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COMPARISON OF AIR POLLUTION COST ON THE DIFFERENT ROAD CORRIDORS

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ABSTRACT: The concentration of activities in the certain areas triggers traffic movements. Different land use generates different amount of traffic, causing different level of traffic delay and air pollutant. Currently, an appropriate policy has not formulated to overcome the concentration of activities related to different road corridors. Therefore, traffic demand management (TDM) should be arranged in order to decrease air pollution regarding to different road corridors. For this reason, this study estimates traffic performance and social costs due to air pollutant emission for different land uses in the city of Malang, East Java, Indonesia. This analysis is based on IHCM (Indonesian Highway Capacity Manual). An approach to estimating pollution costs is based on speed and travel distance in each road corridor. Highway performance for warehousing area has a poor service level. Based on speed analysis, huge concentrations of air pollution such as NO, HC and CO_2 have a significant negative impact on the road corridor as a warehousing area. Another analysis based on travel distance also resulted in the highest air pollution cost on road corridor as a warehousing area. To minimize air pollution cost, the local government should have an effort to reduce air pollution cost by implementing TDM strategies such as minimizing road side friction.

Keywords: Concentrations of air pollution, Air pollution cost, Emission parameter, Road corridor, Travel distance, Speed analysis.

1. INTRODUCTION

Air pollution from transportation is a dominant sector that exhausts seventy percent of air pollutant into urban] ambient air [1]. One of the pollutant parameter is CO, and 59.2% of CO parameter is emitted from motor-vehicle emission due to traffic congestion. CO gas in human body will react with hemoglobin (Hb) in the blood, and form CO_2Hb. CO concentration of up to 2-5% will develop unusual response of the five senses and influence the central nervous system [2]. Decrease of air quality causes other impacts such as eye irritation, respiratory infection, air aesthetic, acid rain, the worst visibility that can cause accident, etc [3].

Strategies with improving highway capacity and reducing air pollution are considerations to integrate environment aspects into traffic management. This strategy becomes a vital requirement in the regulation of transport policies [4]. Travel demand and air pollutant emission level will increase significantly without strategic transport systems and land use managements [5]. The strategic transport systems and land use managements should be linked to improvement of public transport (PT) in order to increase accessibility and to reduce the emission load. Improvement of public transport will only be really successful if linked to an appropriate urban structure. This means that the key to minimizing urban sprawl is the improvement of the public transport system associated with changes in the city's urban structure and consideration of environmental assessment [6]. The strategy by improving PT can reduce ±25% of air pollutant parameter during peak hour [7]. Carbon dioxide emissions are emitted from road traffic, which has major environmental problems with health damage and annual environmental cost approximately US$93 billion in the US [8].

A TDM (transport demand management) strategy related to environmental assessment should be applied in the city of Malang as a study area. This city is the second biggest city in East Java Province - Indonesia, as tourism and education city, and a connection city between provinces.

The growth of motorized vehicles and trips with an increase of vehicles from 441,123 (2015) to 456,693 unit (2016) in the city of Malang [9] will stimulate worse air quality. This condition means an increase in motor vehicle emissions, higher road safety risks, and an unhealthy environment for humans [7].

Different land uses generate different amounts of traffic, as well as cause different levels of traffic delays and air pollutant. As a result, this condition will produce high-cost air pollutant parameters. The parameters of air pollution in different road corridors and economic losses due to decreased air quality have not been considered in previous studies. Attention to assessing the parameters of air emission in different road corridors and air pollution cost imposed on road users based on speed and travel distance considerations will be done in this study.

Air pollutant cost will be determined for various land uses that produce different level of air pollutant. The purpose of this study is analyzed to diminish air pollutant for four areas in Malang City with different combinations of land use types and road functions. The results of this research are expected to diminish air pollutant in these areas by reducing side friction and as a reference in traffic management policies.

Organization of the paper is: research framework is elaborated in ''Methods'' section consisting of background information on the existing traffic characteristics, the highway performance on 3 road sections with various road corridors in the city of Malang, and the basis assessment of emission load and cost. The ''Results'' section explains the analysis of traffic characteristics related to highway performance, measurements of air pollution values as well air pollution cost and concentration based on travel distance and speed analyses. This section discusses estimation of differences of emission parameters and compares the impact of each emission parameter as well as air pollution cost for each parameter with the exiting conditions and side friction management. Section ''Conclusions and recommendations'' presents conclusions and recommendations for further research.

