuals more dependent on the private mode of travel and causes serious traffic jam on a daily basis. The problem of traffic congestion stems to disrupted traffic conditions, such as traffic accidents; and delay in mobility of people and goods, which cause huge economic loss every year.

A public transportation could give an outstanding solution to the above problems by attracting the travellers of private vehicles to mass transportation modes. However, the benefit of the public transportation systems is not easily attained. In general, private vehicles are more attractive mode of transportation because of their comfort and speed. To devise an effective public transportation policy, it is essential to understand the relationship between travellers' mode choice decisions and the factors affecting it.

Abundant studies have analysed the impact of level of services, such as travel time, fare, waiting time and delays, on mode choice preferences. However, the effects of safety aspect have been overlooked. To the best of authors' knowledge, Susilo, et al. [1] is the only study that analyses the impact of "bad experience" on the mode choice behaviour. They identified that the experience of accident or thieves while using public transportation systems has negative impact on the choice preference to the mode. Although the study presents promising findings, it does not quantitatively evaluate the impact of such experience.

1.2 Objectives

This research aims to understand the effect of traffic safety and in-vehicle criminality on the commuter's mode choice preference. SP survey is conducted, based on which a mode choice model is developed based on the binary logit model. The study is performed in two cities: Yogyakarta in Indonesia; and Matsuyama, Japan.

2. Overview of Study Site

This research is conducted in two cities: Yogyakarta in Indonesia; and Matsuyama in Japan. This chapter outlines the public transportation systems and the traffic problems in both cities.

2.1 Yogyakarta, Indonesia

Yogyakarta is one of the most growing cities in Indonesia, and the mobility demand is dramatically increasing. In order to meet the demand, the government provided a public transportation system by operating Transjogja Bus in 2008. However, since its start, the number of passengers has been decreasing [2]. According to Department of Transportation of Yogyakarta, the designed time headway of Transjogja Bus is 16 minutes, and the targeted punctuality tolerance level is 5 minutes with average speed is 25 km/hour. In reality, a lot of schedules are missed from its tolerance level because of many obstacles in a road lane, which shuts away the passengers. Another possible reason is that there are lots of crimes, such as robbery and thieves, happen inside the bus or even in the bus stops because some shelters are located in dangerous area.

2.2 Matsuyama, Japan

Matsuyama has a well-developed transport network as the prefecture capital. It has a network of suburban railways run by the Iyo Railway. Iyo Railway also

operates a system of trams and bus, which serve as the main modes of public transportation in the city. The public transportation network in Matsuyama is almost the same with Yogyakarta. The service area is not as wide as the Transjogja, but the travellers with more than 2-kilometre trip have a higher preference on the public transportation. Nevertheless, the majority of travellers tend to use private vehicles, such as bicycles, motorbikes or private cars.

3. Questionnaire Survey Design

3.1 Overview

The survey is designed to understand traveller preference on mode choice, either public transportation or a private vehicle, under different level of services and conditions. In the survey, respondents are presented hypothetical scenarios, under which they choose their preferred mode of transportation. The survey employs two alternatives, Bus as a public transportation and Motorbike as a private vehicle.

3.2 Questionnaire Sheet

3.2.1 Individual attribute

The first section is devoted for asking individual attributes of the respondents. The questions are designed to comprehend their socio-demographic characteristic, daily travel behaviours and past experiences in using public transportation. The list of questions includes the following:

1. Age
2. Gender
3. Occupation
4. Disposable income per month

The questions related to their travel behaviours seek for the daily commuting characteristics and the past experiences as listed below:

1. Daily mode of transportation for their commuting
2. Travel distance
3. Travel time
4. Travel cost
5. Private vehicle ownership (number of their own private vehicles, including car, motorbike and bicycle)
6. Motorbike availability
7. Experience of encountering crime such as thieves or gender harassment in using public transportation (never, once, twice, or more)
8. Experience of encountering or self-involvement in traffic accident in using private vehicles (never, once, twice, or more)

3.2.2 SP Survey

The Stated Preference (SP) survey presents hypothetical travel scenarios where the respondents are required to choose either Bus (as a public transportation) or Motorbike (as a private vehicle) under various conditions. The factors considered in this study are listed below:

1. Travel Cost (TC)
2. Travel Time (TT)
3. Maximum Delay Time (Max. DT)
4. Average Waiting Time at the bus stop (Ave. WT)
5. Access Time to the bus stop (AT)
6. Frequency of traffic accidents while using the motorbike (Acc.).

