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The Impact of Congestion Pricing Scheme on the Generalized Cost and Speed of Motorcycle to the City of Yogyakarta, Indonesia

Gito Sugiyanto
Department of Civil Engineering, Faculty of Engineering, Jenderal Soedirman University, Purwokerto, Jl. Mayjend Sungkono km 5, Blater, Kalimanah, Purbalingga, 53371 Central Java, Indonesia

Abstract: The increases of car ownership, population growth and urbanization have increased traffic congestion in many cities in the world. One of the alternatives to reduce congestion is application of congestion pricing. The aim of this research is to estimate the congestion cost of motorcycles and the impact of congestion pricing scheme on the generalized cost and speed of motorcycle to the city of Yogyakarta, Indonesia. The amount of the congestion pricing is the difference between generalized cost in free-flow speed and actual generalized cost in traffic jam condition. In this study, generalized costs of motorcycle from origin zone i to destination zone j consists of vehicle operating cost and travel time cost. This study shows that while the free-flow speed of motorcycle to the city of Yogyakarta is 45.45 km h^{-1} bring on the generalized cost is IDR774 per trip, the actual speed in traffic jam condition is 12.57 km h^{-1} produce the generalized cost is IDR1655 per trip, giving the congestion pricing of motorcycle to the city of Yogyakarta is IDR881 per trip. The impact of application of congestion pricing for motorcycles users will increase the vehicle speeds between 0.42-6.32% and decreases the generalized cost. Speed of vehicle will increase as 1.76 kmh^{-1} in Malioboro Street. The amount of generalized cost of motorcycles will decrease IDR36 per trip (3.63%).

Key words: Congestion pricing, generalized cost, vehicle operating cost, motorcycle, speed

INTRODUCTION

The increases of car ownership, population growth and urbanization have increased traffic congestion in many cities in the world. Congestion is one of the significant transport problems in Indonesia. It does not only occur in urban area, but also in rural area, especially during peak hour. Transport problems become more complex and give more effects to the society in the area with high activities such as in Yogyakarta, Indonesia. This situation happens because the imbalance between the number of vehicles and the length of the road. The congestion becomes worse with the increasing activities in the roadside for non-toll road and bad behavior in driving (Sugiyanto *et al*., 2011a, b).

Congestions will generate many problems due to inefficiency. With congested roads, consumption fuel of vehicle will be increase, vehicle speed will be simultaneously up and down and the average speed will be lower and hence the cost will increase. Therefore, road users will suffer from increasing vehicle operating cost and losing more time. The environment will be in worse conditions due to pollutions. In other words, transport costs will increase due to congestions. The costs incurred by the society as the result and the effect of transportation include vehicle operating cost, travel time cost and externality cost (Ortuzar and Willumsen, 2001). Externality cost like the congestion cost (Stubs *et al*., 1980; Verhoef, 2002), environmental cost, pollution cost, traffic accident cost (Tsai *et al*., 2015) and etc. Externality cost is often forgotten because these costs do not directly affect to road users and are distributed to many people so that they are difficult to measure. Transport cost, especially for passengers, can be reduced by the use of public transportation, but, in contrast, in Yogyakarta the use of public transport decreases and the use of private cars and motorcycle are quickly growing. This condition causes the cost that must be borne by passengers even greater. Sugiyanto *et al*. (2011a, b) and Sugiyanto (2011) state that Transportation Demand Management (TDM), application of pricing policy in charging zone, congestion pricing, road pricing and traffic restraint are the alternatives to reduce the transportation cost.

