WALAILAK JOURNAL
http://wjst.wu.ac.th Information Technology

The Effect of Congestion Pricing Scheme on the Generalized Cost and Speed of a Motorcycle

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Received: 8 April 2016, Revised: 19 December 2016, Accepted: 25 January 2017

Abstract

Traffic congestion is one of the significant transport problems in many cities in developing countries. Increased economic growth and motorization have created more traffic congestion. The application of transportation demand management like congestion pricing can reduce congestion, pollution and increase road safety. The aim of this research is to estimate the congestion pricing of motorcycles and the effect of a congestion pricing scheme on the generalized cost and speed of a motorcycle. The amount of congestion pricing is the difference between actual generalized cost in traffic jams and in free-flow speed conditions. The analysis approach using 3 components of generalized costs of motorcycle: vehicle operating, travel time and externality cost (pollution cost). The approach to analyze the pollution cost is marginal-health cost and fuel consumption in traffic jams and free-flow speed conditions. The value of time based on Gross Regional Domestic Product per capita in Yogyakarta City in October 2012. The simulation to estimate the effect of congestion pricing using *Equilibre* Multimodal, Multimodal Equilibrium-2 (EMME-2) software. The results of this study show that while the free-flow speed of a motorcycle to the city of Yogyakarta is 42.42 km/h, with corresponding generalized cost of IDR1098 per trip, the actual speed in traffic jams is 10.77 km/h producing a generalized cost of IDR2767 per trip, giving a congestion pricing for a motorcycle of IDR1669 per trip. Based on the simulation by using EMME-2, the effect of congestion pricing will increase on vehicle speed by 0.72 to 8.11 %. The highest increase of vehicle speed occurred in Malioboro Street at 2.26 km/h, while the largest decrease occurred in Mayor Suryotomo Street at north-south direction at 1.07 km/h. Another effect of this application for motorcycles users will decrease the generalized cost by 1.09 to 6.63 %.

Keywords: Congestion pricing, motorcycle, marginal-health cost, generalized cost, EMME-2

Introduction

Cities in developing countries need innovative and effective solutions to solve their transportation problems like the traffic congestion, accident and delays. The increase in car ownership, population growth, and urbanization has increased traffic congestion in many cities in developing countries like in Indonesia. Traffic congestion does not only occur in urban areas, but also in rural areas, especially during peak hours. Transport problems become more complex and have more effects on society in areas with high activities, such as in Yogyakarta, Indonesia. This situation happens because of the imbalance between the number of vehicles and the length of the road [1]. Solutions to these problems are possible, not only through improvement of public transport, increased pedestrians and bicycle users, but also in the implementation of measures which promote a rational use of the automobile by means Transportation Demand Management (TDM). TDM aims to maximize the efficiency of the urban transport system by discouraging unnecessary private vehicle use and environmental-friendly modes of transport, in general being public transport and non-motorized transport [2].

The costs incurred by society as a result of the effect of congestion on transportation include vehicle operating, travel time and externality costs [3]. Externality costs are the congestion [4,5], environmental, pollution, and traffic accident costs [6]. The internalization of transportation external costs is one of the most relevant issues for policy makers in recent years. Congestion and air pollution are among the most relevant sources of externalities in urban centers and they are increasingly tackled through the adoption of road pricing schemes [7]. TDM, application of pricing policy in charging zone, congestion pricing, road pricing, and traffic restraint are the alternatives to reduce the transportation cost [1,8]. TDM can provide many benefits, for example congestion reduction, road cost savings, parking savings, transportation cost savings to consumers, improved mobility options, increased road safety, reduced per capita energy consumption, reduced per capita pollutions emissions, efficient land use and increased physical activity and associated health benefits [2].

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 [9,10]. The congestion cost for 85 cities in the United States was US$63.3 billion in 2002, for a value of time of US$13.45/hour [11]. The economic loss caused by the traffic congestion in the Jabodetabek region could be as much as US$68 million per year due to traffic congestion and this estimate excludes the impacts of traffic congestion and pollution on human health [12]. Marginal congestion costs for different types of roads in England, for the last update were around 45 pence per passenger car unit (pcu)-km for urban roads at peak time [13]. The congestion cost in CBD Malioboro, Indonesia for private passenger car users are estimated to be IDR2701 (US$0.257) per trip [1] and for motorcycle users IDR522.77 (US$0.05) per trip [14].