Travel Cost (TC) represents the public fare when using bus or the fuel and maintenance cost when using motorbike. Travel Time (TT) represents average on-board time on bus or motorbike. Maximum Delay Time (Max. DT) represents the unplanned extra on-board time on both modes. Average Waiting Time at the bus stop (Ave. WT) represents the average waiting time at the boarding bus stop, and Access Time to the bus stop (AT) is the time from the origin to the bus stop. Safety factor is expressed as Acc., representing

the Frequency of traffic accidents while using the motorbike.

Various scenarios are created by assigning different values to each attribute. In binary choice case,
Eight scenarios are prepared based on orthogonal design method as detailed in section 3.3.

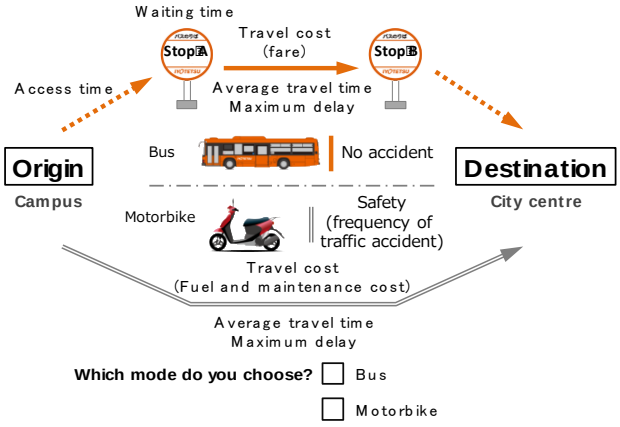

Figure1 Illustration of SP survey questions

3.3 Experimental Design

Scenarios are created by assigning two levels of values to each of the six attributes presented in section 3.2.2. Realistic values are determined considering the traffic conditions and prices in each study site.The list of the values is summarised in Table 1 for Yogyakarta and in Table 2 for Matsuyama.

Table1 Levels of attributes for Yogyakarta

Attribute	Bus	Motorbike
TC (Rp)	1000	2000
		3000
Acc. (accident/month)	0	1
		2
TT (minutes)	20	15
	25	
Max Delay (minutes)	4	5
	6	
Ave WT (minutes)	3	0
	5	
AT (minutes)	5	0
	8	

Table2 Levels of attributes for Matsuyama

Attribute	Bus	Motorbike
TC (Yen)	50	100
		150
Acc. (accident/month)	0	1
		2
TT (minutes)	20	15
	25	
Max Delay (minutes)	4	5
	6	
Ave WT (minutes)	2	0
	4	
AT (minutes)	4	0
	6	

According to Rushing,H., Karl, A,et.al [3] Each of the six attributes has two cases, which creates 64 scenarios ($=2^6$) in total. In order to ease the answering load for respondents, the scenarios are decreased based on 2^{k-2} fractional factorial design [3], where k represents the number of attributes. The 2^{k-2} fractional factorial design is constructed by listing down a basic design consisting of the scenarios consisting of a full factorial in $k-2$ attributes. Then the remaining two attributes are added. The list of 16 scenarios ($=2^4$) are presented in Table 3 for Yogyakarta, and in Table 4 for Matsuyama.

