

THE ESTIMATION OF CONGESTION COST FOR PRIVATE PASSENGER CAR AND ITS EFFECT AS A THROUGH TRAFFIC IN MALIOBORO, YOGYAKARTA, INDONESIA

Gito Sugiyanto

Civil Engineering Department, Faculty of Science and Technology,
Jenderal Soedirman University, Central Java, Indonesia, e-mail: gito_98@yahoo.com

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Abstract

Application of congestion cost for private vehicle in central urban road aims to maximize the efficiency of the urban transport system by discouraging unnecessary private vehicle use and increase the use of public transport. The aim of this research is to estimate the amount of congestion cost and to estimate the effect of application of congestion cost for private passenger cars users as a through traffic in Malioboro corridor. This study shows that estimation the amount of congestion cost for private passenger car users is IDR 2915.00 per trip. The application of congestion cost as IDR 5500.00 per trip for private passenger cars user as a through traffic in Malioboro, Yogyakarta will be shift as 10.901% of private passenger car to bus TransJogja.

Keywords: Congestion cost, Generalized cost, Private passenger car, Stated preference

Introduction

Traffic congestion is one of the significant transportation problems in urban area, especially in Central Business District (CBD) during peak hour. This situation happens because of the imbalance between the number of vehicles and the capacity of the road. The traffic congestion becomes worse with the increasing activities in the roadside and bad behavior in driving. Traffic congestion will generate many problems due to inefficiency. With congested roads, vehicle speed will be simultaneously up and down, the average speed will be lower, travel time will be longer, traffic delay and the total cost will increase. Therefore, road users will suffer from increasing vehicle operating cost and losing more time and environment will be in worse conditions due to pollutions. In other words, transportation costs will increased due to traffic congestion.

Yogyakarta is one of the transportation development regions in Indonesia with specific characteristic. The transportation characteristic in Yogyakarta is mixed traffic and overloaded on some road links. Based on traffic count survey on 2006, in Malioboro corridor, 82.15% of the total traffic volume consist of motorcycle, 17.30% of the total traffic volume consist of private cars [1]. Based on traffic count survey in June 2009, the composition of traffic volume in Malioboro is Motorcycles 64.67%, Private passenger car 29.69%, Micro Truck and pick up 1.01%, Bus 0.96% and Non-motorized vehicle 3.61%.

Center for Transportation and Logistics of Gadjah Mada University [2] has shown that the average growth of private vehicle in Yogyakarta city is 4.04% per year. Meanwhile there was a decrease in public transport users as much as 3% per year. The average load factor of public transport vehicle was 41% in the year 2003 and 27.22% in 2004 [3]. This fact reflected that the service quality was still low. The lack of accessibility for public transport from origin zone to destination zone caused the attractiveness of public transport

decreased. Therefore it is necessary to find solution to reduce the use of private transport by applying road charging for private transport. The proposed concept is introducing congestion cost as a combination of congestion and pollution costs. With the implementation of congestion cost for private cars is expected they will switch to public transport.

This aim of this paper is to estimate the amount of congestion cost and estimate the effect of application of congestion cost for private passenger car user as a through traffic in Malioboro, Yogyakarta, Indonesia.

Literature Review

Estimation of Congestion Cost

The theoretical background of road-use pricing has relied upon the fundamental economic principle of marginal-cost pricing, which states that road users using congested roads should pay a toll equal to the difference between the marginal-social cost and the marginal-private cost in order to maximize the social surplus [4]. The amount of the congestion cost represents the difference of marginal social cost (MSC) to marginal private cost (MPC). Congestion cost is caused by vehicle addition in the same road while the equilibrium is reached at points F with the traffic flow as much as Q_2 and cost is P_2 . The vehicle addition after the optimal traffic flow Q_2 must take travel cost as much as Q_2Q_1HF but only enjoy the benefit Q_2Q_1EF . There is welfare gain as much as FEH. Therefore, the congestion cost is counted based on the difference between marginal social cost and marginal private cost.