The effect of congestion pricing has been long studied in the transport policy area. In the cases of 4 European cities Paris, Brussels, Oslo and Helsinki can get a sizable amount of benefit from commuting time reduction, cost saving in vehicle management, or enhanced quality of public transportation when road pricing was introduced in each country [15]. Implementation of congestion charging for private vehicle users in urban centers in London increased the use of urban bus transport by 18 %, taxi users by 17 % and decreased the use of private cars by 33 % [16]. Application of road pricing in other countries has had 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 by 10 %. If there is application of road pricing with improved public transportation service quality, the use of public transport will increase by 23 % [17]. Based on the simulation, application of a congestion charge of IDR4000 per trip for motorcycle users as through traffic in CBD Malioboro, Yogyakarta will shift 6.848 % motorcycle users to bus TransJogja [18]. Among 15 - 20 %, reductions in generalized cost are surprisingly small for charge levels, which have achieved 15 % reduction in overall trips [19]. Singapore's road pricing system reduced 20 to 30 % of the downtown passenger car traffic and Stockholm's traffic volume decreased by at least 20 % [20]. Commuters switch to public bus services by 12 to 20 % in the morning hours after a S$1 increase and by approximately 10 % in the evening after toll adjustment of S$0.50 to S$1.00 in the affected gantry area compared to the counterfactual through difference-in-difference method [21]. The effect of congestion cost in Stockholm, Sweden, a new Western bypass is estimated to reduce traffic across inner city bridges by 11 % [22]. In New Zealand it was found that the 21 % of survey respondents were willing to choose to walk and to use public transportation, while 67 % insisted that they would still drive cars were congestion pricing to be introduced [23]. Almost 37 % of car users in Edinburgh were willing to spend less or change the shopping destination if they had been asked to pay a congestion tax for their shopping trip to the CBD [24].

The aim of this paper is to estimate the congestion cost of motorcycle users and the effect of the congestion pricing scheme on the generalized cost and speed of motorcycle to the city of Yogyakarta, Indonesia.

Materials and methods

Analysis approach

Generalized cost of travel can be calculated based on a combination of cost paid by the user, travel time cost, vehicle-operating cost and externality cost. Externalities arise when the activity of a group affects the welfare of the other groups without any compensation [25,26]. Externalities in transport include: congestion, accidents, emissions, pollution and noise [2,27]. In this study, the externality cost that was considered was the pollution cost. The approach that is used to analyze the pollution cost is marginal-health cost per vehicle and fuel consumption of vehicle in actual conditions and free-flow speed conditions. The generalized cost by mode *m* from the origin, zone *i* to the destination, zone *j* was determined using Eq. (1).

$$GC_{ij}^{m} = VOT\ (time_{ij}^{m}) + VOC\ (dist._{ij}^{m}) + EC\ (dist._{ij}^{m}) \quad (1)$$

In which GC_{ij}^{m} is the generalized cost per Passenger Car Units (PCU) by mode *m* to go from the origin, zone *i* (O_i) to the destination, zone *j* (D_j), VOT is the value of time per-PCU-min, $time_{ij}^{m}$ is the time taken to complete the trip in minutes, VOC_{ij}^{m} the total vehicle operating cost per PCU-km, and $dist._{ij}^{m}$ is the distance travelled to go from zone *i* to zone *j*, in km, EC is the externality cost per kilometer while *i* is the origin zone and *j* the destination zone.

Data collection

In this paper, the speed of motorcycles was counted in 2 conditions, the first in free-flow speed conditions and the second in actual conditions that potentially cause traffic jams. Traffic is congested if there are so many vehicles that each one travels slower than it would do if the other vehicles were not there and traffic is congested if there are so many vehicles that they are brought to a standstill or can only crawl along [28]. Related with speed is traffic flow congestion which is defined as the impedance vehicles imposed on each other, due to the speed-flow relationship, in conditions where the use of a transport system approaches its capacity [29]. Motorcycle speed data was based on travel time of vehicles and a speed survey using speed gun.