2. METHODS

2.1. Research Framework

Malang City as the case study area comprises 5 districts and 57 villages (Fig.1) with the total area of 110 km² and the population of 861,414 [9]. High traffic volume loads highway networks that serve as gateways to the city center due to the expansion of housing development in the suburbs. This condition results in traffic congestion on the highway and subsequently produces high air pollution.

Some activities are concentrated in certain areas, the impact of which is worsening, because centralized activities triggers traffic movement. Different land uses generate different amount of traffic, causing different level of traffic delay and air pollutant.

This study is focused on some different road corridors with high traffic generated on different road functions, where the areas are around Kyai Tamin, Sulfat, Letjen Sutoyo and SP Soedarmo Streets. Those roads are some of main access roads to the city center, as shown in Fig. 1.

Primary data were collected by surveying traffic counting, speed study and road geometry for four road sections with different road corridors as business areas (Kyai Tamin Street and Letjen Sutoyo Street), residential areas (Sulfat Street), warehousing areas (SP Darmo Street). Vehicle emission values were determined based on traffic volume, speed and travel distance. The survey was carried out on Saturday and Monday during peak and off-peak period (06.00-09.00 am, 11.00-14.00 pm, and 15.00-18.00 pm) in 15 minutes intervals. Secondary data was collected from the Department of the Environment.

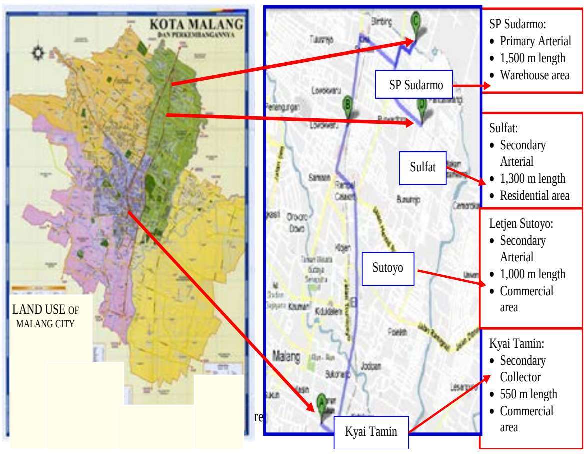

Fig.1 The study area (Malang City), and location of four road sections

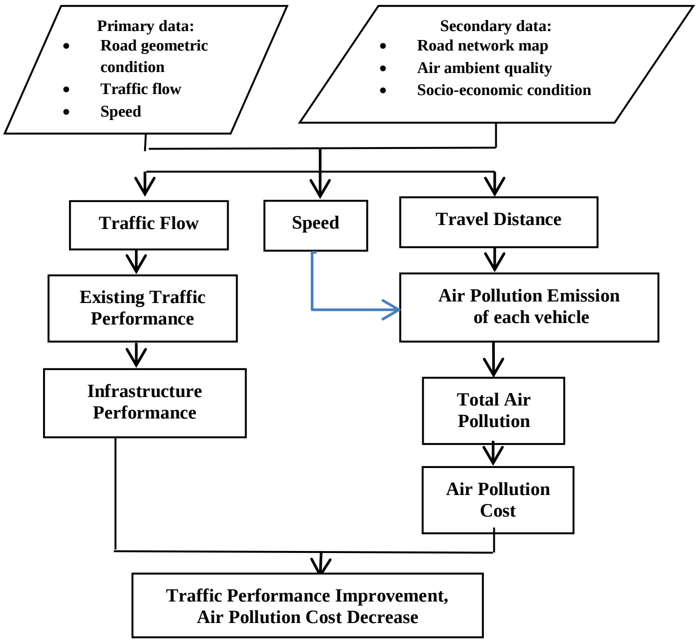

Fig. 2 The research framework

Steps of research are conducted by surveying primary and secondary data in order to assess traffic characteristics and air pollution emission. These data are analyzed to estimate traffic performance and concentration and cost of each emission parameter. Traffic performance improvement is expected to reduce air pollution emission and to increase the benefits received, as shown in Fig. 2. The result will be recommended the strategies by minimizing side friction in order to reduce air pollution cost imposed to the road users.

