Impact of Traffic Volume on Vehicle Operation Cost after Covid-19 Pandemic in DKI Jakarta

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Abstract: In Jakarta, the Covid-19 pandemic has reduced vehicle traffic due to the implementation of work from home (WFH) and activity restriction policy (PPKM). This study aims to analyze the road traffic performance during PPKM and after the relaxation of this policy on Jenderal Sudirman Street in Jakarta. Calculation of vehicle operation cost is done using The LAPI ITB 1996 method. The analysis results indicate change of level of services (LoS). LoS decreases from C level during PPKM to F level after the relaxation. The results also indicate that there are increase in the potential loss due congestion from IDR 199,752,264.00/day during PPKM to IDR 1,633,734,268.00/day, after the relaxation of PPKM policy. Based on this value, the potential loss of costs due to congestion is very large under new normal conditions and after the covid pandemic.

Keywords: Congestion; Covid-19 Pandemic; Performance; Travel Time; Vehicle Operation Cost

1. Introduction

In the last few decades, there have been a rapid increase in the number of vehicles in developing countries, one of which is Indonesia. The increase of vehicles is influenced by several factors, such as people's ability to buy vehicles increased especially for they who have middle incomes, the opportunity to buy vehicles on credit is higher, relative price reduction, a large number of second-hand vehicles, and the population in big cities increased due to the influence of urbanization and urban population growth. These factors influenced individual mobility over time.

BPS RI (2023) reported that DKI Jakarta had 21,856,081 vehicles in 2022 and it is dominated by motorcycle (17,304,447) and private cars (3,766,059). In 2022, DKI Jakarta had 21.85 million unit of vehicles with proportion of motorcycles is 79.1%, private car is 17.2%, truck is 3.4%, and bus is 0.1%[1]. Meanwhile the population of DKI Jakarta reached 10,748,230. Increased activity of people encouraged of economic ratel in DKI Jakarta. In addition, a significant decrease in the spread of Covid-19 cases towards the end of 2022. The economic growth can be seen from the increase of Gross Regional Domestic Product (GRDP). In 2023, DKI Jakarta GRDP growth was 4.96%, which is slightly lower than GRDP growth in 2022 that reach 5.25%. The first increase since the Covid-19 pandemic took place. In 2019, DKI Jakarta GRDP was IDR 2,815,636.16. It decreased to IDR 2,768,289.73 in 2020, indicating decrease in economy activities during the pandemic. The GRDP then increased again to IDR 2,912,563.13, after relaxation of mobility restriction that lead to increase in economy activities. Study by Hera et al (2021) indicates the increase in speed and traffic performance in Surabaya during the pandemic[2] This shows that there is an economic activity on a positive side. Although, the increase has not been like before pandemic. Meanwhile, number of trips made by motorcycle in Jabodetabek increased by 27.5% from 2002 to 2010. In the other hand, trip made by public transportation decreased by 28.4%[3] due to poor public transportation service levels[4]. Thus, improvement of public transportation services are needed[5]. Comparing the driving speeds with cities around the world such as Tokyo, show that congestion conditions in Jakarta are quite severe, indicated by an average vehicle speed of 15 km/hour which is lower than other cities in the world[6]. Meanwhile, the vehicle speed on Jenderal Sudirman Street, one of the main street in Jakarta, ranges between 7.52 km/h to 19.48 km/h[7,8].

The Covid-19 pandemic, which began on March 2, 2020 in Indonesia, has made Indonesia one of the countries affected by the pandemic in the world[9]. The addition of cases and the increase in the number of deaths duel to the Covid-19 pandemic made the government decide policies related to the implementation of work from home (WFH) and restrictions on the movement of community activities (PPKM) throughout Indonesia to reduce the spread of the virus and the implementation of health protocols. The impact of the policy is a decrease in traffic volume due to restrictions on community movement and mobility.

