

Impact of Traffic Volume on the Pollution Cost, Value of Time, and Travel Time Cost in Jakarta City Centre Area

Asep Yayat Nurhidayat^{1,2}, Hera Widyastuti^{1,*}, Sutikno³, Dwi Phalita Upahita², Annissa Roschyntawati²

¹Department of Civil Engineering, Institut Teknologi Sepuluh Nopember, Indonesia

²National Research and Innovation Agency, Indonesia

³Department of Statistics, Institut Teknologi Sepuluh Nopember, Indonesia

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Abstract Traffic congestion is one of the major concerns in the transportation system. The domination of private car as the primary mode of transport in big cities, including Jakarta, has caused negative impacts such as increase of congestion and air pollution. Traffic congestion in Jakarta can be considered quite severe, with an average travel speed of only 15 km/hour. Meanwhile, the use of public transportation continues to decline. Traffic congestion causes high fuel consumption, increased vehicle operation cost, increased travel time, reduced air quality, and increased traffic accident rate. This study aims to analyze the impact of traffic congestion by using congestion cost as a proxy to represent the potential loss. Two major roads in Jakarta, Gadjah Mada and Hayam Wuruk Street were chosen as the study location. The total generalized cost was calculated from several aspects: vehicle operation cost, pollution cost, and time value, based on the actual and perceived traffic conditions. The congestion cost was calculated as the differences between actual condition and perceived condition. It represents the potential loss caused by traffic congestion. The result shows a significant increase in vehicle operation cost, pollution cost, and value of time due to congestion. The results also indicate that users perceived lower travel time and generalized cost than the actual condition. The

congestion cost in Hayam Wuruk Street is IDR 12.149/vehicle, while congestion cost for Gadjah Mada Street is IDR 11.692/vehicle. It means that users experienced higher potential loss due to congestion in Hayam Wuruk Street than Gadjah Mada Street. The result can be served as the basis for developing the implementation model of congestion cost in Jakarta.

Keywords Congestion, Pollution, The Value of Time, Travel Cost

1. Introduction

Many major big cities have experienced congestion in recent years. Major cities have become a magnet for commercial activities and job opportunities [1]. Fast economic growth has caused an increase in trip demand in the cities [2]. Massive urbanization also plays a major factor in causing traffic congestion [3]. Traffic congestion is one of the urban characteristics caused by economic activities, increased people movement productivity, and facility availability. The increase in private vehicle ownership caused an increase in road traffic that led to

congestion problems, a significant problem faced by many cities in the world [4], [5]. Urban congestion is also caused by limited infrastructure that cannot accommodate the demand, especially during peak hours [6]. Limited road capacity that cannot accommodate the traffic has caused traffic jams that lead to slower travel speeds, longer travel time, higher vehicle emissions, and increased traffic accidents [7].

The GDP growth shows that DKI Jakarta's economy had increased about 3.56% in 2021. This is the first increase after the Covid-19 pandemic. It indicates that DKI Jakarta's economy is growing in a positive direction. It is followed by the increase in vehicle ownership and population. According to data from BPS RI (2021), DKI Jakarta had 20.221.821 unit vehicles in 2020. The vehicle population is dominated by motorcycles (16.141.380 units) and private cars (3.365.467 units). DKI Jakarta's population reached 10.609.681 in 2021. Data on the trip by mode in Greater Jakarta Metropolitan Area (Jabodetabek) showed that trips by motorcycle increased by about 27,5% from 2002 to 2010, while trips by public transport decreased by about 28,4% [8]. The economic growth combined with rapid motorization and population growth leads to an increase in economic activities and people movements. An increase in economic activities and movement means more traffic in the transportation system, including road traffic. It could lead to more congestion on the road. Traffic congestion in Jakarta can be considered quite severe, with an average travel speed of only 15 km/hour [9]. On the other hand, the use of public transportation continues to decline by 28.4% [8], so it is necessary to improve mass transportation for dense urban areas [10].

Road traffic is one of the main air pollution contributors to combustion engine emissions. It could affect the urban air quality, the environment, and people's health. Pollution from vehicle emissions is the main cause of 3.3 million death in the world, more than malaria, influenza, and AIDS [11]. According to Raux [12], the transportation sector's contribution to the CO₂ global emission is about 25 – 30%, and almost two thirds of it comes from road transportation [13]. Several studies have been done on the impact of emissions from traffic congestion, and the result showed that emission from traffic congestion has led to an increase in air pollution that can affect health conditions [14]. Air pollution from the motorized vehicle is one of the highest death causes in the world. It contributes to about 50.000 death in UK [15]. Another study by Currie & Walker [16] showed that emission has a negative effect on health, increasing new-born death, increasing premature born, and reducing new-born weight. Heavy road traffic will increase traffic accident risk and fatality [17] [18]. In Beijing, the implementation of congestion pricing could potentially reduce CO and HC emissions by 60 – 70% and reduce NO_x emissions by 35 – 45% inside the congestion pricing zone. It is clear that traffic conditions will affect the environment, such as, air quality conditions. Cities in Germany has implemented clean air guidelines, which include the

prohibition of the vehicle that produce high emission [19].