The congestion costs in France, United Kingdom, United States and Japan are respectively 2.1, 3.2, 1.3% and 2.0% of the respective Gross National Product (GNP) of the countries (Quinet, 1994). Santos (1999) quoted The European Commission report that the congestion costs in Western industrialized countries are 2% of the Gross

Domestic Product (GDP). Santos (1999) quoted Traffic Master which calculates the congestion costs in England for three months in 1996 as £2.1 billion, including wasted2 time, extra fuel, missed deliveries and higher maintenance costs. While in Santos (1999) estimated congestion costs for England as £6.9 billion for 1996. The congestion cost for 85 cities in the United States of America was US\$63.3 billion in 2002, for value of time US\$13.45 h^{-1} (Harford, 2006). Total congestion cost for the year 2000 in The Netherlands are estimated to be 0.799 billion Euros using the traditional speed-flow curve (assignment) based method, while the log sum based method (consumer surplus) provides an estimated value of 1.509 billion Euros).

The economic loss caused by the traffic congestion in the Jabodetabek region could be as much as \$68 million per year due to traffic congestion and this estimate excludes the impacts of traffic congestion and pollution on human health. Estimates of marginal congestion costs for different types of roads in England, the last update being around 45% per passenger car unit (pcu) km for urban roads at peak time. Estimation of congestion cost in CBD Malioboro, Indonesia for private passenger car users as IDR2701 per trip and for motorcycle users as IDR522.77 per trip (Sugiyanto *et al*., 2011a).

The application of road pricing in other countries have a positive impact on reducing the use of private vehicle users and increased the use of public transport. In Belgium, the use of public transport increased 10%. If the application of road pricing with improve the public transportation service quality, the use of public transport will be increase 23% (Armelius and Hultkrantz, 2006). Implementation of congestion charging for private vehicle users in urban centers in London increase the use of urban bus 18%, taxi users 17% and decreased the use of private car 33% (Santos and Bhakar, 2006). The application of congestion charging as IDR 4000 per trip for motorcycles user as a through traffic in Malioboro, Yogyakarta, Indonesia will be shift as 6.848% motorcycle user to bus TransJogja (Sugiyanto *et al*., 2011b). Among 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 (May and Milne, 2000).

The other impact of application of congestion pricing in the other country as follows: Olszewski and Xie (2005) 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 Express way 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.

Eliasson *et al*. (2009) studied the effect of congestion cost in Stockholm, Sweden. The number of passengers by public transit was 6% larger in spring 2006 than 12 months earlier. A new Western bypass is estimated to reduce traffic across inner city bridges by 11% (Eliasson *et al*., 2009). Motorists endure average welfare losses ranging from €0.7-1.0 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 h^{-1} at the most which would require a travel time reduction of around 11 min to outweigh a €2 toll (Bureau and Glachant, 2008).

This aims of this study is to estimate the congestion cost of motorcycle and the impact of congestion pricing scheme on the generalized cost and speed of motorcycle to the city of Yogyakarta, Indonesia.

MATERIALS AND METHODS

Analysis approach: Have shown that generalized cost of travel can be calculated based on combination of cost paid by user, travel time cost and vehicle-operating cost. Equation 1 shows the generalized cost by mode m from origin zone i to destination zone j:

$$GC_{ij}^{m} = VOT\left(time_{ij}^{m}\right) + VOC\left(dis_{ij}^{m}\right) \qquad (1)$$

Where:

- Gc_{ij}^{m} = The generalized cost in pence per Passenger Car Units (PCU) by mode m to go from origin zone i (O_i) to destination zone j (D_j)
- VOT = The value of time in pence per-PCU-min
- $time_{ij}^{m}$ = The time taken to complete the trip in minutes
- VOC_{ij}^{m} = The total vehicle operating cost in pence per PCUkm
- $dist_{ij}^{m}$ = The distance travelled to go from origin zone i to destination zone j, in km
- I = The origin zone
- j = The destination zone

Data collection: In this study, speed of motorcycles is counted in two conditions in free-flow speed condition