Based on data from Tomtom index traffic, Jakarta was rankled the 31st most congested city in the world in 2020. Then in 2021, Jakarta ranked 46th out of 404 congested citie in the world with a congestion percentage of 34% and it was ranked the 29th most congested city in the world in 2022. In recent years many large cities have experienced congestion, these large cities have become magnets for business development and employment opportunities [10]. Economic growth and rapid urbanization are some factors that has caused high travel demand and traffic congestion in the City [11] [12] [13]. Traffic congestion in metropolitan areas is a result of greater economic activity, higher productivity of people movement, and adequate facilities. The increase in the number of private vehicles creates a surge in traffic on the highway and leads to congestion, which is a problem faced by many cities around the world [14,15]. In addition, urban congestion is caused by current infrastructure that is unable to absorb demand, especially during peak hours[16]. Traffic congestion is caused by insufficient road capacity and causes slower travel which leads to fuel wastage, increase in vehicle emissions, increase in travel time and increased accidents[17]. The covid-19 pandemic has reduced people's mobility so that it can reduce the level of traffic congestion that occurs.

The most obvious consequences of congestion are increased travel time, fuel consumption, vehicle operation cost, air pollution, and the number of accidents. Most studies have examined the impact of congestion pricing, which has a significant effect on emission reductions during congestion pricing implementation. Congestion pricing scheme is expected to significantly affect commuter's behavior and model choice. In a long term it will affect the housing and working location as well as the individual welfare duel to the congestion cost[18]. Previous studies have shown that the implementation of congestion pricing was able to reduce the usage of private cars, shifting of departure time, and shifting to public transport mode[19]. Another study showed that implementation of congestion pricing in Netherlands has caused reduction of private cars usage by 11%[20]. Implementation of congestion pricing in Italy has reduced the private cars usage by 25%[21].

This paper examines the performance of road network services and the calculation of vehicle operation cost during the Covid-19 pandemic and post-pandemic Sudirman street in Jakarta Indonesia. Analysis of road network traffic performance during the pandemic and post-pandemic can be used as a basis for policy and input for implementation of congestion pricing. Potential travel cost difference between pandemic and post pandemic condition represent the potential loss due traffic condition. It can be used as the basis for the government to formulate policy to tackle congestion problem in Indonesia major cities.

2. Literature Review

2.1 Congestion Impact

Vehicle exhaust emissions from traffic activities is the main source of air pollution which is the leading cause of death for 3.3 million people each year[18]. About 25-30% of CO2 emissions comes from transport activities[19], and land transportation activities contributes to nearly two-thirds of total transportation-related emissions[20]. Several studies have focused on assessing the emission impact of traffic congestion, especially in large cities, causing increased air pollution that can bel detrimental to health[21]. Air pollution from motor vehicles is one of the highest causes of death in the world and reaches 50 thousand deaths in the UK[22]. While Currie et al[23] shows emissions have a detrimental effect on health, increasing infant mortality, encouraging premature birth and reducing birth weight. The study from Green et al., and Li et al., showed traffic jam can also increase of traffic accidents and fatalities[24),25)].

Traffic congestion causes an increase in vehicle operation cost[13], shows that this is because of higher fuel consumption as a result of erratic traffic pattern, which both use more fuel than traveling at a steady speed; as a result the detected Vehicle Operation Cost (VOC) component include: tire wear, vehicle depreciation, maintenance and repairs, gasoline and oil consumption. While examined the variables and magnitude of vehicle operation cost based on consumer survey data and the results of the VOC components include fuel consumption, tire wear, and mileage-based depreciation, where the magnitude of the cost is the highest cost of expenditure due to use in urban peak conditions to reflect stop-and-go driving conditions[26]. Congestion cost equation that has been tested under real-world conditions, which estimates the effect of congestion on fuel costs and time and correlates it with V/C ratio and vehicle speed variation[27].

2.2 Travel Time and Cost

Travel time is an unpredictable travel variable and an important issue in general. Travel time is the time required from the point of origin of the trip to the destination[8,28]. Traffic congetion not only cause deays but make travel times highly variable and unpredictable[29]. Travel costs incurred are proportional to travel time in economic terms, therefore travel time and travel costs have a close relationship. Unreliable travel times lead to considerable travel costs[30]. This shows that travel time on highways is not stable over time. Road demand, congestion, and road capacity cause travel times to vary, this leads drivers to arrival at their destinations earlier or later than expected. In most cases, time delays can bel detrimental to drivers including longer travel times, increased travel costs, loss of time value and can reschedule activities. In addition to reality vs perception, the individual's perceived travel distribution aspect is an understudied aspect of travel time[31].