Travel time value is one of the important factors in transportation planning [20], and it is also the most unpredictable factor [21]. Many countries have included the value of Time in the transportation planning analysis for several projects, such as high-speed trains, toll road development, light rail transit scheme, congestion pricing, and infrastructure improvement. A study by Yap et al. [22] showed that people are willing to pay more to reduce in-vehicle travel time and increase productivity. The value of time and reliability can be used for the cost-benefit analysis for transportation projects [23].

Traffic congestion can lead to high fuel consumption, an increase in vehicle operation cost, longer travel time, reduced air quality, and lower traffic safety. Most studies analyzed the effect of the implementation of congestion pricing and found that it can significantly reduce the emission in the charging zone. However, studies also showed that in some cases, emission increases outside the charging zone. This study analyses the traffic congestion cost in Jakarta. The main objective of this study is to calculate the amount of private vehicle operation cost based on estimated and actual conditions. The vehicle operation cost data is used to understand the amount of potential loss due to traffic congestion. The pollution cost (marginal health cost) is also calculated based on the estimated emission. Lastly, the value of time and total travel cost from actual and estimated conditions can be used as the basis to prepare a recommendation and model for implementing congestion pricing in Jakarta.

2. Literature Review

2.1. Sustainability Transport

Transportation is important to sustainable development since transportation infrastructure and activities significantly impact the general environment. Many countries in the world have introduced and implemented various strategies on traffic policy to reduce the effect of traffic congestion and emission from the transportation sector, including developing more transportation infrastructure. However, the strategy has some limitations that involve the extension of the urban road network [3]. A study by [24] showed that building more transportation networks will increase road capacity, and it will also increase emissions and reduce air quality since more traffic will be on the road. Therefore, traffic demand management and intelligent transportation system are viewed as one of the more effective, sustainable, and environment-friendly alternatives to increasing travel speed, safety, comfort, and reliability of urban transportation operations [25]. Urban planners have long realized the need to maintain the balance between mobility and infrastructure availability to support economic growth while managing and reducing its

impacts.

2.2. Travel Time and Travel Cost

Travel time is a variable that cannot be easily predicted and becomes an essential issue. Traffic congestion will cause delays and travel time to become more varied and unpredictable [26]. Travel cost and travel time have a strong correlation with each other. Unreliable Travel Time will lead to an increase in travel costs [27]. Variations in trip demand, congestion, and road capacity can lead to the fluctuation of travel time, causing the driver to reach the destination earlier or later than scheduled.

In many cases, the delay will cause loss for the trip makers due to longer travel time, increased travel cost, loss of time value, and to some extent, it will require re-scheduling of activities. The difference between the perceived travel time felt by the trip makers and the actual travel time is an aspect that has yet to be explored [28]. Trip makers usually use the range when they need to estimate their travel time due to the travel time variability and their perception of the travel experience. Therefore, they are usually willing to pay some amount of money to reduce travel time since it is related to their welfare and the value of time [29].

2.3. Vehicle Operation Cost

Vehicle operation cost is the total cost spent by road users using a certain mode from origin to destination. Vehicle operation cost consists of two components: fixed cost and variable cost. Fixed cost is a cost that will not change even with the change of volume of distance, and whole variable cost will change with the change of volume of trip distance. The cost will be varied based on the destination, type of vehicle, fuel, maintenance, and other required costs [30].

The analysis is done using the descriptive approach based on qualitative data collected for vehicle operation cost calculation. All data collected from the survey is converted into a unit of rupiah per km trip distance. The calculation is done using two methods. Table 1 shows the

comparison between the two methods used in this study. The first method is ITB LAPI method (1996). The formulation and cost component is based on the formula for Category 1. The second method is PCI 1988 method for the urban road (non-toll road). The calculation components for PCI 1988 method are as follows:

- Fuel Consumption Cost
- Lubricant Cost
- Tire Cost
- Spare Part Cost
- Maintenance Labour Cost
- Shrinkage Cost
- Capital Interest
- Insurance Cost

2.4. Pollution Cost

Motorized vehicle emission is the source of primary pollutants such as carbon monoxide (CO), hydrocarbon (HC), nitrogen oxide (NO_x), and particles (PM). Recently, it was reported that such pollutants concentration is high in urban corridors [31], [32]. It indicates that urban transport problems, especially vehicle emission, has become more serious. In this study, the calculation of pollution cost uses the marginal health cost method released by World Bank. This method bases the calculation on the type of vehicle, fuel, and the exchange rate to the USD.