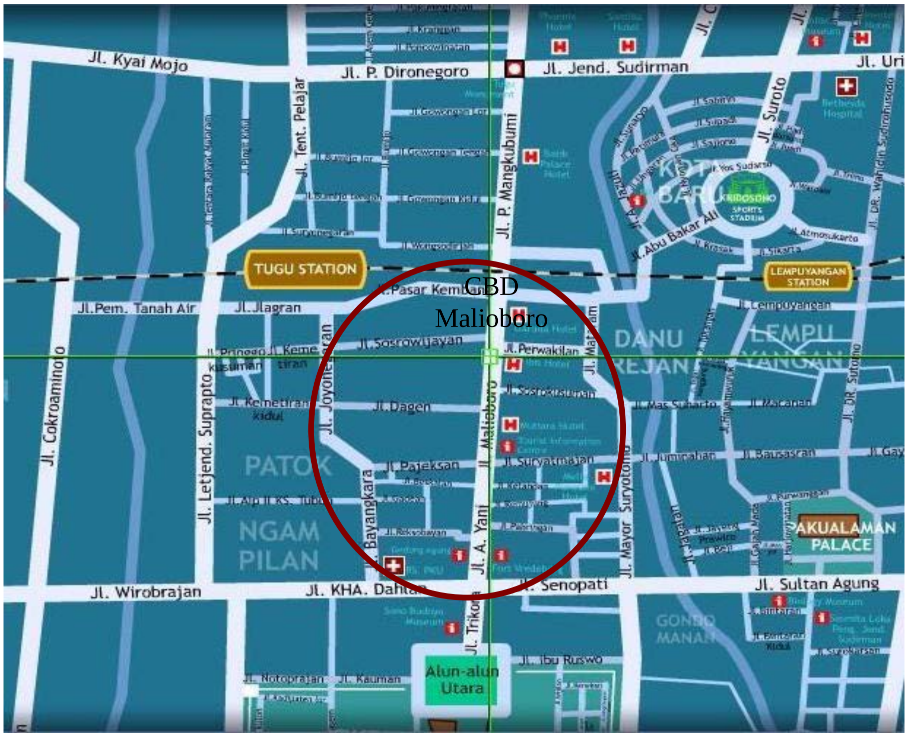

Fig. 1: Study area in CBD Malioboro, Yogyakarta, Indonesia

and in actual condition that potentially cause traffic jam. Traffic is congested if there are so many vehicles that each one travels slower than it would do if the other vehicles weren't there and traffic is congested if there are so many vehicles that they are brought to a standstill or can only crawl along. Related with speed and traffic flow congestion is defined as the impedance vehicles impose on each other, due to the speed-flow relationship, in conditions where the use of a transport system approaches its capacity. The travel time in free-flow speed condition of motorcycles in CBD Malioboro, Yogyakarta is obtained based on formula Indonesian Highway Capacity Manual (IHCM) 1997. The travel time in actual cost condition is obtained from Moving Car Observer (MCO) survey in Central Business District (CBD) Malioboro, Yogyakarta. The CBD Malioboro consist of two lane one-way direction undivided road (2/1 UD) 1.414 km long from Malioboro Street to Ahmad Yani Street. The collection of data in the study area CBD Malioboro, Yogyakarta, Indonesia as can be seen in Fig. 1.

RESULTS AND DISCUSSION

The generalized cost consists of two components of cost: vehicle operating cost and travel time cost.

Vehicle Operating Cost (VOC): In this study, Vehicle-Operating Cost (VOC) of motorcycles is counted in two conditions, based on travel cost in free-flow speed condition and travel cost in actual condition that potentially cause traffic jam. There are five components of vehicle operating costs of motorcycles: consumption of fuel, lubricating oil consumption, tire consumption, maintenance cost (spare part and repair) and fixed cost. Relationship between speed and dependent fuel consumption rates of motorcycles use The Study on Integrated Transportation Master Plan (SITRAMP) for the Jakarta-Bogor-Depok-Tangerang-Bekasi or Jabodetabek in 2004 (JICA and National Development Planning Agency. Fuel economy improvement can be implemented by raising traveling speed and replacing overage vehicles with fuel saving ones like hybrid cars. Especially traveling speed has a significant effect on fuel consumption and the lowest fuel consumption rates occur in a speed range of 40-55 km h^{-1} (JICA and National Development Planning Agency.