2.3 Vehicle Operation Cost

Vehicle operation costs are divided into two categories: fixed and non-fixed costs. fixed costs are costs that remain constant or influenced by the travel-distance. (remain despite changes in the volume of service production to a certain level), while variable costs are costs that change when there is a change in the volume of service production. The costs incurred vary depending on the destination, type of vehicle, fuel, maintenance and other costs incurred[32]. The analysis will bel carried out with a descriptive approach, based on quantitative data as a result of calculating the amount of vehicle operation cost. All cost data collected from the survey activities will be converted into rupiah per kilometer trip distance. The calculation of passenger car operation cost uses the LAPI method of the Bandung Institute of Technology. Cost components and equations for calculating vehicle operation cost for Group I. The calculation of vehicle operation cost components using this method includes :

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

The equation for calculating vehicle operation cost is described in Table 1.

2.4 Travel Time Cost

Value of time (VOT) is an important aspect to measure the cost and benefit of road projects or traffic management. The method that is commonly used to calculate VOT are based on stated preference and revealed preference to measure individual's perception of time and cost scenarios[31]. The value of time is derived by comparing the differences in travel expenditure to the time savings between various modes.

Previous research has analyzed differences between actual and perceived travel time[33,34], the result indicated that travel time are often perceived to be longer than reality. The differences between actual travel time and perceived travel time[35] showed that SP surveys can produce biased estimate of VOT. Study by Brownstone et al., and Small et al., showed that Revealed Preference based VOT estimates are usually higher than SP-based one, it can be attributed to perceived travel time overestimation[35,36].

Travel time cost (TTC) is the value of money per unit of time that a person is willing to spend, in order to save or obtain a unit of time from the result of his decision to travel. Congestion costs arise from the relationship between speed and flow, in which the vehicle speed affect the vehicle operation costs[37]. If a certain traffic flow level is exceeded, the average traffic speed will drop. As speeds began to fall, vehicle operation cost will increase in the range of 0 - 45 mile/hour and travel time will increase. The difference between the marginal social cost and the marginal individual cost is the congestion cost caused by additional vehicles on the same road section. Equilibrium is reached at point B with a traffic flow of Y and a cost of M. From a social point of view, the traffic flow of X is excessively because vehicle drivers only enjoy the benefits of XA or L. Additional vehicles after the optimal point Y must incur a cost of XYBC but only enjoy the benefits of XYAB, so there is a lost welfare gain of BAC area as shown in Fig. 1.

2.5 Research Gap

Previous study has analysis the impact of congestion in major cities. However, previous studies mostly focused on the impact of congestion on vehicle emissions. Whereas this study explains the impact of congestion on road service performance and potential loss that may be occurred from it. The potential loss was calculated based on the operational costs of the vehicle on different traffic condition.

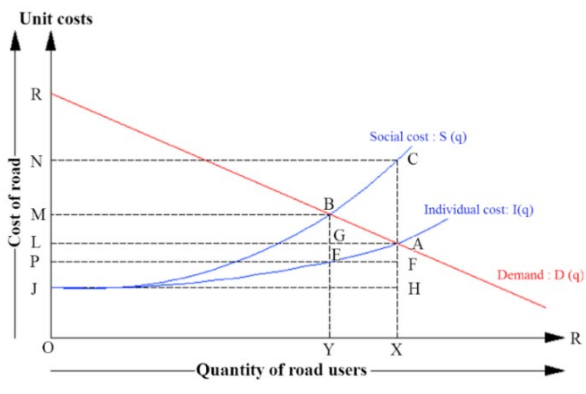

Fig. 1 Congestion Charge[35]

Table 1. Vehicle Operation Cost Equation Model

Components	LAPI ITB 1996
Fuel Consumtion Cost	Y = 0,0284S2 - 3,0644S + 141,68
Lubricant Cost	
Tire Cost	Y = 0,0008848 S - 0,0045333
Spare Part Cost	Y = 0,0000064 S + 0,0005567
Maintenance Labour Cost	Y = 0,00362 S + 0,36267
Shrinkage Cost	Y = 1/(2,50 S + 125)
Capital Interest Cost	INT = AINT / AKM
Insurance Cost	Y = 38 / (500 S)

3. Material and Methods

3.1 Location and Time of Research

The location of this research is along Jenderal Sudirman Street, Jakarta Province with a length of 4 km starting from HI Roundabout to the Youth Statue in Senayan. The location is shown in Fig. 2.