Table3 SP survey scenarios for Yogyakarta

Scene	Motorbike		Bus			
	TC	Acc.	TT	Max Delay	Ave. WT	AT
1	3000	1	20	4	4	2
2	5000	1	20	4	6	2
3	3000	1	25	4	6	4
4	5000	1	25	4	4	4
5	5000	1	20	6	4	4
6	3000	1	20	6	4	4
7	5000	1	25	6	4	2
8	3000	1	25	6	6	2
9	5000	2	20	4	4	4
10	3000	2	20	4	6	4
11	5000	2	25	4	6	2
12	3000	2	25	4	4	4
13	5000	2	20	6	6	2
14	3000	2	20	6	4	2
15	3000	2	25	6	4	4
16	3000	2	25	6	6	4

Table4 SP survey scenarios for Matsuyama

Scene	Motorbike		Bus			
	TC	Acc.	TT	Max Delay	Ave. WT	AT
1	100	1	20	4	4	2
2	159	1	20	4	6	2
3	100	1	25	4	6	4
4	150	1	25	4	4	4
5	100	1	20	6	4	4
6	150	1	20	6	4	4
7	100	1	25	6	4	2
8	150	1	25	6	6	2
9	100	2	20	4	4	4
10	150	2	20	4	6	4
11	100	2	25	4	6	2
12	150	2	25	4	4	4
13	100	2	20	6	6	2
14	150	2	20	6	4	2
15	100	2	25	6	4	4
16	150	2	25	6	6	4

3.4 Questionnaire Survey

The survey was conducted in two cities, Yogyakarta in Indonesia and Matsuyama in Japan. The questionnaire sheets were distributed to 40 respondents in Yogyakarta, and 20 in Matsuyama.

4. Results

4.1 Attributes of respondents

The Socio-demographic attributes of the respondents are summarised in Table 5. In both cities, the majority of respondents are male aged 18-24 years old with an occupation as student. The disposable monthly income varies, but ranges in an average student level in both cities.

Based on travel behaviour factors, the significance factor that could distinguished between Yogyakarta and Matsuyama respondents are number of own private vehicle, availability of motorbike, self-experience of Crime in public transport, Traffic accident while using private vehicle. These table below shows the travel behaviour of respondents in each city.

Table5 Socio-demographic attributes

Attributes	Yogyakarta	Matsuyama
Gender		
Female	36.0%	18.0%
Male	64.0%	82.0%
Age		
18-24	94.0%	88.0%
25-49	6.0%	12.0%
Occupation		
Student	90.0%	100%
Full-time worker	4.0%	
Self-employed	4.0%	
Others	2.0%	
Disposable income		
(Indonesian Rp)		
<500,000	20.0%	-
500,000 -1,000,000	16.0%	-
1,000,000 -1,500,000	28.0%	-
1,500,000 -2,000,000	16.0%	-
>2,000,000	20.0%	-
(Japanese Yen)		
<50,000	-	52.0%
50,000-100,000	-	36.0%
100,000-150,000	-	10.0%
>150,000	-	2.0%
N	50	50

4.2 Test of Significance

The respondents' characteristics and the SP survey results are analysed for estimating the mode choice model. First, in order to create the valid input data, test of significance is conducted to figure out the attributes that affect the preference to the choices. The affecting factors are identified from the statistical test such as Wald-test for each variable. In the Wald-test, the null-hypothesis is $\beta_i = 0$ (Not significantly affecting), while the alternative hypothesis is $\beta_i \neq 0$ (significantly affecting). If the variable is determined as significantly affecting, then the effect will be an input in the mode choice modelling as a variable of utility function.

According to Ben-Akiva, et.al [5] , the Wald-test calculation with $\alpha = 0.05$ and DF = 20 will has critical t-value as 1.96. Besides using Wald-test, the p-value indicator states the significance of a variable as mention above. If the p-value is less than α then the variable is stated to be significant and vice versa. Result from Wald-test and comparison with p-value in a same value of α will make a same conclusion. From the Wald-test and p-value test stated that the

significant variable to affect public preference in Yogyakarta are Travel Cost, Travel Time, Daily Mode of Transportation, Travel Distance, Availability of using Motorbike, Experience of encountering crime on public transportation and Self-involvement of Accident on Private Vehicle. While in Matsuyama, the significant variable to affect public preference in Matsuyama are Travel Cost, Travel Time, Safety while using the mode of transportation, Travel duration to campus, Private Vehicle Ownership, and Availability of using Motorbike.