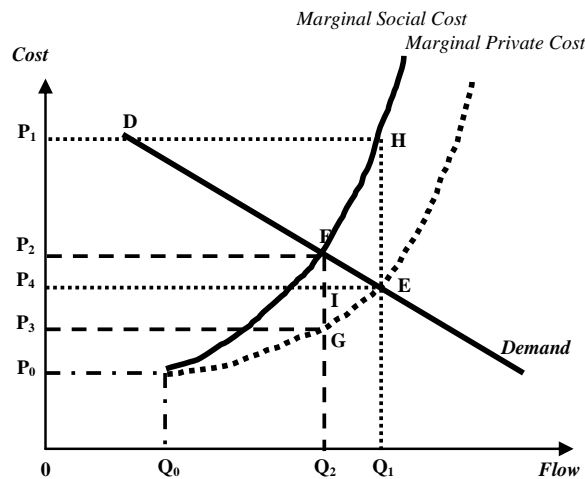


Figure 1. Congestion cost estimation [5]

The amount of congestion cost estimation of mode m from origin zone i to destination zone j can be formulated through the equation:

$$CC_{ij}^m = C_{ij}^m MSC - C_{ij}^m MPC \quad (1)$$

in which CC_{ij}^m is the congestion cost of mode m , $C_{ij}^m MSC$ is the marginal social cost, and $C_{ij}^m MPC$ is the marginal private cost.

The optimal congestion pricing reflects the difference between marginal social cost and marginal private cost. According to the principle of pricing, congestion cost must be balanced with the marginal social cost, so that the traffic flow will decrease from Q_1 to Q_2 . It can be realized if congestion pricing as much as $F-G$ or P_2-P_3 was applied.

Effect of the Application of Congestion Cost

Olszewski and Xie studied the empirical evidence on the effect of Electronic Road Pricing (ERP) rate changes on traffic volumes in Singapore and proposed a practical framework for modeling the impact of road pricing on the time distribution of traffic volumes. The traffic pattern at Ayer Rajah Expressway gantry before and after the implementation of toll and the model predictions. The mean coefficient of variation of 15-min volumes which was 3.9% during the week before ERP started has actually decreased to 3.3% after the ERP introduction and then decreased further to 2.8% in the week after the rate revision. This shows that flow equilibrium conditions developed very quickly after a change in pricing and also confirms that traffic was not congested [6].

Eliasson et al studied the effect of congestion cost in Stockholm, Swedia. The number of passengers by public transit was 6% larger in spring 2006 than 12 months earlier (Stockholm Transport, 2006 in [7]). Based on back-of-the-envelope elasticity calculations, we estimate that 1.5% can be attributed to changes of petrol prices and business-cycle effects, leaving 4.5% to be the result of the road toll. The effect of congestion charges were boosted as modal switch from car to public transport was made easier.

Result of Stockholm trial is that vehicle traffic decreases as driving is made more expensive by road tolls. The trial showed that the tolls resulted in reductions of traffic congestion and travel times that were large compared to the expected effects of other measures that are discussed in Stockholm traffic [7]:

- A new Eastern bypass is estimated to reduce the number of vehicles passing over inner city bridges by approximately 14% (Markstedt et al, 2005).
- A new Western bypass is estimated to reduce traffic across inner city bridges by 11% (Eliasson et al, 2006).
- If public transport was made free-of-charge in the Stockholm, this is estimated to reduce vehicle kilometres travelled in the county by 3% (Stockholm Transport, 2006).

Bureau and Glatchan developed an econometric model to simulate the distributional effects of various urban road pricing scenarios in Paris. The methodology is based on a mode choice model that is nonlinear in income. Motorists endure average welfare losses ranging from €0.7 to €1.0 per trip when a toll that induces a 20% traffic reduction is implemented. Motorists taken as a whole tend to lose when a toll is introduced. This result is not surprising when one considers their values of travel time. They reach €11.4 per hour at the most, which would require a travel time reduction of around 11 min to outweigh a €2 toll [8]. The 15-20% reductions in generalized cost are surprisingly small for charge levels which have achieved 15% reduction in overall trip making. It appears that the ability of traffic to reroute reduces the benefits gained from road pricing to levels significantly below those predicted by strategic models which permit only limited rerouting responses [9].

Armelius and Hultkrantz studied the implementation of road pricing in Stockholm, Swedia which have a positive impact on reducing the use of private vehicle users and increased the use of public transport 10%. If the application of road pricing with improve the public transportation service quality, the use of public transport will be increase 23% [10]. The impacts of the London Congestion Charging Scheme (LCCS) should not be analysed from the standard approach to Value of Travel Time Savings (VTTS). This will inevitably lead to the mistaken conclusion that all those drivers who value their travel time savings below the £5 congestion charge will be regarded as losers from the scheme. The impact of LCCS were: the average speeds of bus and car which inside the Congestion Charging Zone (CCZ) have increased from 10.9 km/h to 11.6 km/h and 14.3 to 16.7 km/h, respectively, increase the use of urban bus and coaches 18%, increase taxi users 17%, and decreased the use of private car 33% [11].