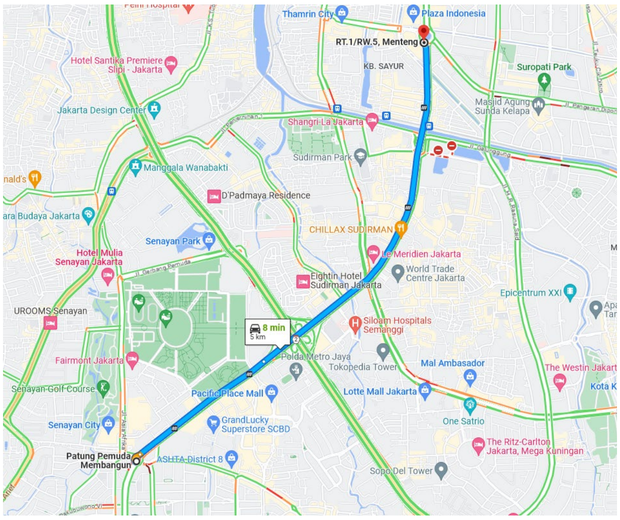

Fig. 2 Study Area (Source: Google Maps; accessed on May, 11th 2023)

3.2 Data Collection Methods

Jakarta Province Transport Authority provided daily traffic information along the studied road sections. For analysis purposes, the daily traffic data from February 1, 2020 to March 1, 2023 were used for the studied road sections. In addition to the daily traffic volume, a field survey was conducted for vehicle traffic volume counts to It was used to check the accuracy of the data obtained and obtain peak hours and vehicle types. In addition to the daily traffic volume, the length of the road section and the condition of the road section were identified to provide a representative picture of the traffic conditions. Traffic volume data for each road section obtained included speed and average travel time. This information was used to calculate the total travel time of vehicles passing through the road section, the data was aggregated into intervals of every 15 minutes to show changes in traffic patterns and time functions.

First, the data was analyzed to determine the performance of the road network during and after the Covid-19 pandemic. Second, the potential loss of travel costs during and after the Covid-19 pandemic were calculate. Third, the total travel costs incurred when driving through the road sections was analyzed. This component is calculated based on pandemic and post-pandemic Covid-19 conditions.

3.3 Data Analysis

Based on the data collected, the data analysis carried out is generally divided into several parts :

3.3.1 Processing of Traffic Volume Data

Traffic flow data from the road survey results (06:00 WIB-22:00 WIB) were classified into private cars, heavy vehicles, buses and motorcycles.

3.3.2 Determination of Peak Hours

The traffic volume data was then recapitulated for 16 hours to determine the maximum traffic volume that occurred at one period, indicating the maximum peak flow that passes through the road section.

3.3.3 Traffic Performance Analysis

Hourly traffic data was processed by calibrating the volume of each vehicle type (veh/h) to passenger car units (pcu) based on the 1997 Indonesia Road Capacity Manual (MKJI). Thus, the traffic volume is then obtained as passenger car unit (pcf). The capacity of the road were calculated with the formula :

$$C = C_0 \times FC_W \times FC_{SP} \times FC_{SF} \times FC_{CS} \quad (1)$$

Where C is the capacity (pcu/h), C0 is the basic capacity (pcu/h), FC_w is the traffic lane adjustment factor, FC_{SP} is the direction separation adjustment factor, FC_{SF} is the roadside obstacles adjustment factor, and FC_{CS} is the city size adjustment factor.

Free flow speed is the speed (km/hour) when the speed of the vehicles is chosen according to the driver's desire to travel comfortably in the existing geometry, environment and traffic conditions and without interference from the presence of other motorized vehicles[38]. Equation 2 is used to calculate the free flow speed :

$$V_B = (V_{BD} + V_{BL}) \times FV_{BHS} \times FV_{UK} \quad (2)$$

Wheler V_B is free flow speed for passenger cars under field conditions (km/hour), V_{BD} is free basic free flow speed for passenger cars measured under ideal traffic, geometry and environmental conditions, V_{BL} is speed correction value due to lane width or road lanes (km/hour), FV_{BHS} is free speed correction factor due to side obstacles, and FV_{UK} is free speed correction factor for some city sizes.