2.5. Value of Time and the Travel Time Cost

The urban transportation system has become inefficient, leading to congestion, air pollution, noise, accident, and greenhouse gas emission. In Bangkok, the total externalities cost is about 7 – 10%, half of which comes from traffic congestion [31], [32]. The study by Albalate & Fageda showed that economic transformation has rapidly increased people's mobility by using cars [33]. Several countries have implemented congestion pricing to reduce traffic congestion. Reducing travel time is the prominent benefit people hope from implementing congestion pricing [34]. Therefore, it is essential to carefully analyze the effect of congestion pricing on travel Time savings.

Table 1. Vehicle Operation Cost Equation and Components

Components	LAPI ITB 1996	PCI 1988
Fuel Consumption	$Y = 0,0284S^2 - 3,0644S + 141,68$	$Y = 0,05693S^2 - 6,42593S + 269,18567$
Lubricant		$Y = 0,00037S^2 - 0,0407S + 2,20403$
Tire	$Y = 0,0008848 S - 0,0045333$	$Y = 0,0008848 S - 0,0045333$
Spare Part	$Y = 0,0000064 S + 0,0005567$	$Y = 0,0000064 S + 0,0005567$
Maintenance Personnel	$Y = 0,00362 S + 0,36267$	$Y = 0,00362 S + 0,36267$
Shrinkage	$Y = 1/(2,50 S + 125)$	$Y = 1/(2,50 S + 125)$
Capital Interest	$INT = AINT / AKM$	$Y = 150/(500 S)$
Insurance	$Y = 38 / (500 S)$	$Y = 38 / (500 S)$

Value of Time is defined as the willingness to pay in order to gain shorter travel time [35]. The value of Time is an important aspect that needs to be considered in the development of transportation policy. The study has shown that each individual perceives their travel Time differently from the actual travel Time [28]. It will lead to different estimations of travel time. The value of Time is an essential aspect of transportation analysis. For example, it gives a basis for route assignment in transportation modeling.

Assessment of a major highway project in UK found that the advantage of the development of the highway is travel Time savings of about 80%. Project assessment is an important decision-making aspect to compare the cost of the project and the benefit that the communities can feel; thus, it is important to have an accurate VOT for the assessment. Stated preference and revealed preference are two methods that are usually used to calculate the VOT by measuring individual perception toward time and cost scenarios [28].

VOT is calculated based on the comparison of the differences in travel cost and travel time savings from origin to destination among different modes of transport (Fowkes,1991). The income method is usually applied in developing countries as the practical step to define not only resource value but also behavioral value. In several studies, the perceived travel time by the respondents is higher by 1.5 times the actual travel Time [36], [37]. The differences between actual and perceived travel Time means that SP survey can produce a biased estimated VOT. Meanwhile,

estimated VOT based on RP survey is found to be more accurate than VOT based on SP survey [38], [39]. VOT, as the comparison between time and cost, is shown in Equation 1 as follows:

$$VOT_{iq} = \frac{\partial v_{iq} / \partial t_{iq}}{\partial v_{iq} / \partial C_{iq}} \tag{1}$$

Travel time cost (TTC) is defined as the monetary value per time unit that is willing to be spent by an individual, in this case, a private car user, to save a time unit from their decision to make a trip. TTC is obtained from the product of each type of vehicle VOT with the travel time of mode m from i to j (TT_{ij}^m). TTC can be formulated as follows:

$$TTC_{ij}^m = VOT (TT_{ij}^m) \tag{2}$$

Where:

TTC_{ij}^m = travel time cost of mode m from i to j

VOT = value of time

(TT_{ij}^m) = total travel time of mode m from i to j

The estimated cost is a cost that can influence the behavior in a short Time and can only be affected by several cost elements; thus, it can not represent the actual external cost. The actual externality cost appears when a production or consumption activity causes direct loss from the usage or increase of production cost that is not included in the calculation during the decision-making process. Private car users, as well as public transport users, will imagine the perceived cost before they enter the traffic zone. However, when they are inside the traffic zone, the actual cost may be higher than the perceived cost.