Methodology

Analysis Approach

The analysis approach is used Stated Preference Technique. Most Stated Preference using design of experiments to construct alternatives that presented to respondents. This design is usually made orthogonal, meaning that the combination of attributes that are presented vary independently of each other. The advantage of this method is that the effect of each attribute that responded more easily identified [12]. The formula of binomial logit different can be arranged:

The probability of private passenger cars choice can be formulated as:

$$P_{PC} = \frac{\exp^{U_{Private\ Car}}}{\exp^{U_{Private\ Car}} + \exp^{U_{Bus\ TransJogja}}} = \frac{\exp^{(U_{Private\ Car} - U_{Bus\ TransJogja})}}{1 + \exp^{(U_{Private\ Car} - U_{Bus\ TransJogja})}} \quad (2)$$

The probability of bus TransJogja choice can be formulated as:

$$P_{BT} = 1 - P_{Private\ Car} = \frac{1}{1 + \exp^{(U_{Private\ Car} - U_{Bus\ TransJogja})}} \quad (3)$$

in which P_{PC} is the probability of choosing private passenger cars, P_{BT} is the probability of choosing bus TransJogja, $U_{Private\ Car}$ is private passenger cars utility and $U_{Bus\ TransJogja}$ is bus TransJogja utility. While the utility model which is used in (2) and (3) is:

$$U_i = \beta_0 + \beta_1 \text{Travel_Cost} + \beta_2 \text{Congestion_Cost} + \beta_3 \text{Headway} + \beta_4 \text{Travel_time} + \beta_5 \text{Walking_time} \quad (4)$$

in which U_i is the utility of choice i ; β_0 is the constants of model and $\beta_1, \beta_2, \beta_3, \beta_4$ and β_5 is the coefficient of model.

Mode choice model between private passenger cars and bus TransJogja in Malioboro, Yogyakarta is affected by five travel attributes are travel cost, congestion cost, travel time, headway, and walking time [1]. In this paper, respondents reported their choice with rating technique that is divided in five scale of semantic are presented in Table 1.

Table 1. Point Rating and Semantic Scale

No.	Semantic Scale	Point Rating
1.	It must choose a private passenger car	1
2.	Maybe choose a private passenger car	2
3.	The option is balanced	3
4.	Maybe choose bus TransJogja	4
5.	It must choose bus TransJogja	5

There are five design of selected attributes, each attribute consists of 2 levels. So, when we combined all of the attributes and their level will be obtained $2^5=32$ alternative combination. This alternative combination is very much and will be difficult for res-pondents to select the mode. Therefore, the development of the third partial replication of factorial design 2^5 through confounding. By following the design using Plan 6A.2 [13], the questionnaire design is planned consist of eight alternative of choice as shown in Table 2.

Table 2. Factorial Combination Treatment 2^5 in 8 Unit

Choice	Combination Treatment	Different of Level Attribute				
		Travel Cost	Congestion Cost	Headway	Travel Time	Walking Time
1	(-)	-	-	-	-	-

2	ab	+	+	-	-	-
3	cd	-	-	+	+	-
4	ace	+	-	+	-	+
5	bce	-	+	+	-	+
6	ade	+	-	-	+	+
7	bde	-	+	-	+	+
8	abcd	+	+	+	+	-

The different level of five travel attributes for private passenger car users and bus TransJogja are shown in Table 3. While in Table 4 is presented the value of positive and negative service conditions for each travel attribute in stated preference questionnaire.