3.3.4 Road Section Performance Parameter.

The degree of saturation is the flow-to-capacity ratio used in measuring road's and peak-hour performance [38,39]. The following equation is used to calculate the degree of saturation :

$$D_J = \frac{Q}{C} \quad (3)$$

Where D_J is degree of saturation, Q is traffic flow (pcu / hour) and C = capacity (pcu/ hour).

3.3.5 Vehicle Operation Cost.

According to the survey data, decrease in speed is the most evident indicators on the road congestion problem. The vehicle travel time in congested condition were also calculated. Slowness is defined as the amount of time lost because of the reduction in speed compared to the normal limit as a result of traffic interruption. From the results of the analysis of travel time and speed above, there are two differences in travel time, namely travel time in actual conditions during the pandemic, post-pandemic and travel time in free flow conditions. The speed will be an input to calculate the difference in VOC with the LAPI ITB method according to Table 1.

3.3.6 Potential Congestion Charge Losses.

The congestion cost of private car vehicles is obtained by calculating the total vehicle operation cost and travel time cost under pandemic and post-pandemic Covid-19 conditions. The difference in costs resulting from these calculations is the total cost of congestion lost while passing through the road section for each private vehicle.

4. Results and Discussion

4.1 Traffic Volume

Vehicle speed data and traffic count data are obtained from field surveys. Traffic count data is taken at the beginning of the road section manually by grouping vehicles by vehicle type and counting all vehicles passing through the road section in certain period of time. Vehicle speed data is taken using the moving car observer method. Daily traffic information was calculated every 15 minutes period and then analyzed to determine road performance of the road section. Figure 3 shows the daily traffic fluctuations on the Jenderal Sudirman Street, starting from February 7, 2020 to February 7, 2023. During the pandemic, the daily traffic was only 11,731 vehicle per day. After the Covid-19 pandemic, the daily traffic reached 204,707 vehicles per day.

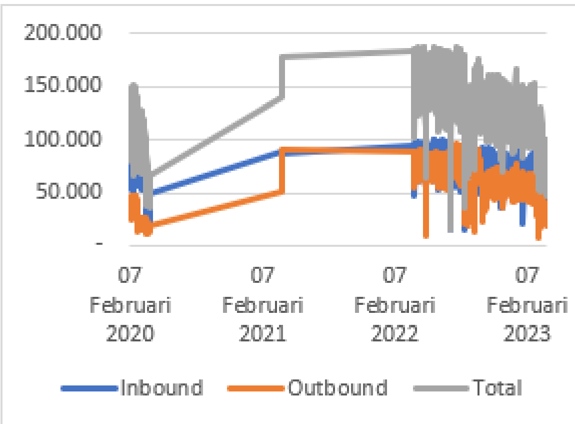

Fig. 3 The Daily Traffic Fluctuation from February 7, 2020 to February 07, 2023.

The traffic volume trend illustrates the fluctuation of traffic in the observation area. In the graph above, the peak hour trend of the road section can be seen. Based on the results of the traffic counting survey, the same trend of daily traffic happens with major cities in the world. The traffic volume reaches the peak hour between 07.00-08.00, this shows the high activity of the population at that hour. The ratio of volume to road capacity shows that congestion has occurred, especially for the period after PPKM relaxation. It was characterized by traffic volume approaching or at the capacity. Meanwhile, during pandemic and PPKM period, the traffic is relatively low and did not reach the capacity, indicating not congested condition.

4.2 Road Performance

Road capacity is obtained with a capacity adjustment factor so that the capacity adjustment factor for both directions on Jenderal Sudirman Street is 3,991.68 pce/hour. The basic capacity (C_0) is 1650 with adjustment factors such as traffic lane adjustment factor (FC_W) is 0.96, the direction separation adjustment factor (FC_{SP}) is 1, the side obstacles adjustment factor (FC_{SF}) is 0.84, and the city size adjustment factor (FC_{CS}) is 1.