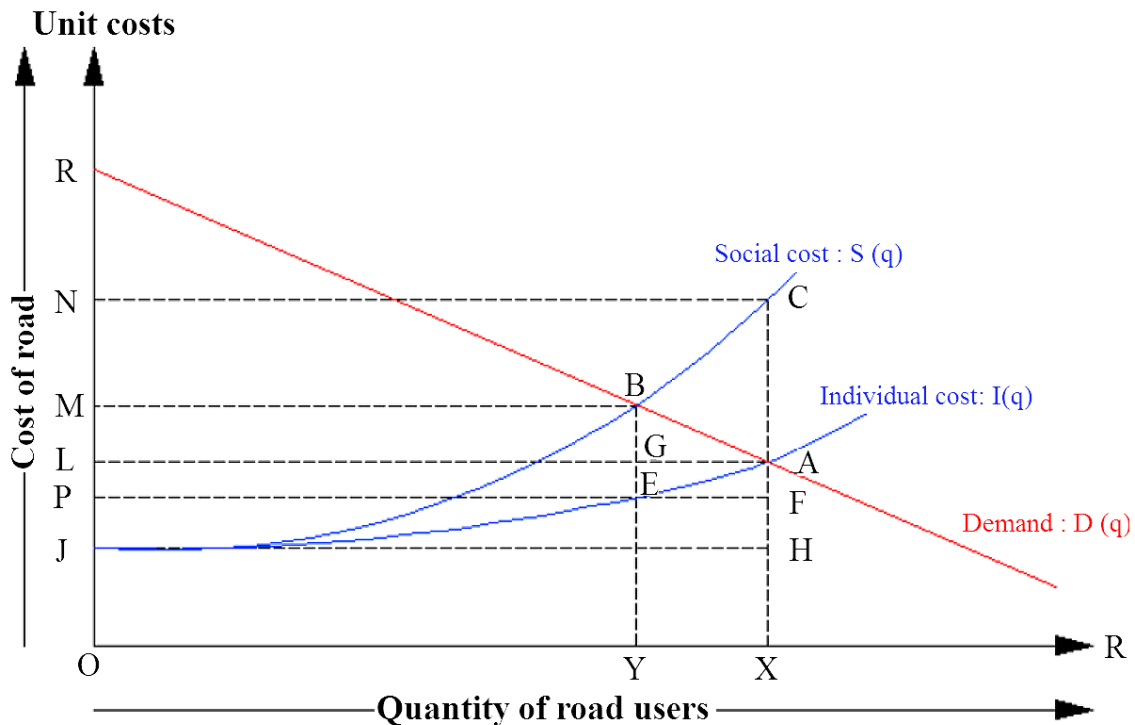


Figure 1. Relationship between Traffic Volume and Congestion Cost [38]

The study by January showed that congestion cost comes from the relationship between speed and flow on the road and the relationship between speed and vehicle operation cost [40]. Figure 1 shows the graph representing the relationship between cost and flow regarding road congestion. Vehicle travel costs will increase with the reduction of speed, and so does the travel Time. The difference between marginal social cost and marginal private cost is defined as the congestion cost caused by the addition of vehicles on the same road. The equilibrium is reached at point B with Y traffic flow and costs M. From the social point of view, the traffic flow of X unit is considered excessive since the driver can only enjoy the benefit of XA or L. Additional vehicle after the optimal point Y has to spend money on XYBC, but they can only enjoy the benefit of XYAB. Thus, there is a welfare gain equal to the area of BAC that was lost.

3. Materials and Methods

3.1. Study Location

This study is focused on two road segments in DKI Jakarta, Hayam Wuruk Street, and Gajah Mada Street. Figure 2 shows the study area of this study. Both segments lie between Jakarta Kota and Harmoni. The road segment's length is about 3,3 km in total. Those two road segments are two of the busiest roads in DKI Jakarta that connect activity centers in DKI Jakarta. It goes through the area dominated by commercial activity centers such as shopping malls, markets, small-medium shops, offices, and hotels. There is also a housing area near these road segments.