Table6 Mode choice behaviours

Attributes	Yogyakarta	Matsuyama
Daily mode of travel		
Car	6.0%	2.0%
Bicycle	10.0%	88.0%
Motorbike	84.0%	10.0%
Daily travel distance		
<3km	46.0%	90.0%
3-6km	24.0%	10.0%
6-9km	14.0%	0%
>9km	16.0%	0%
Daily travel time		
<5 minutes	14.0%	44.0%
5-10 minutes	42.0%	52.0%
10-15 minutes	20.0%	4.0%
>15 minutes	24.0%	0%
Daily travel cost		
(Indonesian Rp)		
0 - 1,000	4.0%	-
1,000 – 3,000	32.0%	-
3,000 – 5,000	28.0%	-
5,000 – 7,000	22.0%	-
>7,000	14.0%	-
(Japanese Yen)		
0 - 50	-	98.0%
50 – 100	-	2.0%
>100	-	0%
Number of Own private vehicle		
0	6.0%	32.0%
1	86.0%	58.0%
2	4.0%	8.0%
3 or more	4.0%	2.0%
Availability of motorbike		
Yes	88.0%	24.0%
No	12.0%	76.0%
Crime in public transport		
Once	10.0%	2.0%
Twice	2.0%	0%
Three times or more	2.0%	0%
Never	86.0%	98.0%
Traffic accident while using private vehicle		
Once	34.0%	34.0%
Twice	10.0%	0%
Three times or more	36.0%	0%
Never	20.0%	66.0%
N	50	50

4.3 Binary Logit Modelling

4.3.1 Method

According to Hensher,D.A [6], logistic regression is part of regression analysis that is used when dependent variable is dichotomous which represents whether an event appears or not. This regression forms a dependent variable as a linear combination of independent variables. The linear function, a utility function, is then transformed to probability using logit function. To predict if an alternative is chosen based on model, the value of utility function should be contrasted by alternative choice and transformed into a probability with score between 0 and 1.

Based on Issac K,et.al [7] citated from Ben-Akiva,et.al [4], the assumption of the model is that respondents would choose the travel mode for the greatest utility under certain condition, and the utility function of it is composed by fixed term and random term. The formulas are as follows:

$$U_{in} = V_{in} + \varepsilon_{in} \quad (1)$$

$$V_{in} = \beta_0 + \sum_{k=1}^{K} \beta_k X_{ink} \quad (2)$$

where U_{in} is utility function of the $i-th$ travel mode chosen by the $n-th$ respondent ($Bus\ (i=1), Motorbike\ (i=2)$); V_{in} is the fixed term of utility function (U_{in}); ε_{in} is the random term of utility function (U_{in}); K is the number of attributes (which is also called characteristic variables) affecting on the mode choice of respondents; β_k is the undetermined coefficients; X_{ink} is the $k-th$ factor of the $i-th$ travel mode chosen by the $n-th$ respondent.

If the random term ε_{in} follows the Gumbel distribution and all variables are independent each other, the probability for the $n-th$ respondent choosing $i-th$ travel mode, P_{in}, is defined by the following equations:

$$P_{in} = \frac{\exp(V_{in})}{\sum_{i=1}^{2} \exp(V_{in})} \quad (3)$$

$$\ln\left(\frac{p_{in}}{1-p_{in}}\right) = \beta_0 + \sum_{k=1}^{K} \beta_k X_{ink} \quad (4)$$