Table 3. The Different Level of Travel Attribute

No.	Travel Attribute	Type of Mode	
		Private Passenger Cars	Bus TransJogja
1.	Travel cost	IDR 3500.00-7500.00	IDR 3000.00
2.	Congestion cost	IDR 4000.00-8000.00	-
3.	Headway	-	3.0-10.0 minutes
4.	Travel time	4.0-8.0 minutes	10.0 minutes
5.	Walking time	-	2.0-5.0 minutes

Table 4. Value of Travel Attribute in Stated Preference Questionnaire

No.	Travel Attribute	Condition of Service	
		Positive (+)	Negative (-)
1.	Travel cost	IDR 500.00 (more expensive IDR500.00)	IDR 4500.00 (more expensive IDR4500.00)
2.	Congestion cost	IDR 4000.00 (more expensive IDR4000.00)	IDR 8000.00 (more expensive IDR8000.00)
3.	Headway	-10.0 minutes (saving time 10.0 minutes)	-3.0 minutes (saving time 3.0 minutes)
4.	Travel time	-6.0 minutes (faster 6.0 minutes)	-2.0 minutes (faster 2.0 minutes)
5.	Walking time	-5.0 minutes (saving time 5.0 minutes)	-2.0 minutes (saving time 2.0 minutes)

Data Collection

Data collection include travel attribute survey in August 7-15, 2009, Moving Car Observer (MCO) survey in July, 2009. Stated preference (SP) survey was divided in two stage, the first stage of stated preference in September, 2009 and the second stage in October, 2009. The number of samples stated preference survey is 289 respondents. The Stated preference data is obtained from questionnaires distributed to respondents who used the private passenger cars that pass through in Malioboro Corridor, Yogyakarta with direct interview. The location to distribute stated preference questionnaires are Ramai Mall, Civil Engineering Department Gadjah Mada University, Taman Pintar Yogyakarta, Griya Kencana Permai Housing, Senior High School (SMA) 1 Yogyakarta, Bank BPD Yogyakarta and Local Government of Yogyakarta. The respondents were conducted with random sampling techniques to the traveler who uses a private passenger car as a through

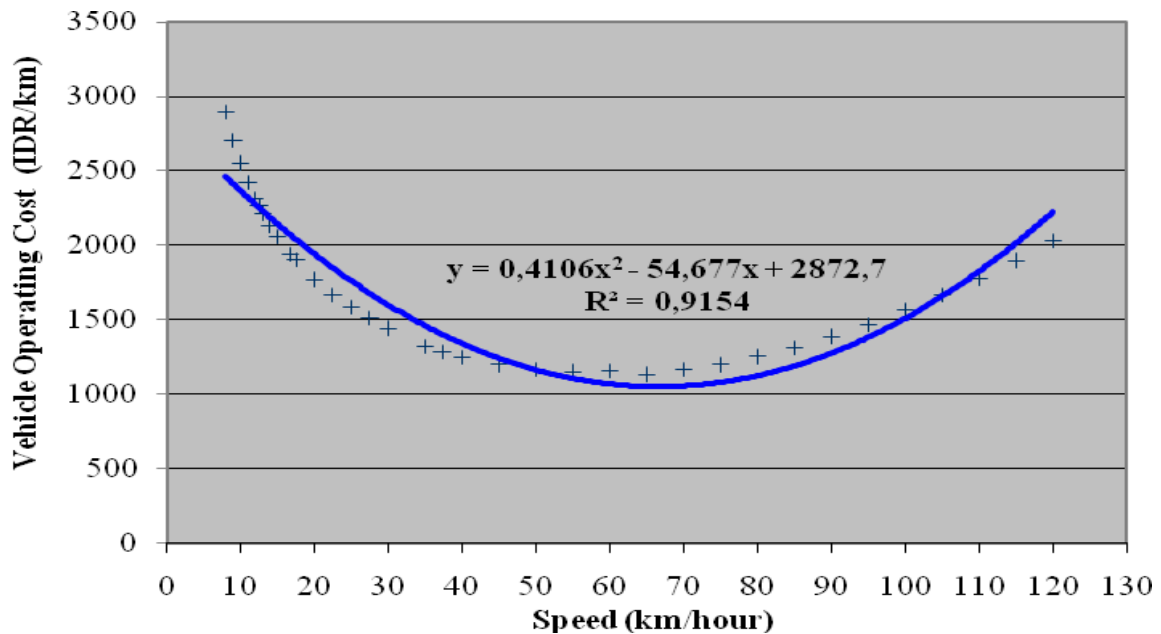


Figure 3. Relationship between Speed and Vehicle Operating Cost [14]

From the Figure 3, it can be seen that the relationship between speed and vehicle operating cost for private passenger cars is formulated as:

$$y = 0.4106V^2 - 54.677V + 2872.7 \quad (5)$$

in which V is speed (km per hour) and y is vehicle operating cost (IDR per kilometer).