The travel time in free-flow conditions for motorcycles in CBD Malioboro, Yogyakarta is obtained based on the formula in the Indonesian Highway Capacity Manual (IHCM) 1997 [30]. The actual travel time cost conditions were obtained from a Moving Car Observer (MCO) survey in the Central Business District (CBD) Malioboro, Yogyakarta. The CBD Malioboro consists of a 2 lane one-way direction undivided road (2/1 UD) 1.414 kilometers long from Malioboro Street to Ahmad Yani Street. The width of Malioboro Street is 7.00 m. The value of time data for motorcycle users is based on Gross Regional Domestic Product (GRDP) per capita in Yogyakarta city. The fuel consumption was obtained from the relationship between speed and dependent fuel consumption rates of motorcycles reported in the Study on Integrated Transportation Master Plan (SITRAMP) for the Jakarta-Bogor-Depok-Tangerang-Bekasi or Jabodetabek in 2004 [31]. The street where data was collected in the study area in CBD Malioboro, Indonesia is shown in **Figures 1** and **2**.

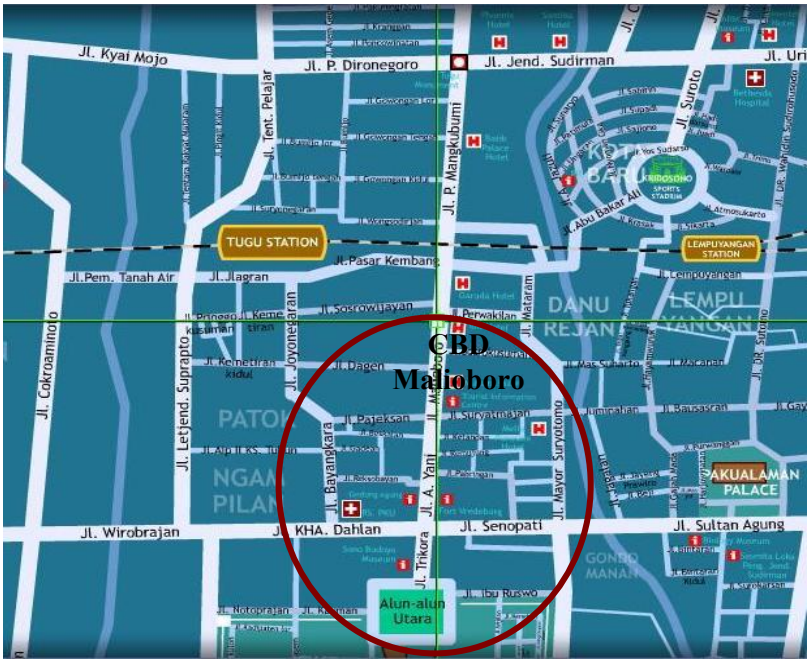

Figure 1 Study area in CBD Malioboro, Indonesia [1,14,18].

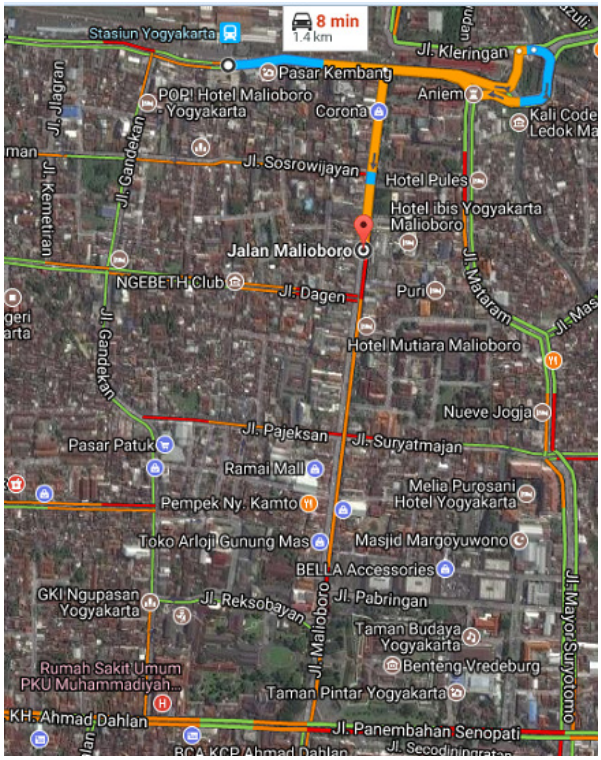

Figure 2 Street in the study area in CBD Malioboro.

Results and discussion

The generalized cost of a motorcycle from origin to destination consists of 3 components of cost: the first is the vehicle operating cost, the second is the travel time cost and the third is the pollution cost.