2.2. Assessment of Highway Performance

First analysis is to determine traffic performance based on traffic condition and road geometry. The traffic performance is analyzed applying the Indonesian Highway Capacity Manual [10]

The degree of saturation is assessed to determine traffic performance, as explained as follow:

$C = C_o \times FC_w \times FC_{sp} \times FC_{sf} \times FC_{cs}$ (1)

$DS = Q/C$ (2)

where C is the capacity (pcu/hour), C_o is the basic capacity (pcu/hour), FC_w, FC_{sp}, FC_{sf}, and FC_{cs} are the correction factors due to road width, traffic distribution (directional split), side friction, and city size, respectively, DS is the degree of saturation, and Q is the traffic flow (pcu/hour).

2.3. Assessment of Emission Load

The composition of air pollutant is based on traffic volume for each observation point because of air pollutant emissions emitted from each vehicle type. The analysis of emission loads is assessed based on traffic speed and travel distance. Thus, pollutant values can be calculated based on traffic volume and traffic composition [11], as follows:

Air pollutant (gr) = traffic flow of each vehicle class (veh.) x emission value for each parameter for each vehicle type (g/veh.mile) x road length (mile) (3)

Unit of emission load (g/veh mile varies depending on the types of transport modes, speed and travel distance. Emission substances assessed are CO, CO_2, NOx, SO, HC and PM. The average vehicle occupancy is required to calculate the unit of emission load, i.e. automobiles/private cars, minibuses, medium buses, large buses, trucks and motorcycles that accommodate 3 passengers, 8 passengers, 30 passengers, 55 passengers, 2 passengers, and 2 passengers respectively. Table 1explaines the vehicle emissions standard values based on traffic volume and traffic composition.

Table 1. Emission value for each vehicle (gram/person-mile)

Mode	Passengers	HC	CO	NOx	SOx	PM
Motorcycle	2	5	12	na	-	-
Automobile	3	3,15	23,57	1,91	0,07	0,01
Diesel Bus (medium or large bus, truck)	30, 55, 2	0,11	1,50	0,67	0,09	0,17

Source: [11]

2.4. Assessment of Pollution Cost

2.5. Evaluation of the results

Air pollution costs are obtained for each type of gas emission from each type of vehicle. Air pollution cost is calculated based on speed and distance [11].

The air pollution cost is determined by the equation 4.

Air pollution cost ($) =air pollution cost constant ($/veh-mile) x peak hour traffic volume (veh) x road length (mile) (4)

The results are evaluated to recommend actions to control the impacts of air pollution and to overcome traffic congestion by considering environmental and transportation aspects. Table 2 informs air pollution cost constant.

Table 2. Air pollution cost content ($/veh-mile)

HC	CO	NOx	Sox	PM
7.20	12	0.60 – 8.40	0.01 – 0.36	0.08 - 0.13

Source: [11].

Note : the value will be converted from USD to IDR

3. RESULTS

3.1. Space Mean Speed

Space Mean Speed for each vehicle type (motorcycle, car, and heavy vehicle) on each road is analyzed for 85-percentile on weekday and weekend, as shown in Table 3. The lowest speed occurs on Kyai Tamin Street in the afternoon and evening time.

3.2. Highway Performance (Level of Service)

Highway performance is based on the road capacity and traffic flow. Road capacity depends on road geometry and side friction related to the activities around the road. The side friction value is influenced by the number of pedestrians, stopping vehicles, parking on the road, and access vehicles along the road [10]. Highway performance of each road is as informed in Table 4.

Level of service of SP Sudarmo Street approaches traffic jam in the morning of weekday due to the degree of saturation (DS) ≥ 1 and huge heavy vehicles that load this road. On the other hand Kyai Tamin, Sulfat and Sutoyo Street have standard service level (LOS =C).