Based on the survey and analysis of travel time and speed, the average speed of private passenger cars in free-flow speed condition is 40.00 km/hour so the vehicle operating cost is IDR 1342.58/km (Figure 4). Based on Moving Car Observer survey, the speed of private passenger cars in actual cost condition which potentially cause traffic jam is 9.98 km/hour so the vehicle operating cost is IDR 2367.92/km (Figure 4). The vehicle operating cost of private passenger cars at Malioboro in free-flow speed is IDR 1898.41 per trip and VOC in actual condition is IDR 3348.24 per trip.

Pollution Cost

The pollution cost was calculated based on Marginal Health Cost (MHC) in USD cent/liter [15]. The fuel consumption of private passenger cars were counted based on fuel consumption model of LAPI ITB 1996 in [14]. MHC can be calculated in actual condition as IDR 384.45 per km and in free-flow speed condition as IDR 209.12 per km. Multiplying with 1.414 km, the length of Malioboro, the pollution cost of private passenger cars at Malioboro is IDR 295.70 per trip in free-flow speed condition and IDR 543.61 per trip in actual condition.

Travel Time Cost (TTC)

Value of time of private passenger cars users in September 2010 in Yogyakarta city is IDR 11447.52/hour [16]. Based on the survey and analysis of travel time of private passenger cars in Malioboro, the average of travel time in free-flow speed condition is 2 minutes 8 second. Based on moving car observer survey, the average of travel time in actual cost condition is 8 minutes 30 second. Travel time cost of private passenger cars in Malioboro was calculated by multiplying travel time with the value of time. Travel time cost of private passenger cars at Malioboro is IDR 404.67 per trip in free-flow speed condition and IDR 1621.92 per trip in actual condition.

Generalized Cost

Generalized cost consists of vehicle operating cost, travel time cost and pollution cost. The generalized cost of private passenger cars users in actual condition and free-flow speed condition in Malioboro Corridor are presented in Table 5.

Table 5. Generalized Cost of Private Passenger Cars in Actual and Free-Flow Speed Condition in Malioboro Corridor, Yogyakarta

Type of Condition	VOC (IDR/trip)	Pollution Cost (IDR/trip)	TTC (IDR/trip)	Generalized Cost (IDR/trip)
Free-flow speed	1898.41	295.70	404.67	2598.77
Actual condition	3348.24	543.61	1621.92	5513.77

Congestion Cost

The amount of congestion cost of private passenger cars is the difference between generalized cost in actual condition with speed 9.98 km/hour and generalized cost in free-flow speed condition with speed 40.00 km/hour. The generalized cost of private passenger cars in actual condition as marginal private cost and generalized cost in free-flow speed condition is marginal social cost. The total amount of delay encountered, calculated across all traffic from the difference between the actual speed encountered and free-flow speed. It is shown in Table 5, that the generalized cost of private passenger cars in actual condition is IDR 5513.77 per trip, and generalized cost in free-flow speed condition IDR 2598.77 per trip, thus the congestion cost of private passenger cars in Malioboro is IDR 2915.00/trip.

Characteristic of Respondents

The characteristics of respondents stated preference include: sex, age, education, job, income, travel purpose, and the average visit to Malioboro. The general characteristics of respondents stated preference can be seen in Table 6.

Table 6. General Characteristics of Respondent Stated Preference

No.	Item	Percentage
1.	Sex: Male	50.67%
	Female	49.33%
2.	Age: 16-20 years old	9.33%
	21-30 years old	42.67%
	31-45 years old	24.00%
	46-55 years old	22.67%
	> 55 years old	1.33%
3.	Education: Senior High School	33.33%
	Diploma (D1/D2/D3)	17.33%
	Undergraduate Program (D4/S1)	44.00%
	Postgraduate Program (S2/S3)	5.33%
4.	Job: Student/Graduate	30.67%
	Armed Forces/Police	4.00%
	Government Official	22.67%
	Private Workers	32.00%
	Entrepreneur	8.00%
	House Wife	2.67%

Continued of Table 6

No.	Item	Percentage
5.	Income: < IDR 500000.00	12.00%
	IDR 500000.00 - IDR 1000000.00	18.67%
	IDR 1000000.00 - IDR 1500000.00	8.00%
	IDR 1500000.00 - IDR 2000000.00	17.33%
	IDR 2000000.00 - IDR 2500000.00	18.67%
	IDR 2500000.00 - IDR 3000000.00	14.67%
	IDR 3000000.00 - IDR 4000000.00	5.33%
	> IDR 4000000,00	5.33%
6.	Travel Purpose: Studying	16.00%
	Working	53.33%
	Trading	1.33%
	Family affairs	16.00%
	Shopping	10.67%
	Tour/Traveling	2.67%
7.	Average visit to Malioboro:	
	> 3 times per day	1.33%
	2 times per day	1.33%
	1 time per day	8.00%
	3-5 times per week	36.00%
	2 times per week	53.33%