Vehicle operating cost

In this paper, the vehicle operating cost (VOC) of motorcycles was counted in 2 conditions, based on travel cost in free-flow conditions and travel cost in actual conditions that potentially involved traffic jams. There are 5 components of vehicle operating costs of motorcycles: (a) consumption of fuel, (b) lubricating oil consumption, (c) tire consumption, (d) maintenance cost (spare parts and repair), and (e) fixed cost. The fuel consumption was obtained from the relationship between speed and fuel consumption rates of motorcycles reported in the Study on Integrated Transportation Master Plan (SITRAMP) for the Jakarta-Bogor-Depok-Tangerang-Bekasi or Jabodetabek in 2004 [31]. Fuel economy improvement can be implemented by raising traveling speed and replacing average vehicles with fuel saving ones like hybrid cars. For instance, traveling speed was reported to have a significant effect on fuel consumption and the lowest fuel consumption rates occur in a speed range of 40 km/h to 55 km/h [31,32].

Vehicle operating cost and speed relationship

Speed is the main factor to estimate the vehicle operating cost of motorcycles. The relationship between vehicle operating cost and speed of motorcycles for CBD Malioboro, Yogyakarta is presented in [14]. The optimum speed for motorcycles in CBD Malioboro along the 1.414 km is 47.20 km/h with vehicle operating cost of IDR350.77 per km (IDR496 in CBD Malioboro). The vehicle-operating cost model for motorcycles was determined using Eq. (2).

$$y = 0.0921V^2 - 8.6847V + 555.51 \text{ with } r^2 = 0.9686 \quad (2)$$

in which V is the speed of the motorcycle (km per hour) and y is vehicle operating cost of motorcycles (IDR per km).

Based on the survey and the analysis of Indonesian Highway Capacity Manual (IHCM) 1997 the speed of motorcycles in free-flow conditions is 42.42 km/h so the vehicle operating cost is IDR352.84/km (using Eq. (2)). Based on the Moving Car Observer (MCO) survey, the average speed of motorcycles under actual conditions is 10.77 km/h, so the vehicle-operating cost is IDR472.66/km (using Eq. (2)). The vehicle operating cost of motorcycles at CBD Malioboro, Yogyakarta in free-flow speed and actual conditions was calculated by multiplying by 1.414 km, the length of CBD Malioboro, the vehicle operating cost in free-flow speed condition is IDR499 per trip and the actual conditions were IDR669 per trip.

Travel time cost

Gross Regional Domestic Product (GRDP) per capita in Yogyakarta city in October 2012 is IDR51,649,500 [33]. The approach in this research was 25 workdays every month, 8 hours/day, a motorcycle occupancy of 1.5 peoples per motorcycle and percentage of workers 45 %. The value of time of motorcycle users in Yogyakarta city based on Gross Regional Domestic Product (GRDP) is IDR14,526.42 per hour. Based on the survey and analysis of the speed of motorcycles in CBD Malioboro, the travel time in free-flow conditions is 2 min. Based on the moving car observer (MCO) survey, the average of travel time in actual conditions is 7 min 52.5 s. The travel time cost of motorcycles in CBD Malioboro, Yogyakarta was calculated by multiplying the travel time with the value of time based on GRDP is IDR14,526.42 per hour. The travel time cost (TTC) in free-flow conditions is IDR485 per trip while the actual cost is IDR1,907 per trip.

Externality Cost: Pollution Cost

The marginal health-cost (MHC) approach is used to calculate the pollution cost per motorcycle. This approach was the result of a World Bank study in Jakarta in 1990. MHC is value expressed in US cents per litre and cents/pass-kilometer [14]. In this study, we used MHC in cents per litre, then converted

into IDR per litre using an exchange rate of 1 US$ = IDR10,500. The pollution cost for motorcycles was determined using Eq. (3).

Pollution cost (PC) = Marginal Health-cost (MHC) × Consumption of fuel (CF) (3)

In which PC is pollution cost (IDR/km), MHC is marginal health-cost of motorcycle (IDR/litre) and CF is the fuel consumption (litre/km).

The relationship between fuel consumption and the speed of the motorcycle is based on the result of the SITRAMP study by [31] and measurements in the field is formulated in the quadratic function of Eq. (4).