Table7 List of influencing attributes

The category of factors	Influencing factors	Explanation
Individual attribute	Sex	Male =1, female = 0
	Age	Age under 18 = 0, age between 18-24 = 1, age between 25-49 =2, age over 45 = 3
	Occupation	Full-time worker= 0, Student= 1, Self-employed= 2, Others = 3
	Disposable income	*Yogyakarta, Indonesia* Under 500.000RP=0, income between 500.000-1.000.000RP=1, income between 1.000.000-1.500.000RP=2, income between 1.500.000-2.000.000RP=3, over 2.000.000RP=4 *Matsuyama, Japan* Under 50.000¥=0, income between 50.000-100.000¥=1, income between 100.000-150.000¥=2, income between 150.000-200.000¥=3, over 200.000¥=4
Travel Behaviour	Daily mode of travel	bicycle=0, motorbike=1, car =2
	Daily travel distance	Under 3 km=0, travel between 3-6km=1, travel more than 6km=2
	Daily travel time	Under 5min=0, travel more than 5min=1
	Daily travel cost	*Indonesia (Rupiah)* 0-1.000=0, travel for 1.000-3.000=1, travel for 3.000-5.000=2, travel for 5.000-7.000=3, travel for more than 7.000=4 *Japan (Yen)* 0-50=0, travel for 50-100=1, travel for more than 100=2
	Number of Own private vehicle	Have no private vehicle=0, own 1 private vehicle=1, own 2 private vehicle =2, own more than 2 = 3
	Availability of motorbike	Have no motorbike=0, have and can use motorbike=1
	Crime in public transport	Never have experienced=0, experienced once=1, experienced twice=2, experienced three times or more=3
	Traffic accident while using private vehicle	Never have experienced=0, experienced once=1, experienced twice=2, experienced three times or more=3

4.3.2 Results

A statistical software, SPSS, is employed to estimate the model presented in 4.3.1. The outputs are the coefficients for each variable inputted in the utility function and their significance based on the Wald-test. Table 7 summarises the estimation results of the model, including the estimated coefficients of each variable, the Wald-test value and the p-value.

Table7 Model estimation result (Yogyakarta)

	Coefficient	Wald	p-value
TC	-0.004	0.109	0.041
TT	-0.272	29.964	0.000
$Mode\_1$	-3.914	30.643	0.000
Dist_2	0.947	7.191	0.007
Dist_3	0.609	2.928	0.008
BK	-2.197	8.695	0.003
ExAcc_2	0.693	5.636	0.018
$ExCrime$	-0.260	0.559	0.015
Constant	5.228	24.093	0.000

Based on tables above, the utility function equation in binary logistic regression model is

$$\ln\left(\frac{p_{bus}}{1-p_{bus}}\right) = -0.004\text{TC} - 0.272\text{TT} - 3.914\text{Mode\_1} + 0.947\text{Dist\_2} + 0.609\text{Dist\_3} - 2.197\text{BK} + 0.693\text{ExAcc\_2} - 0.260\text{Crime} + 4.484 \quad (5)$$

Where :

p_{bus} : Probability that Bus is chosen
TC : Travel Cost of Bus in a Scenario
TT : Travel Time of Bus in Scenario
$Mode\_1$: Motorbike as respondent daily mode of transportation
Dist_2 : Daily travel distance about 3 – 6 km
Dist_3 : Travel distance more than >6 km
BK : Bikeavailable(yes), The respondent has a motorbike and/or could use it
ExAcc_2 : The experience of traffic accidents more than twice
$ExCrime$: The experience of encountering a crime on public transportation

Since some factors are different from Yogyakarta and Matsuyama and all the preferences is different based on several factors like socio-demographic, travel behaviour, self-experience, and also public transportation services, then the equation of utility function will be different too based on the significant factors affecting the preferences. The output table of logistic regression based on Matsuyama correspondence will be showed as below

Table8 Model estimation result (Matsuyama)

	Coefficient	Wald	p-value
TC	-0.011	9.328	0.002
TT	-0.061	2.732	0.038
Acc	-0.539	9.328	0.002
Dur_1	0.505	5.030	0.025
$OwnVeh\_1$	-0.471	3.992	0.046
BK	-2.095	55.874	0.000
Constant	2.765	9.257	0.002