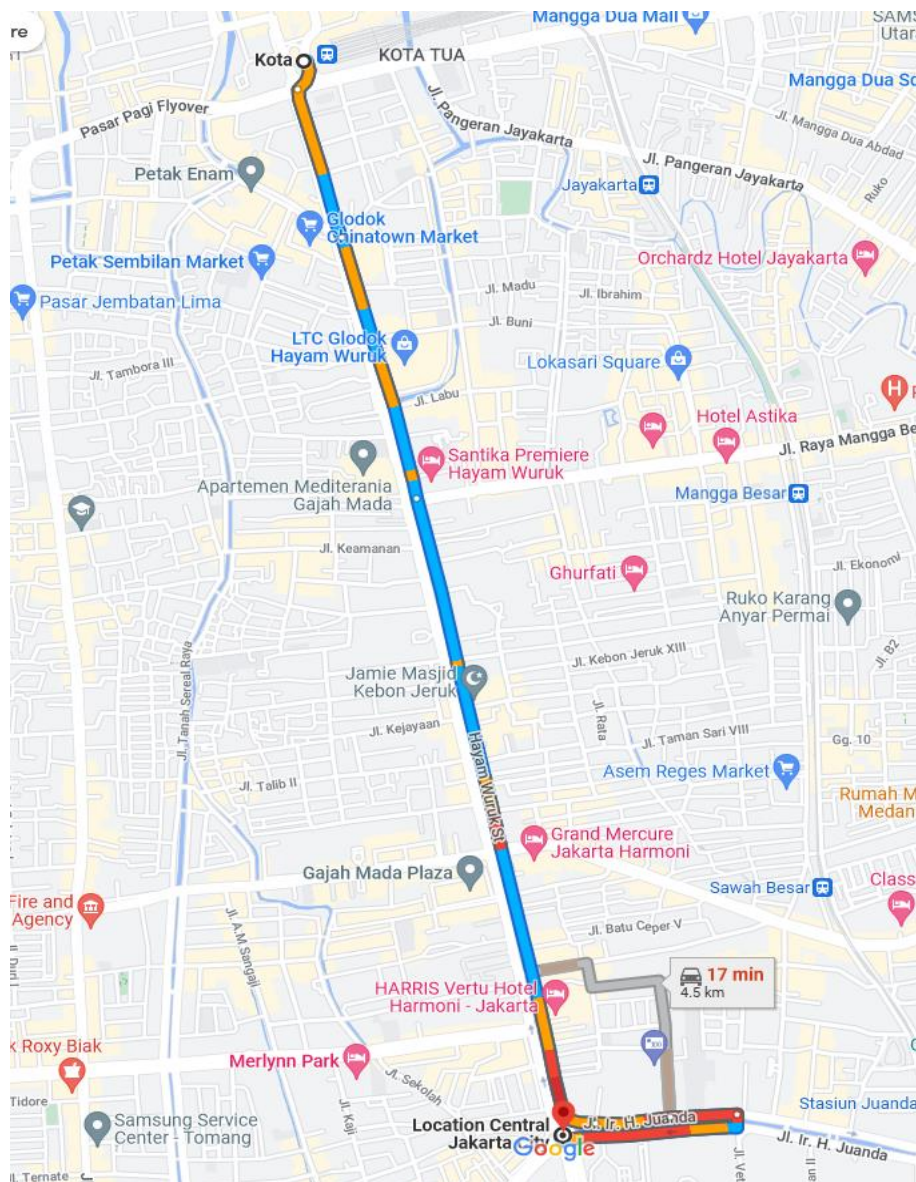


Figure 2. Study Area (Source: Google Maps; accessed on 10 Juli 2022)

3.2. Materials and Data

The Transportation Agency of DKI Jakarta Province provided data on daily traffic in the study area (Hayam Wuruk Street and Gadjah Mada Street). Daily traffic data from 1st May 2022 until 23rd June 2022 was used for the analysis. A traffic counting survey was conducted for one day to validate the data provided by the DKI Jakarta Transportation Agency. Additional data such as road dimension, road condition, speed, and average travel Time were also collected during the field survey. This information was used to calculate the total travel time of the vehicle that passes through this road segment. Data were collected and grouped every 15 minutes interval to show the correlation between time and traffic conditions.

3.3. Study Design

The objective of this study is to calculate the vehicle operation cost, emission cost, value of Time, and travel Time in different traffic conditions. Several approaches are used in this study to calculate and analyze the relationship between variable costs and traffic conditions. First, a field survey was conducted to collect the daily traffic data for every 15 minutes interval. The data was used to validate the data obtained from DKI Jakarta Transportation Agency. Furthermore, the data was also used to analyze the road segment traffic performance and understand the potential loss due to the traffic condition based on the vehicle operation cost. Then, the data was used to calculate the pollution cost (marginal health cost) produced by the vehicle. Last, the time and total travel cost value were calculated based on the actual field data and respondents' perceptions when they passed through the study area.

3.4. Actual and Estimated Condition

Estimated travel Time by private car is used to calculate perceived travel cost by private car. The actual travel Time by private car is collected using the moving car observer method. In this method, the observer car travels on the observed road segment following the traffic flow while one of the surveyors inside the car record the traveling Time from the starting point until the ending point. The data is needed to define the actual travel Time with congestion. It will be further used to calculate the vehicle operation cost, travel Time, and actual travel cost.

3.5. Data Analysis

After all the data were collected, the data was used to calculate several traffic and cost indicators. The data analysis process can be divided into several stages, as follows:

3.5.1. Traffic Data

Traffic data was classified based on the vehicle types: passenger car, heavy vehicle, and motorcycle. The data was grouped every 15 minutes. The trend was analyzed to find

the peak hour traffic and define the maximum peak hour traffic that passed through the road segments.

3.5.2. Traffic Performance Analysis

Traffic data was calibrated into the passenger car unit so that all the traffic volume data would be on the passenger car/hour (pce/hour) unit. Based on the guidelines from Indonesia Highway Capacity Manual (MKJI), the passenger car equivalent for each vehicle type is passenger car/light vehicle (1), motorcycle (0,25), and heavy vehicle (1,2) [41].

The traffic performance of urban roads was calculated based on the formula as follows:

$$C = C_0 \times FC_W \times FC_{SP} \times FC_{SF} \times FC_{CS} \quad (3)$$

Where

C = Road capacity (pce/hour)

C_0 = Base road capacity (pce/hour)

FC_{SP} = Directional factor

FC_{SF} = Side friction factor

FC_{CS} = City size factor.

3.5.3. Vehicle Operation Cost

An increase in vehicle operational cost can be influenced by factors, one of them being vehicle speed. Traffic congestion can lead to slower speed which affects the vehicle operating cost. Traffic speed data were obtained based on road observation. Travel Time data was also collected. The analysis obtained two travel time types: actual travel Time and perceived travel Time. On weekdays, the difference between actual and estimated travel Time tend to be higher, especially during peak hours. The travel Time is then converted into actual and perceived travel speed. The actual and estimated travel speed was used to calculate the vehicle operation cost using both LAPI ITB and PCI methods, as mentioned in Table 1.