$y = -0.008V^2 + 0.7991V + 9.6933$ with $r^2 = 0.8299$ (4)

In which y is fuel consumption (km/litre) and V is speed of motorcycle (km/h). The coefficient determination (r^2) value 0.8299, indicated that there was a strong correlation between motorcycle speed and fuel consumption. Fuel consumption using Eq. (4), was 17.37 km/litre in actual conditions with a speed 10.77 km/h and 29.20 km/litre in free-flow conditions with a speed 42.42 km/h. Speed and fuel consumption are the main factors in determining pollution cost. The pollution cost of motorcycle in free-flow conditions was IDR 80 and IDR135 in actual conditions. The pollution cost of motorcycles in Malioboro along 1.414 km in actual conditions at 10.77 km/h is IDR 191 and in free-flow conditions at 42.42 km/h is IDR 114.

Generalized cost

The generalized cost of motorcycles consists of vehicle operating cost, travel time cost and externality cost. From the results above, the generalized cost of motorcycles in actual conditions is IDR2767/trip and generalized cost in free-flow conditions is IDR1098/trip. The generalized cost of motorcycles in actual conditions is more expensive (152 %) than in free-flow conditions. The value of travel time cost in actual conditions is 69 % of the generalized cost but in free-flow conditions is only 44 %. The generalized cost of the motorcycle in CBD Malioboro is shown in **Table 1**.

Table 1 Generalized cost of motorcycle in CBD Malioboro.

Type of condition	VOC (IDR/trip)	Pollution cost (IDR/trip)	TTC (IDR/trip)	Generalized cost (IDR/trip)
Free-flow speed	499	114	485	1,098
Actual cost	669	191	1,907	2,767

Congestion cost

The approach to estimate congestion cost in this study is similar to the approach of Dodgson and Lane [34] in their study on the costs of road congestion in Great Britain. Congestion costs as the difference between the level of costs in actual and the level of costs in free-flow conditions [34]. The amount of congestion cost of motorcycles is the difference between the generalized cost in actual conditions at 10.77 km/h and a travel time of 7 min 52.5 s, and the generalized cost in free-flow conditions at 42.42 km/h and a travel time of 2 min. From above, the generalized cost of motorcycles in actual conditions is IDR2,767 per trip, and the generalized cost in free-flow conditions is IDR1,098 per trip, thus the congestion cost of motorcycles in CBD Malioboro, Yogyakarta is IDR1,669 per trip.

Effect of congestion pricing

The simulation to estimate the effect of congestion pricing in CBD Malioboro using *Equilibre* Multimodal, Multimodal Equilibrium-2 (EMME-2) software. Distribution of traffic zones, nodes and links in EMME-2 to simulate the application of congestion pricing in CBD Malioboro can be seen in **Figure 3**. The result of the simulation of congestion cost for motorcycle users in CBD Malioboro includes Malioboro Street (along 809 m) and Ahmad Yani Street (along 605 m) using EMME-2 software as presented on auto speed can be seen in **Figure 4**.

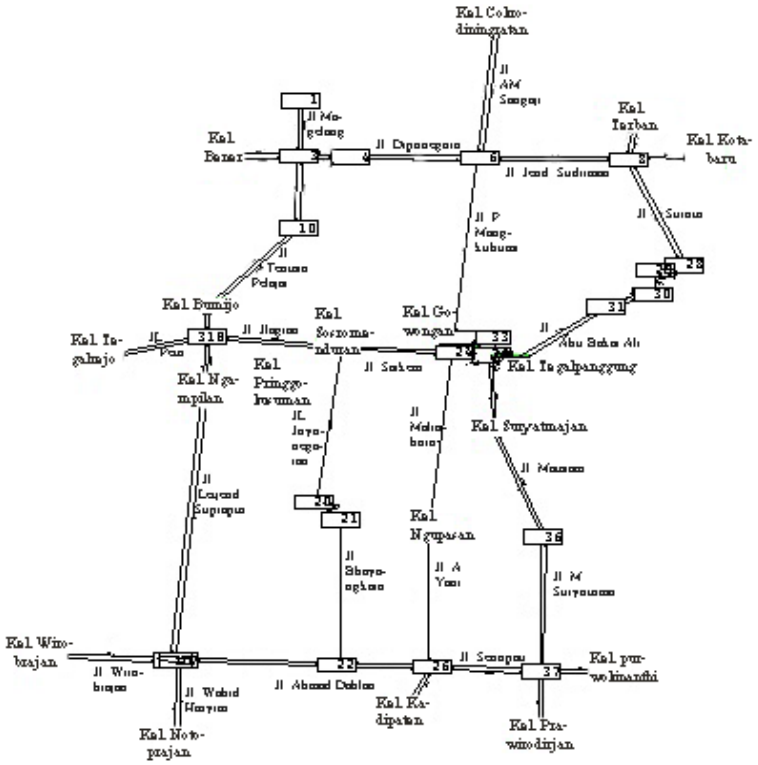

Figure 3 Distribution of traffic zones, nodes and links in EMME-2 software.