Distribution Choice of Stated Preference Respondents

Distribution choice of stated preference respondents are presented in Figure 4 - Figure 9. Figure 4 presented the main reason why respondents use private passenger cars because the private cars is more convenient and more flexible than TransJogja. Figure 5 presented distribution of travel time from origin zone to destination zone. The most travel time of respondent is about 20-30 minutes. The main reason why respondent is not interested to use TransJogja because of travel time is longer than use private. The distribution of main reason why respondent is not interested to use bus TransJogja are presented in Figure 6.

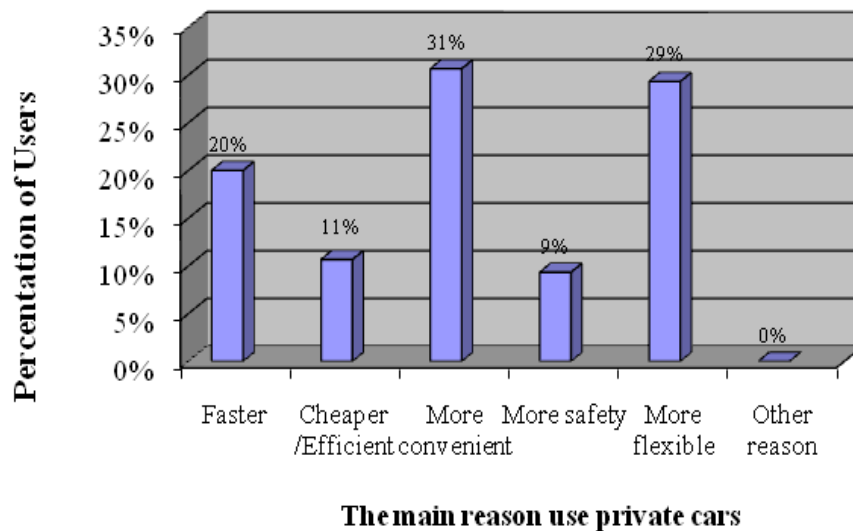


Figure 4. The Main Reason why Respondents Use Private Passenger Cars

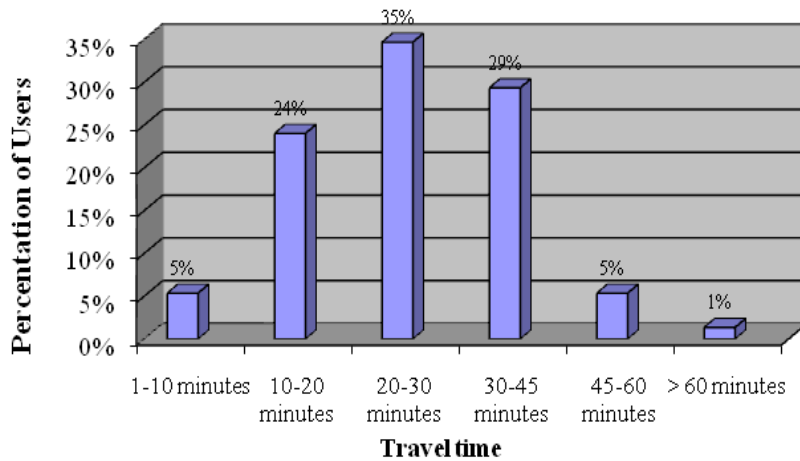


Figure 5. Travel Time Distribution of Respondents as a Through Traffic in Malioboro