Vehicle operating cost and speed relationship: Speed is the main factor to estimate the vehicle operating cost of motorcycles. Figure 2 shows a graph to estimate vehicle-operating cost of the motorcycles. Figure 2

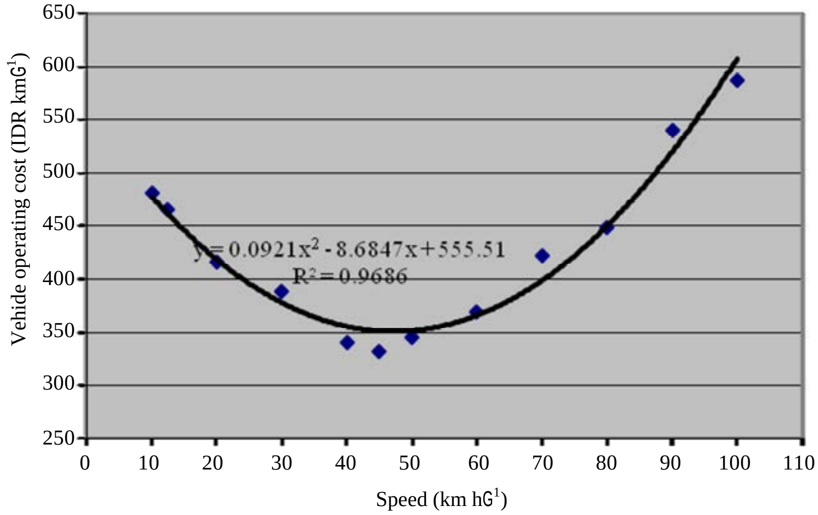

Fig. 2: Relationship between speed and vehicle-operating cost (Sugiyanto, 2011; Sugiyanto *et al*., 2011a, b)

showing the relationship between vehicle operating cost and speed of motorcycles for CBD Malioboro, Yogyakarta, Indonesia as presented in Sugiyanto (2011) and Sugiyanto *et al*. (2011).

From Fig. 2, it can be seen that there is an optimum speed with the minimum vehicle operating cost. The optimum speed for motorcycles in CBD Malioboro, Yogyakarta along the 1.414 km is 47.50 km h^{-1} with vehicle operating cost of IDR350.79 km^{-1}. The vehicle-operating cost model for motorcycles is formulated as:

$$y = 0.0921V^2-8.8647V+555.51 \quad (2)$$

Where:

V = The speed of motorcycle (km h^{-1})

y = The vehicle-operating cost of motorcycles (IDR per km)

Based on the survey and then is analyzed with Indonesian Highway Capacity Manual (IHCM) 1997 the speed of motorcycles in free-flow speed condition is 45.45 km h^{-1} so the vehicle operating cost is IDR351 km^{-1} (Fig. 2). Based on the Moving Car Observer (MCO) survey, the speed of motorcycles in actual cost condition that potentially cause traffic jam is 12.57 km h^{-1}, so the vehicle-operating cost is IDR461 km^{-1} (Fig. 2). The vehicle-operating cost of motorcycles at CBD Malioboro, Yogyakarta in free-flow speed and actual cost condition was calculated by multiplying with 1.414 km, the length of CBD Malioboro, the vehicle operating cost in free-flow speed condition is IDR496.4 per trip and in actual cost condition is IDR651.9 per trip.