3.5.4. Pollution Cost

Marginal health cost, released by World Bank, was used to calculate the pollution cost. This method calculated the pollution cost based on the type of vehicle, fuel type, and dollar exchange rates.

3.5.5. Travel Time Cost

The income method is commonly used in developing countries as a practical way to calculate the resource value and behavioral value. After the value of Time was obtained, the total travel time cost was calculated using the formula stated in Equation 2.0

3.5.6. Congestion Cost

The congestion cost of the passenger car was obtained by calculating the total vehicle operational cost, pollution cost, and travel time cost in actual and perceived conditions. The differences from the calculation were defined as the loss of congestion cost experienced by the vehicle when passing through the road segment using a passenger car.

4. Results and Discussion

4.1. Traffic Volume

Daily traffic data from DKI Jakarta Transportation Agency was analyzed to understand the road traffic performance and condition of Hayam Wuruk Street and Gajah Mada Street. Figure 3 shows the fluctuation of daily traffic on Hayam Wuruk Street and Gajah Mada Street between 5th May until 22nd June 2022. Gajah Mada Street peak traffic can reach 137.334 vehicles/day. Meanwhile, Hayam Wuruk Street has lower traffic compared to Gajah Mada Street, with peak traffic that reaches 72.851 vehicles/day.

From the traffic data, one can see the day-to-day and weekly fluctuation of traffic conditions in the study area.

The graph shows that the traffic tends to be lower during the weekend, especially on Sunday. It might come due to the car-free day in the area near the road segment so that people will avoid going to the area using the motorized vehicle on a Sunday morning.

Traffic counting data collected during the field survey is also analyzed to understand the daily traffic pattern of the study area. Figure 4 shows the hourly fluctuation of both road segments based on a one-day traffic counting survey. Like other cities, the traffic peaks between 07.00 – 08.00 am and 05.00 – 06.00 pm. It indicates high people activities during this period. The peak hours traffic volume has reached the road capacity, which indicates that the road segment is congested during peak hours. The congestion is also indicated by unstable traffic flow, low speed, and long vehicle queues.