The degree of saturation value will determine the level of service on a road. The following is the level of service on Jenderal Sudirman Street. Road service levels in 2020, 2022, and 2023 are summarized in Table 2. The calculation results indicate that at the beginning of the pandemic, the degree of saturation is 0.467 which equal to level of service (LoS) C. Meanwhile, post Covid-19 pandemic and after PPKM relaxation the degree of saturation is 1.212 with LoS F.

The results of vehicle speed survey on this road section are summarized in Table 3. The data shows that the average speed was decrease as the government relaxed the activity restriction. After the relaxation of activity restriction, the economic and people activities increase which result in more traffic on road. As the traffic increase, the speed decrease indicating that the traffic has reached the capacity. The free flow speed that was obtained using eq 2 is 44.55 km/hour with V_{BD} is 57, V_{BL} is (-2), FV_{BHS} is 0.81 and FV_{UK} is 1.

During pandemic period, the average speed was 42 km/hour, slightly decrease from the free flow condition. It indicates a low traffic condition thus the average speed only slightly decrease from the free flow condition. It is in line with the degree of saturation that indicates that the volume less than the half of the road capacity. Meanwhile, during post pandemic period, the volume increased and exceeded the capacity, which is indicated by degree of saturation higher than 1. It caused decrease in the average speed, which is significantly lower than the free flow speed.

Table 2. Road Level of Service.

Time	Volume (pce/hour)	Capacity	Degree of Saturation	Service Level
March 2020	1.864,08	3.991,68	0,467	C
March 2022	4.756,45	3.991,68	1,192	F
March 2023	4.842,56	3.991,68	1,212	F

Table 3. Vehicle Speed.

Time	Road Length (km)	Speed (km/h)
March 2020	4,00	42,22
March 2022	4,00	19,48
March 2023	4,00	7,52

4.3 Vehicle Operation Cost

The LoS of Jenderal Sudirman Street, which is C at the beginning of the pandemic and F during the post-Covid-19 pandemic period, indicate that the road has unstable flow, low speed and long queues. So, it is necessary to analyze vehicle operation cost (VOC) to understand the cost that occurred when a vehicle drive on certain speed. LAPI ITB 1997 method was used to obtain the costs that is incurred during vehicle operation. The calculation of VOC is carried out based MPV type because it is the most frequent vehicle that passes through the road based on the observations. Table 4 describes the components of the calculation of vehicle operation cost used for analysis.

The VOC calculation was done based on the vehicle speeds data shown in Table 2 and the equations in Table 1. The vehicle operation costs are summarized in table 5.

The results show that during the Covid-19 pandemic, the vehicle speed was 42.22 km/hour so that the VOC was at IDR 12,470/vehicle. Meanwhile during Covid-19 pandemic period the vehicle spelled reduce to 7.52 km/hour as the traffic volume increase. It causes an increase of VOC to IDR 27,460/vehicle. This shows a decrease in vehicle speed, which was resulted from higher traffic and poor road traffic performance, increases vehicle operation cost.

Table 4. Components of Vehicle Operation Cost Calculation.

Components	Rate
New Car (MPV type)	IDR 255,100,000/Vehicle
Fuel (Pertalite)	IDR 7,650-10,000 /Liter
Lubricant	IDR 120,000 /Liter
Mechanic Fee	IDR 24,246 /hour
Car Tires	IDR 590,000 /tire

Table 5. Vehicle Operation Cost.

Time	Road Length (km)	Speed (km/hour)	VOC (IDR/km/vehicle)	VOC (IDR/vehicle)
March 2020	4,00	42,22	3.117,51	12.470,00
March 2022	4,00	19,48	4.218,10	16.872,00
March 2023	4,00	7,52	6.864.96	27.460,00

4.4 Pollution Cost

Measurements on various major roads concluded that congestion resulted in steadily increasing pollution costs. This indicates that transport is a major contributor to pollution in urban areas. Sharp and Jennings (1989) argued that emission production is related to vehicle speed. Emission levels are highest at low speeds during congestion. The calculation of pollution costs in this case used the Marginal Health Cost approach. This method is issued by the World Bank which depends on the type of vehicle, fuel, and the exchange rate of the dollar against the rupiah.