Travel Time Cost (TTC): Value of time of motorcycles users in Yogyakarta City in December 2009 based on Gross Regional Domestic Product (GRDP) is IDR3367.55 h^{-1} (Sugiyanto, 2011). Based on the analysis of questionnaires from 150 respondents, value of time with Willingness To Pay (WTP) of motorcycles users to the CBD Malioboro, Yogyakarta is IDR8912.62 h^{-1}. Based on the survey and analysis of speed of motorcycles in CBD Malioboro, Yogyakarta, travel time in free-flow speed condition is 1 min 52 sec. Based on Moving Car Observer (MCO) survey, the average of travel time in actual cost condition is 6 min 45 sec. Travel time cost of motorcycles in CBD Malioboro, Yogyakarta was calculated by multiplying travel time with the value of time based on Willingness To Pay (WTP) of respondent is IDR8912.62 h^{-1}. The travel time cost in free-flow speed condition is IDR277.3 per trip and in actual cost condition is IDR1002.7 per trip

Generalized cost: Generalized cost of motorcycles consists of vehicle operating cost and travel time cost. The generalized cost of motorcycles in actual cost condition is IDR1655/trip and generalized cost in free-flow speed condition is IDR774/trip. Generalized cost of motorcycles in actual condition is more expensive than in free-flow speed condition.

Congestion cost: The approach to estimate congestion cost in this study is similar with Santos (1999). They define congestion costs as the difference between the level of costs in actual speeds and the level of costs in free flow speeds. The amount of congestion cost of motorcycles is the difference between generalized cost in actual cost condition with the speed

Table 1: Impact of congestion pricing of motorcycles users on vehicle speed

		Vehicle speed (km h^{-1})			
Node origin-destination	Name of link and direction movement	Without pricing	With pricing	Δ Vehicle speed (km h^{-1})	Δ Vehicle speed (%)
2-3	Kyai Mojo Street (W-E)	45.10	44.21	-0.89	-1.97
3-2	Kyai Mojo Street (E-W)	45.34	45.97	0.63	1.39
3-4	Pangeran Diponegoro A Street (W-E)	44.85	45.29	0.44	0.98
4-3	Pangeran Diponegoro A Street (E-W)	44.89	44.43	-0.46	-1.02
4-6	Pangeran Diponegoro B Street (W-E)	44.85	45.04	0.19	0.42
6-4	Pangeran Diponegoro B Street (E-W)	44.89	44.43	-0.46	-1.02
6-8	Jend.Soedirman Street (W-E)	45.24	44.51	-0.73	-1.61
8-6	Jend.Soedirman Street (E-W)	45.09	44.13	-0.96	-2.13
9-8	Urip Sumoharjo Street	43.29	42.11	-1.18	-2.73
6-23	Pangeran Mangkubumi Street	36.16	37.53	1.37	3.79
24-25	Malioboro Street	27.85	29.61	1.76	6.32
25-26	Ahmad Yani Street	31.59	32.34	0.75	2.37
26-22	Ahmad Dahlan Street (E-W)	45.16	44.30	-0.86	-1.90
22-26	Ahmad Dahlan Street (W-E)	45.53	44.95	-0.58	-1.27
22-21	Bhayangkara Street	31.63	30.70	-0.93	-2.94
26-37	Pangeran Senopati Street (W-E)	42.27	41.62	-0.65	-1.54
37-26	Pangeran Senopati Street (E-W)	42.38	41.88	-0.50	-1.18
36-35	Mataram Street (S-N)	30.19	30.48	0.29	0.96
35-36	Mataram Street (N-S)	30.23	29.47	-0.76	-2.51
36-37	May. Suryotomo Street (N-S)	40.48	39.41	-1.07	-2.64
37-36	May. Suryotomo Street (S-N)	40.39	40.68	0.29	0.72

W is West, E is East, S is South and N is North

12.57 km h^{-1} and travel time 6 min 45 sec, then generalized cost in free-flow speed condition with speed 45.45 km h^{-1} and travel time 1 min 52 sec. The generalized cost of motorcycles in actual condition is IDR1655 per trip and generalized cost in free-flow speed condition IDR774 per trip, thus, the congestion cost of motorcycles in CBD Malioboro, Yogyakarta is IDR881 per trip.