Based on tables above, then the utility function equation in binary logistic regression model that suits in Matsuyama is:

$$\ln\left(\frac{p_{bus}}{1-p_{bus}}\right) = -0.011\text{TC} - 0.061\text{TT} - 0.539\text{Acc} + 0.505\text{Dur\_1} - 0.471\text{OwnVeh\_1} - 2.095\text{BK} + 2.765 \quad (6)$$

Where :

p_{bus} : Probability that Bus is chosen
TC : Travel Cost of Bus in a Scenario
TT : Travel Time of Bus in Scenario
Acc : Number of accident on private vehicle in

scenario

Dur_1 : Travel duration that takes more than 5 minutes

OwnVeh_1 : One vehicle ownership

BK : The respondent has a motorbike and/or could use it

The goodness fit between Yogyakarta and Matsuyama also has different result due to the limitation number of respondent, but both model in Yogyakarta and Matsuyama has been fulfilled the criteria by the Omnibus test that state the significance of the model which is lower than 0.05 as α-value and also Hosmer Lemeshow value that is bigger than 0.05 which means that the model chosen is fit. Yet the variance in Indonesia can represent 54.7 % to the respondent variance, while in Matsuyama only represent 47.0%. In overall percentage, both are more than the null hypothesis which is 50%, the overall percentage in Matsuyama is 64.8% and in Yogyakarta is 83.9%. The -2 Log Likelihood shown in Yogyakarta is 686.335 which if compared to Chi-critical (α = 0.05 and DF = 20) which is 422.695 (Chi-square of Omnibus Test),then the value of -2LL is bigger and stated on rejection area, which means Ho is rejected and proved that the unrestricted model is better than restricted model. While in Matsuyama the -2LL value which is 1000.201 is also higher than Chi-critical (108.835). Both cities stated the unrestricted model is better than restricted model. Restricted model is a model with only estimating the constant parameter, while the parameter inside scenario is not being used, while unrestricted model in involving socio-demograph factors, travel behaviour factors and all attributes in scenario.

5. Conclusions

In transportation system, every aspects should be considered to affect the preference including the safety and criminality aspects. In order to investigates this aspects it will need Revealed Preference data to discover the passenger characteristic. In this model there are 12 variables, with 4 socio-demograph factors (age, gender, occupation, income per month) and 8 travel behaviour factors (daily mode of transportation, travel distance, travel duration, travel cost, vehicle ownership, availability of motorbike, self-experience on criminality and accident).

Wald test and p-value test being used in this observation as the indicator of which factor is significantly affecting the preferences or not significantly affecting the preferences. Wald test will be done through comparing the Wald value from each variables and the value of critical Wald (on α = 0.05 and DF = 20). Based on those two tests, factors that is significantly affecting the preference in Yogyakarta are are Travel Cost, Travel Time, Daily Mode of Transportation, Travel Distance, Availability of using Motorbike, Self-experience of Crime on public transportation and Self-experience of Accident on Private Vehicle. While in Matsuya the significant factors are Travel Cost, Travel Time, Safety while using the mode of transportation, Travel duration to campus, Private Vehicle Ownership, and Availability of using Motorbike.

Seeing from the preferences in Yogyakarta and Matsuyama, the factors that distinguished between those cities are the service and trip quality. These factors might include the safety and security from anything called crime and accident while using their chosen mode, especially bus.

The safety and security should has been guarantee by the government. The criminality will decreased the public preferences on using Transjogja bus, thus at whole time of operation should be proceeded through the general procedure particularly while on a critical condition.

On the other hand, the higher safety of public transportation would increase the preference on using public transportation. Therefore, the driver should be following a strict procedure and requirements to operates the bus and also the Transportation Department of Yogyakarta should be conducted a routine performance check-up to reduce the probability of accident caused by machine error.

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