Table 3. The 85-percentile speed data on observed roads

Time	Vehicle type	Kyai Tamin		SP Sudarmo		Sulfat		Sutoyo	
		Saturday	Monday	Saturday	Monday	Saturday	Monday	Saturday	Monda
06.00 - 09.00	Motor cycle	44.4	44.6	39.0	31.5	41.0	44.0	49.6	42.6
	Automobile	36.8	35.2	34.2	29.4	39.2	38.4	42.6	39.2
	Diesel	37.0	33,8	28.2	24.4	37.0	37.3	42.6	36.2
11.00 - 14.00	Motor cycle	21.4	23.6	42.0	37.4	41.6	41.0	51.8	41.0
	Automobile	19.4	19.8	36.8	31.6	40.6	36.8	39.4	39.5
	Diesel	18.5	17.6	32.0	26.2	37.0	35.4	42.8	36.4
15.00 - 18.00	Motor cycle	41.0	36.8	41.6	33.0	42.0	43.2	49.4	43.0
	Automobile	35.4	35.4	37.0	30.4	38.6	39.4	45.6	36.4
	Diesel	31.0	30.0	31.0	24.8	32.2	34.0	37.4	31.6

Table 4. The level of service of each road

Road	Time	Capacity (C) (pcu/hour)	Traffic Flow (Q) (pcu/hour)	Road width (m)	Degree of Saturation (DS=Q/C)	Level of Service (LoS)
KYAI TAMIN			Saturday			
	06.00 - 09.00	2184.64	1040.60	8.00	0.48	C
	11.00 - 14.00	2210.66	1019.55	8.00	0.46	C
	15.00 - 18.00	2252.09	1005.90	8.00	0.45	B
			Monday			
	06.00 - 09.00	2080.38	1335.70	8.00	0.64	C
	11.00 - 14.00	2208.06	1239.30	8.00	0.56	C
	15.00 - 18.00	2354.29	1141.15	8.00	0.48	C
S P SOEDARMO			Saturday			
	06.00 - 09.00	3325.96	2612.50	10.00	0.80	D
	11.00 - 14.00	3388.91	2393.60	10.00	0.71	C
	15.00 - 18.00	3415.18	2623.70	10.00	0.77	D
			Monday			
	06.00 - 09.00	3275.34	3313.75	10.00	1.01	E
	11.00 - 14.00	3312.52	2497.10	10.00	0.75	C
	15.00 - 18.00	3421.08	2889.95	10.00	0.84	D
SULFAT			Saturday			
	06.00 - 09.00	3007.56	1722.90	8.00	0.57	C
	11.00 - 14.00	3166.50	1815.20	8.00	0.57	C
	15.00 - 18.00	3002.04	1505.20	8.00	0.50	C
			Monday			
	06.00 - 09.00	2868.45	2144.50	8.00	0.75	C
	11.00 - 14.00	3156.68	1517.90	8.00	0.48	C
	15.00 - 18.00	3093.82	1620.30	8.00	0.52	C
SUTOYO			Saturday			
	06.00 - 09.00	3102.00	1407.30	7.00	0.45	C
	11.00 - 14.00	3102.00	1583.15	7.00	0.51	C
	15.00 - 18.00	3102.00	1519.20	7.00	0.49	C
			Monday			
	06.00 - 09.00	3102.00	2082.95	7.00	0.67	C
	11.00 - 14.00	3102.00	2070.00	7.00	0.67	C
	15.00 - 18.00	3102.00	2014.40	7.00	0.65	C

3.3. Emission Parameters for Each Road Corridor

Concentration and cost of each emission parameter is determined for each road corridor. The emission concentrations are based on vehicle speed and travel distance investigated. Table 5 and Table 6 describe significant differences in emission concentrations and costs for each road corridor. The value of air pollutant can be analyzed using the Equation (3) and Table 1. Based on road performance, further analysis focuses on the worst road performance during observation, i.e. on weekday (Monday).

The amount of CO_2 pollutant is the main emission parameter due to the increasing number of motorcycles and private cars. Currently, transport mode choices are private car (30%), motorcycle (66%), and other vehicle types (4%, minibuses, buses and trucks).