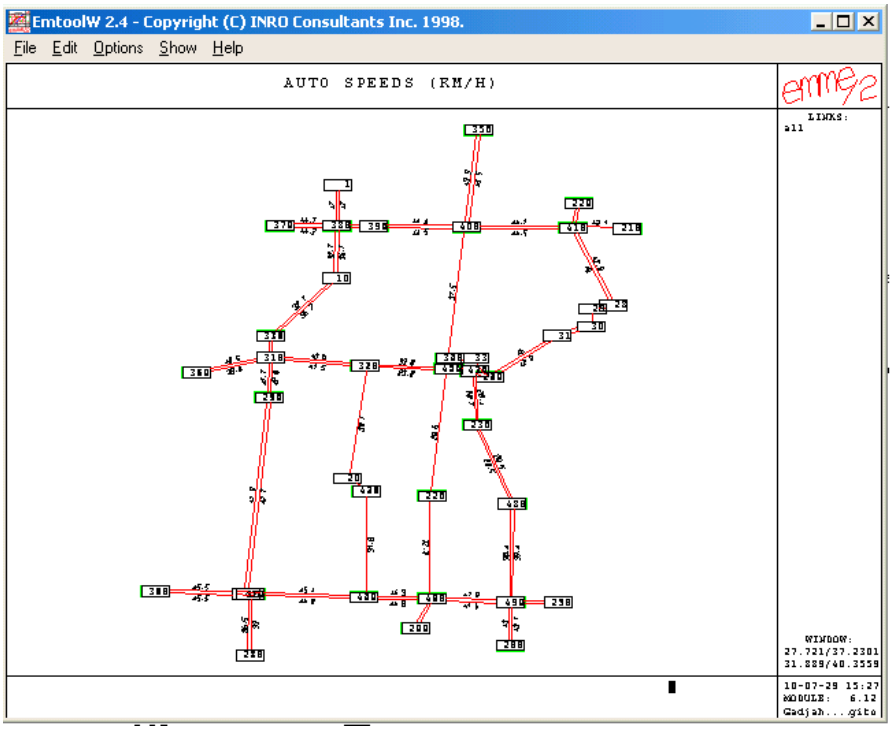

Figure 4 Auto speeds from simulation results using EMME-2 in CBD Malioboro, Yogyakarta.

Implementation of congestion pricing for motorcycles users at Malioboro Street and Ahmad Yani Street in Yogyakarta resulted in a change in vehicle speed of 0.72 to 8.11 % (**Table 2**). The speed in some roads increased like at Pangeran Diponegoro Street (W-E), Pangeran Mangkubumi Street, Malioboro Street, Ahmad Yani Street, Mataram Street (S-N) and Mayor Suryotomo Street (S-N), while in Jenderal Sudirman Street, Pangeran Diponegoro Street (E-W), Ahmad Dahlan Street, Pangeran Senopati Street and Mayor Suryotomo Street (N-S) the speed decreased. The highest increase of vehicle speed occurred in Malioboro Street at 2.26 km/h (8.11 %) while the largest decrease occurred in Mayor Suryotomo Street in the north-south direction at 1.07 km/h (2.64 %) and in Bhayangkara Street at 0.88 km/h (2.78 %). These results are similar with the research of [35] which examined the implementation of Electronic Road Pricing (ERP) in Paris, ERP increased the vehicle speed from 44.80 to 45.40 km/h. Based on the results of the simulation of application of congestion pricing for motorcycles users in Malioboro, there was an improvement in the road network performance. Application of congestion pricing increased the vehicle speed and decreased the generalized cost. These results are similar to the study of [36] that examined the application of congestion charging in central London that can increase the average speed of vehicle by ±4 km/h. 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 of 2.1 km/h and that these changes are significant at the p = 0.05 level [36]. This result is in line with the findings of Percoco [7], the road pricing scheme in Milan has had limited impact in terms of congestion and environmental quality because of the behavioral response of road users. In fact, we have found that the policy did not produce a reduction in the number of vehicles entering the city center, while it did lead to an increase in the number of motorbikes and, in part, LPG, bi-fuel and hybrid cars [7]. The effect of congestion pricing of motorcycles users on vehicle speed in 16 links can be seen in **Table 2**.