Impact of congestion pricing: Implementation of congestion pricing for motorcycles users at Malioboro Street and Ahmad Yani Street resulted change in vehicle speed between 0.42-6.32%. Speeds in some roads have increase like at Pangeran Mangkubumi Street, Malioboro Street and Ahmad Yani Street while in Jenderal Sudirman Street and Mayor Suryotomo Street decrease. The highest increase of vehicle speed occur in Malioboro Street as 1.76 km h^{-1} while the largest decrease occurs in Mayor Suryotomo Street at north-south direction as 1.07 km h^{-1} (2.64%) and in Bhayangkara Street as 0.93 km h^{-1} (2.94%) (Table 1).

Based on the results of the simulation of application congestion pricing for motorcycles users in Malioboro was obtained the improvement of road network performance. Application of congestion pricing increase the vehicle speeds and decreases the generalized cost. These results are similar with study of Beevers and Carslaw (2005) that examine the application of congestion charging in central London that can increase the average speed of vehicle ±4 km h^{-1}. The highest increase of vehicle speed due to the implementation of congestion pricing occurs in Malioboro Street 1.76 km h^{-1} (6.32%). These results are consistent with the research of Palma and Lindsey (2006) which examined the implementation of Electronic Road Pricing (ERP) in Paris. ERP increase the vehicle speed from 44.80-45.40 km h^{-1}.

Vehicle speed on Malioboro Street in existing condition without pricing is 27.85 km h^{-1}. In this condition, the amount of vehicle-operating cost of motorcycles is IDR538 per trip, travel time cost is IDR453 per trip and therefore, the generalized cost is IDR991 per trip. Based on the results of the simulation, vehicle speed on Malioboro Street with pricing is 29.61 km h^{-1}. In this condition, the amount of vehicle-operating cost of motorcycles is IDR529 per trip, travel time cost is IDR426 per trip and therefore, the generalized cost is IDR955 per trip. The amount of generalized cost will decrease IDR36 per trip (3.63%).

Within the Charging Zone (CZ), the Wilcoxon test has shown that the difference in speed between pre and post London's Congestion Charging Scheme (CCS) periods has increased on average 2.1 km h^{-1} and that these changes are significant at the $p = 0.05$ level (Beevers and Carslaw, 2005). In Mashhad CBD urban road network, the cordon based pricing scheme brings 7.99% social welfare improvement. The maximal social welfare is achieved when the value of time is equal to 1200 tomans per hour (Afandizadeh *et al*., 2011). Impact of the congestion pricing scheme with Sioux Falls network, the number of links with Level of Service (LoS) D, LoS E and LoS F are reduced and LoS of a great number of links becomes LoS C. The value of objective function improves 65.97% after toll pricing process (Soudmand *et al*., 2013). Blythe (2004) and TfL explained the boundary of charging zone marked by tollgate that separates with the other road networks. Implementation of congestion costs in CBD Malioboro, Yogyakarta needs two tollgates at the intersections of Malioboro Street with Pasar Kembang Street.

CONCLUSION

The estimation of congestion cost for motorcycles users in CBD Malioboro, Yogyakarta Indonesia and the impact of congestion pricing scheme on the generalized cost and speed of motorcycles to the city of Yogyakarta presented in this study. From the analysis and results, it can be concluded as follows: The generalized cost at CBD Malioboro, Yogyakarta, Indonesia for motorcycles in free-flow speed condition IDR774 per trip and in actual cost condition is IDR1655 per trip, giving the congestion pricing of motorcycle to the city of Yogyakarta is IDR881 per trip.

The impact of congestion pricing scheme on the generalized cost for motorcycles to the city of Yogyakarta will decrease IDR36 per trip (3.63%). The impact of application of congestion pricing on vehicle speed will increase between 0.42-6.32%, the highest increase of vehicle speed occur in Malioboro Street as 1.76 km h^{-1} (6.32%) while the largest decrease occurs in Mayor Suryotomo Streets at North-South movement as 1.07 km h^{-1} (2.64%) and Bhayangkara Street as 0.93 km h^{-1} (2.94%).

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