Table 5 explains that CO_2 is a major component of the motor vehicle emissions. Thus, motorcycle contributes the largest air pollution, followed by automobile. The amount of air pollution is influenced by the characteristics of the vehicle engine.

The air pollution costs charged to users on each street can be calculated after the values of air pollutant on Kyai Tamin St. Sunandar P.Sudarmo St. Sulfat St and Sutoyo St. were identified, using the Equation (2), and converted into IDR (1 USD = 13,500 IDR). The results of air pollution cost are explained in Table 6. Table 6 identified the highest air pollution cost occurs on Priyo Sudarmo Street as warehousing area on Monday at 06.00-09.00 a.m. (± 101,085,308.93 IDR). Other street with commercial area on the corridor, Sutoyo Street also has an impact on air pollution cost of 74,481,825.31 IDR.

By minimizing side friction of road, it is expected that motorized vehicles use standard speed (40 km/hour). Table 7 informs the difference of air pollution cost between the existing speed and the standard speed of each road. The highest disadvantage cost due to congestion is approximately 89 million IDR during peak hour. It means that this cost will be charged to the surrounding community and road users. Improved traffic performance to reduce air pollution cost by reducing side friction is needed.

Another focus analysis is the assessment of air pollution cost based on travel distance, as described in Table 8. The highest cost for each air pollution parameter (±110 million IDR) occurs in the morning on Sutoyo Street with corridor as commercial area. Warehousing area as a road corridor also has high air pollution cost (±95 million IDR).

Table 5. Analysis of the value of air pollutant for each vehicle based on measured speed (gram)

Street	Time	Type of vehicle	HC	CO	NO	CO_2
KYAI TAMIN	06.00 - 09.00	Motor cycle	17,923.9	139,174.2	16,166.7	1,071,922.5
		Automobile	4,972.8	36,960.0	3,185.3	229,152.0
		Diesel	82.5	16.5	224.4	73,332.6
	11.00 - 14.00	Motor cycle	21,975.0	169,940.0	11,427.0	1,057,730.0
		Automobile	4,989.4	44,642.0	2,429.1	256,691.5
		Diesel	50.5	25.2	414.1	121,452.5
	15.00 - 18.00	Motor cycle	17,061.2	130,468.0	11,591.5	835,998.8
		Automobile	4,998.7	37,152.5	3,201.8	230,345.5
		Diesel	107.1	17.8	267.7	82,288.5
S. PRIYO SOEDARMO	06.00 - 09.00	Motor cycle	61,659.9	443,650.5	35,191.3	2,684,461.5
		Automobile	11,648.6	82,572.0	6,723.7	517,549.5
		Diesel	179.6	10.0	748.5	195,109.0
	11.00 - 14.00	Motor cycle	27,808.6	212,654.0	18,893.5	1,296,371.5
		Automobile	13,353.7	125,394.5	7,719.1	560,855.4
		Diesel	195.0	104	936.0	263,250.0
	15.00 - 18.00	Motor cycle	43,059.6	303,012.0	24,666.2	1,812,756.0
		Automobile	13,509.0	99,864.0	7,729.2	634,410.0
		Diesel	201.6	23.7	853.9	247,281.0
SULFAT	06.00 - 09.00	Motor cycle	30,109.3	229,512.4	26,587.1	1,778,153.0
		Automobile	8,552.3	65,703.0	6,570.3	437,658.0
		Diesel	35.2	3.2	99.2	31,760.0
	11.00 - 14.00	Motor cycle	22,335.5	184,169.5	18,103.5	1,234,327.5
		Automobile	6,630.0	50,700.0	4,504.5	324,870.0
		Diesel	52.0	12.2	189.7	64,321.2
	15.00 - 18.00	Motor cycle	20,269.4	157,982.4	17,065.1	1,141,646.4
		Automobile	7,337.7	54,677.7	5,444.1	365,701.5
		Diesel	29.5	16.1	85.8	28,877.0
SUTOYO	06.00 - 09.00	Motor cycle	53,055.75	395,506.5	43,795.11	2,865,010.5
		Automobile	16,500	128,150	12,705	855,250
		Diesel	10.6	2.65	32.86	10,600
	11.00 - 14.00	Motor cycle	38,753	310,024	32,129.76	2,149,030
		Automobile	19,809	153,849.9	15,252.93	1,026,766.5
		Diesel	12.8	3.2	39.68	12,800
	15.00 - 18.00	Motor cycle	40,815.6	308,490	37,018.8	2,335,032
		Automobile	23,070.15	170,518.5	15,380.1	1,126,759.5
		Diesel	5.3	2.12	36.04	11,262.5