The analysis of pollution cost per vehicle on Jalan Jenderal Sudirman is obtained by product of marginal cost/vehicle (cent/liter) with exchange rate of the dollar against the rupiah and road length, divided by 1 liter of gasoline that can cover the distance at actual cost. The results show that the pollution cost incurred on the road is IDR 1,549 – IDR 2,433 for each vehicle. The cost will be greater if the road is longer than the analysis used in this study. The summarized results of pollution cost can be seen in Table 6.

Table 6. Pollution Cost.

Type of Vehicle	Marginal Health Cost/Vehicle		Occupancy	Fuel Consumption	Long Road	Marginal Health Cost
	(Cent/litre)	(Rp/litre)		(Km/1 litre)	(Km)	(Rp)
Passanger Car Gasoline (LAPI)	23	3,680	2.5	9.5	4	1,549
Passanger Car Gasoline (PCI)	23	3,680	2.5	6.05	4	2,433

4.5 Travel Cost during The Pandemic and Post Covid-19 Pandemic

Congestion costs during the pandemic and post-Covid-19 pandemic were obtained by performing calculations from the analysis of vehicle operation cost and speed. This study only used VOC in the calculation of congestion costs without considering the value of time and travel time costs. A summary of the total vehicle operation cost during the pandemic and post-pandemic can be seen in Table 7.

Based on the VOC calculated in the previous section and road section data as well as the traffic data, the total congestion cost of the road segment was calculated for both pandemic and post-pandemic condition. From the analysis, it was found that the operational cost of vehicles during the Covid-19 pandemic on Jenderal Sudirman was IDR 199,752,264.00/day. While the vehicle operation cost during the post-Covid-19 pandemic period increases to IDR. 1,633,734,268.00/day. It due to more traffic on road that results in lower speed and higher operational cost.

Table 7. Total Vehicle Operation Cost during and after Covid-19 Pandemic.

Time	Speed (km/h)	VOC (IDR/km/vehicle)	VOC (IDR/vehicle)	VOC (IDR/day)
March 2020	42.22	3,117.51	12,470.00	199,752,264.00
March 2022	19.48	4,218.10	16,872.00	683,283,264.00
March 2023	7.52	6,326.69	25,307.00	1.633,734,268.00

5. Conclusions

The results of the road performance analysis show that the degree of saturation on Jenderal Sudirman Street has increased while the speed decreased as the government relaxed the activity restriction in post pandemic period. The value of D_J at the beginning of the pandemic was 0.467 with a level of service C where the flow was stable, and the speed of vehicle was high. Meanwhile, during the post-Covid-19 pandemic period the degree of saturation was 1.212 with level of service F In that condition, the flow was forced, speed was low, volume exceeded capacity, and long queues (traffic jams). The low degree of saturation during pandemic occurs due to restrictions on the movement of community activities (PPKM) so that traffic movements are reduced. As an efort to reuce the spread of Covid 19, a work from home (WFH) policy was implemented as well as restrictions on the operating schedules of malls, shops, offices and other business centers. This condition directly causes restrictions on the movement of people, which causes the volume of vehicles to decrease. In the post-pandemic period, the government lifted up the activity restriction policy which caused increase in people activity and more traffic on road.

The results of the VOC analysis show a very large increase in the total operational cost of vehicles post pandemic compared to at beginning of pandemic when the activity restriction policy was implemented. The VOC at the beginning of pandemic was IDR. 199,752,264.00/day, while the VOC during the post-Covid-19 pandemic period amounted to IDR. 1,633,734,268.00/day. The results of the analysis show that the VOC at the beginning of the pandemic was IDR 12,470/vehicle and after the pandemic it was IDR 27,460/vehicle with a cost difference of around IDR 14,990 / vehicle which can be used as a basis for determining congestion charge rates for private car types. The differences indicate the potential loss that happen due to increase in traffic flow and congestion. The amount of potential loss of private vehicle operation cost can be used as a basis for policy and input in order to develop policy for implementation of congestion pricing.

The amount of potential cost loss is not only come from the increase in the vehicle operational cost. There are other factors that may causes the cost of loss to be even greater. Future research may look into congestion cost from the value of a person's time lost due to congestion, vehicle emissions generated, and other related aspects to create sustainable transportation. Future studies can look into the effect of congestion on the operation cost of other type of vehicle. The result can be the basis for the regulation on congestion pricing for other type of vehicle.

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