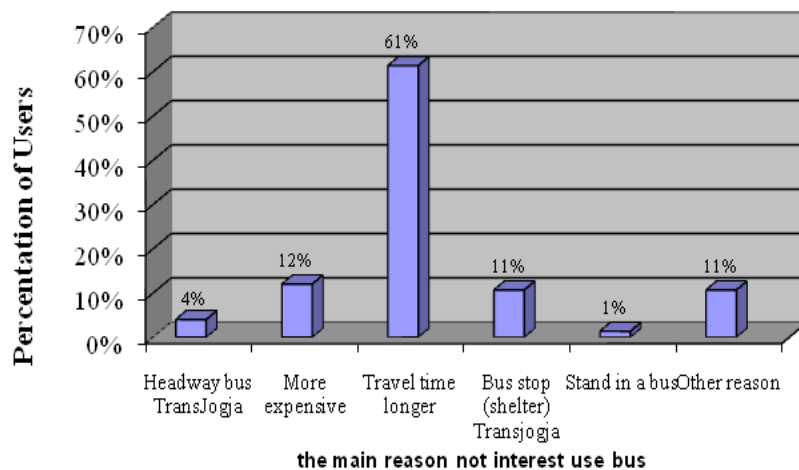


Figure 6. The Main Reason why Respondent is not Interested to Use Bus TransJogja

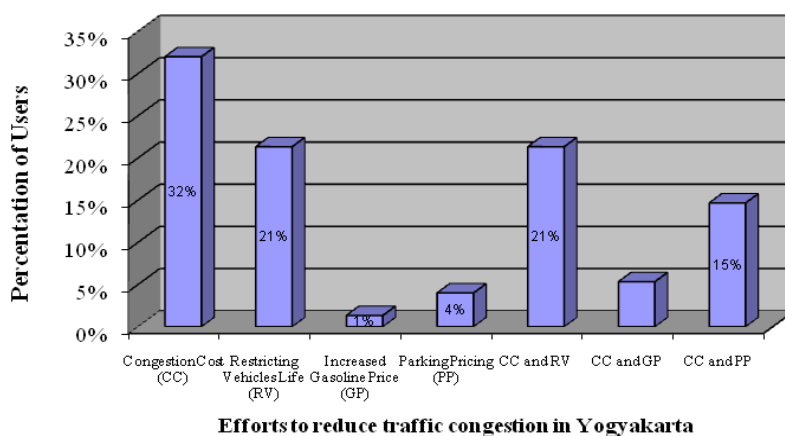


Figure 7. Efforts to Reduce Traffic Congestion in Yogyakarta City

Based on Figure 7, almost 32% of private passenger cars user as a through traffic in Malioboro choose the application of congestion cost to reduce the traffic congestion in Yogyakarta. Almost 25% of respondent who used the private passenger cars in Malioboro choose the limit of congestion cost for private passenger cars user as IDR 5000.00/trip,

14.67% of respondent choose IDR 4000.00/trip, 13.33% of respondent choose IDR 6000.00/trip, as presented in Figure 8.