This study also analyses difference of air pollution cost based on travel distance and speed for each road. Table 9 informs that air pollution cost based on mileage is higher than based on the existing speed. It means that road with high road length has high air pollution cost.

Minimizing side friction on road, especially from public transport stopped and car parking on the road can be carried out as an action program to improve traffic performance in terms of road capacity and average speed. High values of side friction occur at most roads at certain time (normal and peak hour condition). The strategies to improve road performance are considered by equipping a lay-by-lay bus stop for paratransit access, for passenger boarding and alighting and prohibiting parking on the road. Parking lots should be prepared in all buildings or offices to reduce on-street parking around the areas. As a result, the existing speed will approach design speed 40 km/hour and decrease pollution cost imposed to drivers or road users.

Table 6. Analysis of the cost of air pollutant for each road based on measured speed (IDR)

Street	Time	cost of emission gas (IDR)				Air pollution cost (IDR)
		HC	CO	NO	CO2	
KYAI AMIN	06.00 - 09.00	757,598.30	9,679,128.66	403,381.10	597,873.96	11,437,982.02
	11.00 - 14.00	890,648.84	11,792,239.17	294,043.58	624,612.37	13,601,543.95
	15.00 - 18.00	730,819.39	9,211,392.06	310,343.56	499,661.01	10,752,216.01
SP DARMO	06.00 - 09.00	7,268,442.42	86,746,266.93	2,637,307.01	4,433,292.56	101,085,308.93
	11.00 - 14.00	4,090,501.66	55,742,410.71	1,702,956.80	2,767,254.16	64,303,123.32
	15.00 - 18.00	5,614,938.09	66,415,601.44	2,055,359.06	3,516,293.75	77,602,192.35
ULFAT	06.00 - 09.00	3,368,073.49	42,825,213.11	1,809,108.73	2,581,140.20	50,583,535.53
	11.00 - 14.00	2,525,611.88	34,072,584.08	1,240,160.60	1,864,470.31	39,702,826.86
	15.00 - 18.00	2,405,425.96	30,851,385.15	1,229,131.30	1,764,220.95	36,250,163.36
UTOYO	06.00 - 09.00	5,045,741.98	63,302,850.54	2,562,758.25	3,570,474.54	74,481,825.31
	11.00 - 14.00	4,248,509.91	56,076,061.56	2,149,755.62	3,051,521.93	65,525,849.01
	15.00 - 18.00	4,634,104.75	57,905,486.21	2,376,985.94	3,323,750.88	68,240,327.78

Tabel 7. The difference in air pollution cost between the existing speed and standard speed

Street	Time	Air pollution cost (IDR)		
		Existing speed	Standard speed	diferences
KYAI TAMIN	06.00 - 09.00	11,437,982.02	9,166,813.48	2,271,168.54
	11.00 - 14.00	13,601,543.95	7,601,303.56	6,000,240.39
	15.00 - 18.00	10,752,216.01	9,166,813.48	1,585,402.53
PRIYO SOEDARMO	06.00 - 09.00	101,085,308.93	12,286,189.36	88,799,119.57
	11.00 - 14.00	64,303,123.32	10,950,800.68	53,352,322.64
	15.00 - 18.00	77,602,192.35	12,286,189.36	65,316,002.99
SULFAT	06.00 - 09.00	50,583,535.53	24,285,784.53	26,297,751.00
	11.00 - 14.00	39,702,826.86	9,311,157.75	30,391,669.11
	15.00 - 18.00	36,250,163.36	24,285,784.53	11,964,378.83
SUTOYO	06.00 - 09.00	74,481,825.31	24,285,784.53	50,196,040.78
	11.00 - 14.00	65,525,849.01	19,245,310.15	46,280,538.86
	15.00 - 18.00	68,240,327.78	24,285,784.53	43,954,543.25