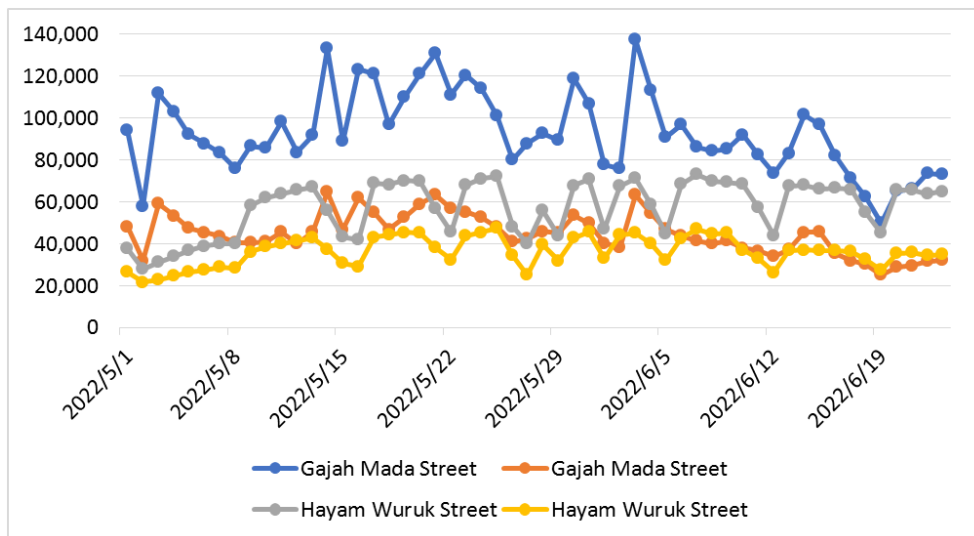


Figure 3. Average Daily Traffic (ADT) 5 May - 22 June 2022

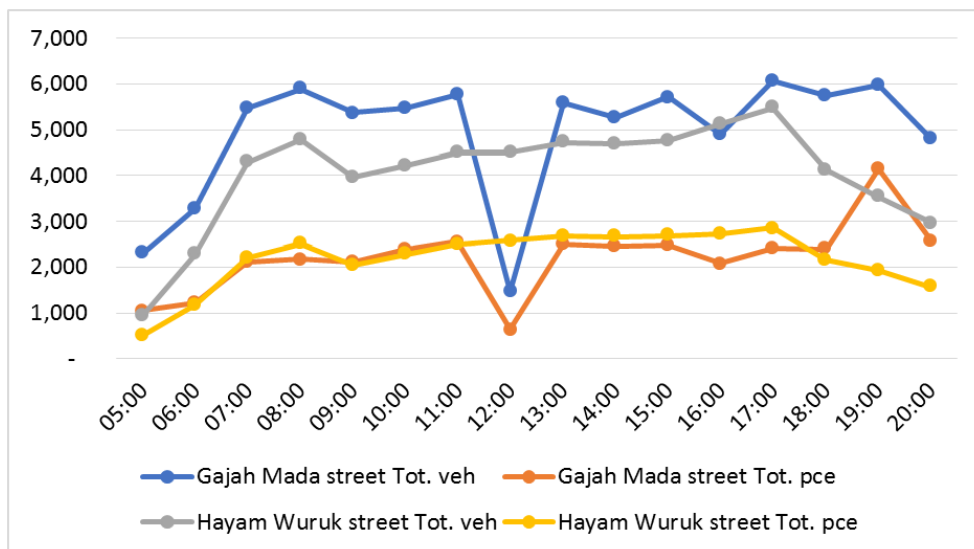


Figure 4. Average Daily Traffic (ADT) 13 June 2022

4.2. Vehicle Operation Cost

Vehicle operation cost was calculated based on two conditions: perceived travel cost and actual travel cost. Two methods were used for the calculation, namely: LAPI ITB Method and PCI 1988 Method for a non-toll road. For Gadjah Mada Street, the traveling Time of a passenger car in the perceived cost condition is 9 minutes with an average speed 22 km/hour. Meanwhile, the traveling Time in the actual cost condition for Gadjah Mada Street is 15 minutes with an average speed 13.2 km/hour. The travel Time in the perceived cost condition for Hayam Wuruk Street is 7 minutes (average speed 28.3 km/hour), and the actual condition travel Time is 13 minutes (average speed 15.2 km/hour). All road segments have an average speed of less than 25 km/hour. Speed can be used as a proxy for the value of time and travel costs [42].

The vehicle operation cost at Gadjah Mada Street in the actual cost condition is IDR 4.480/km and in the perceived cost condition is IDR 3.651/km. Meanwhile, the vehicle operation cost in the actual cost condition for Hayam Wuruk Street is IDR 4.266/km, and in the perceived cost condition, the vehicle operating cost is IDR 3.313/km. The travel Time in free flow conditions is about 5 minutes; thus, the average car speed is around 39.6 km/hour. The vehicle operation cost in free flow is about IDR 2.935/km. The above analysis shows that on-road congestion causes additional vehicle operation costs. It confirms the assumption that congestion causes higher vehicle operation costs.

4.3. Pollution Cost

The marginal health cost approach is used to calculate the pollution cost. Pollution cost for each vehicle is obtained from the product of marginal cost/vehicle (cent/liter) with the exchange rate between Rupiah and US Dollar and road length, by the distance that can be taken with 1 liter of gasoline in actual cost condition. Table 2 shows the result of the pollution cost calculation. The calculation is done using data from travel cost calculation using LAPI ITB and PCI 1988 approach. The marginal health cost is about IDR 1.200 – 1.884.

4.4. Value of Time and the Travel Time Cost

Data collection on the perceived cost for private

passenger cars was done for trip makers that passed the road segments using passenger cars. Respondents were randomly picked from the passenger car user that passed through the study area.

The calculation of the value of time was done based on the IHCM study by using the welfare level method. The value of time of each type of vehicle in 2022 was calculated by multiplying GDP growth rate factors of DKI Jakarta. Based on the calculation, the value of Time of passenger cars is IDR 84.117/hour. This value was obtained by multiplying the GDP and the occupancy and percentage of private car usage divided by the population and monthly working hours. Travel Time cost calculation is highly influenced by travel Time on each road segment, both in actual cost and perceived cost condition. Therefore, the travel time cost should be calculated for both conditions and the free flow condition.

Table 3 shows the calculation result for the total actual generalized cost, and Table 4 shows the perceived generalized cost conditions. Overall, the actual cost condition is higher than the perceived cost condition. It means that trip makers tend to underestimate the cost that they spend compared to the actual cost. It could also be because of various factors that influence the cost during the trip that can increase the overall cost. Table 5 shows the total congestion cost, which is the difference between actual and perceived generalized cost.

The calculation of vehicle operation cost using LAPI ITB and PCI Methods produced a different result. The vehicle operation cost calculated using the PCI method is higher than that calculated with the LAPI ITB method. The PCI method includes more components than the LAPI ITB, namely lubricant cost. The higher vehicle operation cost also affects the generalized and total congestion cost. As shown in Table 5, the total actual and perceived generalized cost of PCI 1998 method is higher than LAPI method. The total congestion cost also shows the same trend. However, while the generalized cost of Gajah Mada Street is higher than Hayam Wuruk Street, the total congestion cost of Hayam Wuruk Street is higher than that of Gadjah Mada Street. Higher traffic on Gadjah Mada Street caused slower speed and led to higher operating costs as well as pollution and travel Time cost. However, the differences between the perceived and actual speed of Hayam Wuruk Street is higher than Gajah Mada Street. It means that the trip makers experience more loss caused by congestion in Hayam Wuruk Street than in Gajah Mada Street.