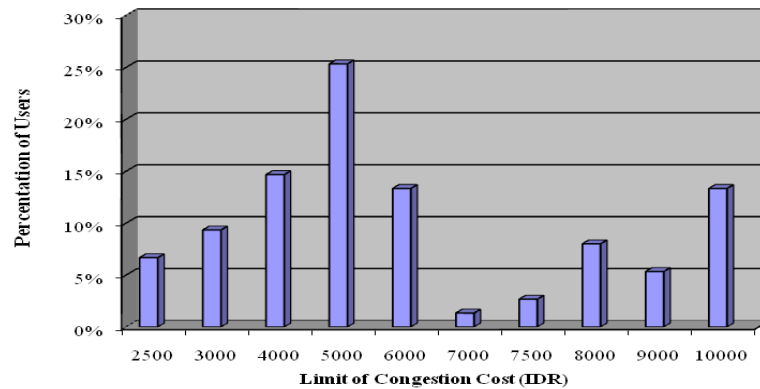


Figure 8. The Limit of Congestion Cost in Malioboro Corridor, Yogyakarta

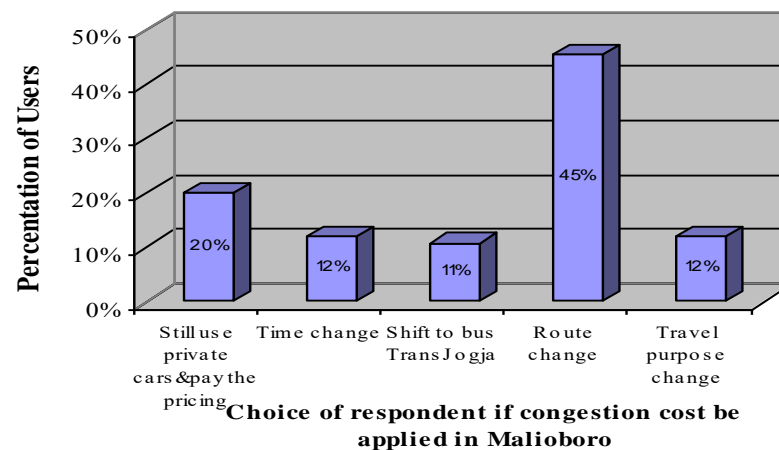


Figure 9. Distribution of Choice if the Congestion Cost is Applied in Malioboro

Based on Figure 9, 45% respondent will change the travel route, 20% respondent still use private cars and pay the congestion pricing and 12% of respondent will change the travel destination if congestion cost is applied for private passenger car user in Malioboro Corridor.

Utility Function Equation

From the analysis of 31 alternative utility function equation, interpretation, statistical tests ($t_{\text{-test}}$ and $f_{\text{-test}}$) and calibration, alternative 31 is the best utility function. Utility function differential of binomial logit model between private cars and bus TransJogja is presented:

$$U_{\text{PC}} - U_{\text{BT}} = 21.13522 - 0.00476X_1 - 0.00435X_2 - 0.37541X_3 - 2.52003X_4 - 2.24683X_5$$

$$(2.85192) \quad (-6.35453) \quad (-5.81016) \quad (-0.87680) \quad (-3.36325) \quad (-2.24897)$$

with coefficient of determination (r^2) is 0.97855.

in which:

- X_1 = the different of travel cost between private passenger cars and bus TransJogja,
- X_2 = the different of congestion cost between private passenger cars and bus TransJogja,
- X_3 = the different of headway of bus TransJogja,
- X_4 = the different of travel time between private passenger cars and bus TransJogja,
- X_5 = the different of walking time to the bus stop of TransJogja.

Travel cost is the travel attribute that have strong correlation, followed by congestion cost, travel time, walking time and headway. Correlation analysis result of five travel attributes can be seen in Table 7.

Table 7. Correlation Analysis Result of Five Travel Attributes

	Probability	Travel Cost	Congestion Cost	Headway	Travel Time	Walking Time
Probability	1,00000					
Travel Cost	-0,65796	1,00000				
Congestion Cost	-0,60159	0,00000	1,00000			
Headway	-0,09079	0,00000	0,00000	1,00000		
Travel Time	-0,34824	0,00000	0,00000	0,00000	1,00000	
Walking Time	-0,23286	0,00000	0,00000	0,00000	0,00000	1,00000

The validation of choosen utility function equation using statistical analysis. The result is the following:

- The choosen utility function equation has the largest coefficient of determination (R^2) 0.97855. It means that the influence of all the travel attributes which changes in the utility of this model amounts to 97.855% and the remaining 2.145% is influenced by the other attributes that are not considered in this model.
- The choosen utility function equation has $F_{\text{-stat}}$ value is $18.2553 > F_{\text{-critical}} = 2.210$. This means that all travel attributes simultaneously and significantly affects in the utility function at the level of significance (α) = 0.05.
- The choosen utility function equation has four attributes with $t_{\text{-stat}}$ value $> t_{\text{-critical}}$ value (1.910): travel cost, congestion cost, travel time and walking time. It means that travel cost, congestion cost, travel time and walking time by individually, significant in the utility function at the level of significance (α) = 0.05 and one travel attribute: headway by individually is not significant at the level of significance (α) = 0.05.

Proportion of Private Passenger Cars Users Shift to Bus TransJogja

The different utility value of private passenger cars users as a through traffic in Malioboro, Yogyakarta and bus TransJogja is 2.10094 so that the probability of choosing private passenger cars is 89.099% and the probability of choosing bus TransJogja is 10.901%. It means that the proportion of private passenger cars users as a through traffic in Malioboro which will shift to bus TransJogja after the implementation of congestion cost IDR 5500.00 per trip is 10.901%.

Conclusions

The effect of application of congestion cost for private passenger cars as a through traffic and bus TransJogja in Malioboro, Yogyakarta, Indonesia includes the amount of congestion cost can be concluded as follows:

1. Congestion cost in Malioboro Corridor, Yogyakarta for private passenger cars is IDR 2915.00 per trip.
2. The application of congestion cost as IDR 5500.00 per trip for private passenger cars user as a through traffic in Malioboro Corridor, Yogyakarta will be shift as 10.901% private passenger car user to bus TransJogja.

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