Tabel 8. Air pollution cost for each parameter based on travel distance

Street	Time	HC	CO	NO	SO	PM	Air pollution cost
KYAI TAMIN	06.00 - 09.00	2,922,251.57	16,834,561.62	239,369.56	275.38	191.13	19,996,649.27
	11.00 - 14.00	2,476,031.39	14,531,690.94	215,078.15	246.96	171.18	17,223,218.63
	15.00 - 18.00	2,211,487.10	13,581,705.96	219,256.94	249.68	172.10	16,012,871.78
S. PRIYO SOEDARMO	06.00 - 09.00	12,752,123.11	81,298,116.90	1,517,445.07	1,603.33	1,254.14	95,570,542.55
	11.00 - 14.00	8,726,609.94	66,845,148.29	1,601,517.90	1,695.61	1,327.10	77,176,298.83
	15.00 - 18.00	10,450,385.26	75,587,503.46	1,688,695.87	1,775.05	1,386.36	87,729,746.00
SULFAT	06.00 - 09.00	8,493,885.64	53,941,025.62	912,673.57	757.61	545.70	63,348,888.13
	11.00 - 14.00	5,940,606.75	38,248,324.80	667,512.06	567.88	413.02	44,857,424.51
	15.00 - 18.00	6,110,315.49	42,092,542.23	798,702.78	641.83	456.19	49,002,658.51
LETJEND SUTOYO	06.00 - 09.00	13,499,348.10	94,711,233.77	1,826,623.27	1,426.97	1,002.05	110,039,634.15
	11.00 - 14.00	11,935,046.32	95,066,834.14	2,124,716.84	1,663.56	1,169.33	109,129,430.19
	15.00 - 18.00	11,874,553.95	89,950,422.84	1,911,547.15	1,511.59	1,067.08	103,739,102.60

Table 9. The difference in air pollution cost based on travel distance and the existing speed

Street	Time	Air pollution cost (IDR) based on	
		Travel distance	Existing speed
KYAI TAMIN	06.00 - 09.00	19,996,649.27	11,437,982.02
	11.00 - 14.00	17,223,218.63	13,601,543.95
	15.00 - 18.00	16,012,871.78	10,752,216.01
S. PRIYO SOEDARMO	06.00 - 09.00	95,570,542.55	101,085,308.93
	11.00 - 14.00	77,176,298.83	64,303,123.32
	15.00 - 18.00	87,729,746.00	77,602,192.35
SULFAT	06.00 - 09.00	63,348,888.13	50,583,535.53
	11.00 - 14.00	44,857,424.51	39,702,826.86
	15.00 - 18.00	49,002,658.51	36,250,163.36
LETJEND SUTOYO	06.00 - 09.00	110,039,634.15	74,481,825.31
	11.00 - 14.00	109,129,430.19	65,525,849.01
	15.00 - 18.00	103,739,102.60	68,240,327.78

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

The worst road performance (service level E) occurs during peak hour on Priyo Sudarmo Street because traffic volume is approaching value of road capacity and in unstable condition. The highest traffic volume occurs during the morning peak hour on Monday (3,313 pcu/hour) because of many activities in the road corridors as warehousing area.

Based on speed analysis, Priyo Sudarmo Street has the highest air pollutant in the morning. Consequently, the maximum air pollution cost charged to road users is ± 101,085,309.93 IDR at speed investigated. It means that more than 88 million IDR will be imposed to road users with traffic congestion. Briefly, the highest air pollutant cost arises from road corridors that are used as warehousing areas.

Another analysis based on travel distance, the warehousing area as road corridor also has the highest air pollution cost. Improvement of road performance is conducted by minimizing side friction from pedestrians, stopping vehicles, parking on the road, and access vehicles along the road to reduce negative impacts as well air pollution cost declined.

4.2 Recommendations

The further research by managing road corridors in order to reduce traffic congestion and to increase speed is required, as well as air pollutant cost reduced. Integration of spatial-transport strategies will provide more sophisticated and long-term advantages when designing efforts to decrease road side friction and to manage road corridors.

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