Table 2. Pollution Cost

Type of Vehicle	Marginal Health		Occupancy	Fuel Consumption (km/1 liter)	Road Length (km)	Marginal Health Cost (IDR)
	Cost/Vehicle					
	(Cent/liter)	(IDR /liter)				
Passenger Car	23	3454.37	2.5	9.5	3.3	1,200
Gasoline (LAPI)						
Passenger Car	23	3454.37	2.5	6.05	3.3	1,884
Gasoline (PCI)						

Table 3. Total Cost on Actual Cost

		Actual			
Gajah Mada Street		Vehicle Operation Cost (IDR)	Pollution Cost (IDR)	Travel Time Cost (IDR)	Generalised Cost (IDR)
1	LAPI ITB	14,785	1,200	21,029	37,014
2	PCI 1998	16,176	1,884	21,029	39,089
Hayam Wuruk Street		Vehicle Operation Cost (IDR)	Pollution Cost (IDR)	Travel Time Cost (IDR)	Generalised Cost (IDR)
1	LAPI ITB	13,945	1,200	18,225	33,370
2	PCI 1998	15,200	1,884	18,225	35,309

Table 4. Total Cost on Perceived Cost

		Perceived			
Gajah Mada Street		Vehicle Operation Cost (IDR)	Pollution Cost (IDR)	Travel Time Cost (IDR)	Generalized Cost
1	LAPI ITB	12,048	1,200	12,618	25,866
2	PCI 1998	12,895	1,884	12,618	27,397
Hayam Wuruk Street		Vehicle Operation Cost (IDR)	Pollution Cost (IDR)	Travel Time Cost (IDR)	Generalized Cost
1	LAPI ITB	10,933	1,200	9,814	21,947
2	PCI 1998	11,462	1,884	9,814	23,160

Table 5. Total Congestion Cost (IDR)

		Actual	Perceived	Total
Gajah Mada Street		Generalized Cost	Generalized Cost	
1	LAPI ITB	37,014	25,866	11,148
2	PCI 1998	39,089	27,397	11,693
Hayam Wuruk Street		Generalized Cost	Generalized Cost	Total
1	LAPI ITB	33,370	21,947	11,423
2	PCI 1998	35,309	23,160	12,149

5. Conclusions

Traffic congestion happens in areas with high vehicle ownership and a dense population. Traffic congestion is one of the most significant contributors to air pollution worldwide. Traffic congestion has a strong correlation with vehicle emissions. In 2015, air pollution due to road traffic

caused significant health problems in the community in UK. It contributes to the emission of pollutants of about 34% of nitrogen oxide (NO_x), 14% of PM₁₀ and 13% of PM_{2.5} [43]. Therefore, implementing congestion pricing needs to be considered to reduce traffic congestion and vehicle emission. Big cities such as Singapore, London, Stockholm, and Beijing used the congestion pricing approach to solve

the urban congestion problem [4], [5], [7], [17], [44], [45]. In 2014, the average speed in the Beijing urban road network at morning and evening peak hours was about 28 km/hour and 25 km/hour, respectively [5]. This is much lower than free flow speed, which means that the city is in serious traffic congestion problem. One of the solutions is to increase the level of service of public transport so that people are more willing to move from private car to public transport and reduce the usage of private vehicles [46].

This study calculated the cost caused by traffic congestion in Jakarta, Indonesia, by analyzing the potential cost from vehicle operation, pollution, travel Time value, and total travel cost. This study aims to understand the potential loss caused by the vehicle operation cost, pollution cost from vehicle emission, and the value of Time as well as the total travel cost. The result can be served as the basis for developing the implementation model of congestion cost in Jakarta.

The result shows that the travel Time differences between actual and perceived conditions lead to differences in the vehicle operational cost. The differences between actual and perceived cost are calculated as the congestion cost. The congestion cost for Gajah Mada Street calculated using PCI method is IDR 11.693/vehicle, while LAPI ITB method result is IDR 11.148/vehicle. For Hayam Wuruk Street, the congestion cost is IDR 12.149/vehicle using PCI and IDR 11.423/vehicle using LAPI ITB Method. The result is similar to other studies that found that the congestion cost per vehicle is about IDR 1.530/km per vehicle [47]. The result also shows that Hayam Wuruk Street has a higher congestion cost than Gajah Mada Street. The higher the Time differences, the higher the differences in the vehicle operational cost. The study also finds that the value of Time of the people is quite high. Therefore, congestion will cause people to lose their value of Time. This study can be the basis for estimating the cost caused by congestion and to analyse the calculation of congestion pricing. Future research needs to evaluate the impact of implementing a congestion pricing policy, from traffic and emission aspects, in reducing traffic congestion in Jakarta.

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