Table 2 Effect of congestion pricing of motorcycles users on vehicle speed.

No.	Node Origin-Destination	Name of link and direction of movement	Vehicle speed (km/h)		Difference in vehicle speed (km/h)	Difference in vehicle speed (%)
			Without pricing	With pricing		
(1)	(2)	(3)	(4)	(5)	(6) = (5) - (4)	(7) = (6)/(4)
1.	3 - 4	Pangeran Diponegoro Street (W-E)	44.85	45.29	0.44	0.98 %
2.	4 - 3	Pangeran Diponegoro Street (E-W)	44.89	44.43	-0.46	-1.02 %
3.	6 - 8	Jenderal Soedirman Street (W-E)	45.24	44.51	-0.73	-1.61 %
4.	8 - 6	Jenderal Soedirman Street (E-W)	45.09	44.13	-0.96	-2.13 %
5.	6 - 23	Pangeran Mangkubumi Street	36.16	37.53	1.37	3.79 %
6.	24 - 25	Malioboro Street	27.85	30.11	2.26	8.11 %
7.	25 - 26	Ahmad Yani Street	31.09	32.34	1.25	4.02 %
8.	26 - 22	Ahmad Dahlan Street (E-W)	45.16	44.30	-0.86	-1.90 %
9.	22 - 26	Ahmad Dahlan Street (W-E)	45.53	44.95	-0.58	-1.27 %
10.	22 - 21	Bhayangkara Street	31.63	30.75	-0.88	-2.78 %
11.	26 - 37	Pangeran Senopati Street (W-E)	42.27	41.37	-0.90	-2.13 %
12.	37 - 26	Pangeran Senopati Street (E-W)	42.38	41.63	-0.75	-1.77 %
13.	36 - 35	Mataram Street (S-N)	30.19	30.48	0.29	0.96 %
14.	35 - 36	Mataram Street (N-S)	30.23	29.47	-0.76	-2.51 %
15.	36 - 37	Mayor Suryotomo Street (N-S)	40.48	39.41	-1.07	-2.64 %
16.	37 - 36	Mayor Suryotomo Street (S-N)	40.39	40.68	0.29	0.72 %

Note: W is west, E is east, S is south, and N is north.

The vehicle speed on Malioboro Street in existing conditions without pricing is 27.85 km/h. In these conditions, the vehicle operating cost of motorcycles is IDR311.53 per trip, travel time cost is IDR421.97 per trip, pollution cost is IDR73.42 per trip and therefore the generalized cost without congestion pricing is IDR806.92 per trip. Based on the simulation by using EMME-2, vehicle speed on Malioboro Street with congestion pricing is 30.11 km/h. Under these conditions, the vehicle operating cost of motorcycles is IDR305.41 per trip, travel time cost is IDR390.30 per trip, pollution cost is IDR71.32 per trip and therefore the generalized cost with pricing is IDR753.40 per trip. The generalized cost in Malioboro Street will decrease to IDR53.51 per trip (6.63 %). Vehicle speed on Ahmad Yani Street under existing conditions without pricing is 31.09 km/h. Under these conditions, the vehicle operating cost of a motorcycle is IDR226.59 per trip, travel time cost is IDR282.68 per trip, pollution cost is IDR52.73 per trip and therefore the generalized cost without pricing is IDR562 per trip. Based on the results of the simulation, vehicle speed on Ahmad Yani Street with congestion pricing would be 32.34 km/h. Under these conditions, the vehicle operating cost of a motorcycle is IDR224.44 per trip, travel time cost is IDR271.76 per trip, pollution cost is IDR52.03 per trip and therefore the generalized cost with pricing is IDR527.66 per trip. The generalized cost in Ahmad Yani Street will decrease to IDR34.33 per trip (6.11 %). The effect of congestion pricing of motorcycles users on generalized cost in 16 links can be seen in **Table 3**.

Table 3 Effect of congestion pricing of motorcycles users on generalized cost.

No.	Name of link and direction movement	Length of link (km)	Generalized cost (IDR/trip)		Δ Generalized cost (IDR/trip)	Δ Generalized cost (IDR/trip)
			Without pricing	With pricing		
(1)	(2)	(3)	(4)	(5)	(6) = (5) - (4)	(7) = (6)/(4)
1.	Malioboro Street (N-S)	0.809	806.92	753.40	-53.51	-6.63 %
2.	Ahmad Yani Street (N-S)	0.605	562.00	527.66	-34.33	-6.11 %
3.	Jenderal Soedirman Street (W-E)	1.274	957.39	992.42	35.03	3.66 %
4.	Jenderal Soedirman Street (E-W)	1.274	958.86	996.40	37.54	3.92 %
5.	Pangeran Mangkubumi Street	0.814	689.20	662.01	-27.18	-3.94 %
6.	Pangeran Diponegoro Street (W-E)	0.686	517.59	498.18	-19.41	-3.75 %
7.	Pangeran Diponegoro Street (E-W)	0.686	517.38	502.78	-14.60	-2.82 %
8.	Ahmad Dahlan Street (E-W)	1.022	768.64	777.40	8.76	1.14 %
9.	Ahmad Dahlan Street (W-E)	1.022	765.77	772.09	6.32	0.83 %
10.	Bhayangkara Street	0.574	527.42	515.55	-11.87	-2.25 %
11.	Pangeran Senopati Street (W-E)	0.715	555.34	545.16	-10.17	-1.83 %
12.	Pangeran Senopati Street (E-W)	0.715	554.60	543.35	-11.25	-2.03 %
13.	Mataram Street (S-N)	0.564	533.83	508.98	-24.84	-4.65 %
14.	Mataram Street (N-S)	0.564	533.37	520.34	-13.03	-2.44 %
15.	Mayor Suryotomo Street (N-S)	0.750	595.86	589.36	-6.50	-1.09 %
16.	Mayor Suryotomo Street (S-N)	0.750	596.57	579.16	-17.40	-2.92 %

Note: W is west, E is east, S is south, and N is north.

These results are in line with the findings of May and Milne [19] and Sugiyanto [37] that congestion pricing will yield reductions in generalized cost. The generalized cost in Malioboro Street, Ahmad Yani Street, Pangeran Mangkubuni Street, Pangeran Diponegoro Street, Bhayangkara Street, Pangeran Senopati Street, Mataram Street and Mayor Suryotomo Street will decrease, while the generalized cost in Jenderal Soedirman Street and Ahmad Dahlan Street will increase. The highest increase in generalized cost occurred in Malioboro Street at IDR53.51 per trip (6.63 %) while the largest decrease occurs in Jenderal Soedirman Street in the east-west direction at IDR37.54 per trip (3.92 %). Under these conditions, there is a change of route from the commuter to the city of Yogyakarta.

Conclusions

The estimation of congestion cost for motorcycles users in CBD Malioboro, Yogyakarta and the effect of a congestion pricing scheme on the generalized cost and speed of motorcycles to the city of Yogyakarta is presented in this paper. From the analysis and results, it can be concluded that:

1. The generalized cost at CBD Malioboro, Yogyakarta for motorcycles in free-flow conditions is IDR1,098 per trip and in actual conditions is IDR2,767 per trip, giving a congestion pricing for motorcycles to the city of Yogyakarta of IDR1,669 per trip.
2. Based on the simulation by using EMME-2, the effect of the application of congestion pricing will increase vehicle speed by 0.72 to 8.11 %. The highest increase of vehicle speed occurred in Malioboro Street at 2.26 km/h (8.11 %) while the largest decrease occurred in Mayor Suryotomo Street at north-south direction at 1.07 km/h (2.64 %) and in Bhayangkara Street at 0.88 km/h (2.78 %).
3. The effect of the congestion pricing scheme on the generalized cost for motorcycles will decrease to IDR53.51 per trip (6.63 %) in Malioboro Street and IDR34.33 per trip (6.11 %) in Ahmad Yani Street.

Acknowledgements

This research was carried out by the financial support of Ministry of Education and Culture, Republic of Indonesia through Research Grant: Doctorate Development Program (*Beasiswa Unggulan Program Pengembangan Doktor* or P2D) in the fiscal year 2012.

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