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Efficiency of Vehicle Operational Cost at Intersection with Geometric Widening Design in Makassar, South Sulawesi

[1]Ahmad Husain, [2]Maryunani, [3]As'ad Munawir and [3]Lambang Basri Said
[1]Graduate School of Environmental Sciences,
[2]Department of Economics, Faculty of Economics and Business, University of Brawijaya,
Veteran Malang, 65145 Malang, Indonesia
[3]Department of Civil Engineering, Faculty of Engineering, Makassar Islamic University,
Urip Sumohardjo, km. 5 Panakkukang, Makassar, Indonesia

Abstract: Congestion is a major problem of transport activities in big cities including in Indonesia. There are a lot of factors have caused congestion, there are indiscipline of road user, weak law enforcement and the increase of two-wheeled vehicles. The objectives of this study are to analyze change in travel time values, efficiency of vehicle operating costs and carbon dioxide emission efficiency with applied geometric widening intersection in Makassar. This study was performed at Makassar City, South Sulawesi. The sampling technique in this study was accidental sampling and direct field observation of vehicle at the intersection. The study sites were 4 arm of intersection In Makassar as follows Veteran Utara (VU) Street Veteran Selatan (VS) Street Sungai Saddang (SS) Street and Sungai Saddang Baru (SSB) Street. Data of vehicle volume from 4 arms were used to estimate the projected situation from 2015-2025, consisted of speed, capacity, delay and level of services. Data of vehicle operating cost was analyzed using assumptions of income approach. This study showed that travel time values were highest on Class 2A vehicle and lowest on Class IIB vehicle. Projection data showed that in 2025 the travel time values were triple. Overall, VOC efficiency in all arms was lowest in Class 2A while the highest was in Class 1. In the analysis intersection improvement through geometric design may increase vehicle speed and thus more benefit in VOC in order to accelerate the movement of goods and people.

Key words: CO_2 emission, geometric widening intersection, vehicle operating cost, assumptions, analyzed, people

INTRODUCTION

Congestion is a major problem of transport activities in major cities including in Indonesia (Arnott and Small, 1994). Generally, the large cities in Indonesia experience high density of vehicle on the road and highway, for example, capital City of Jakarta and Yogyakarta with the latest information not getting solutions appropriate in terms of overcoming the traffic congestion; Alhadar, 2011). Traffic congestion occurs when the capacity of the road is fixed but the number of road users increase continuously, resulting in longer travel time (Wohl and Hendrickson, 1984; Banister, 2015). Several strategies have been developed to reduce congestion including the improvement of urban road network, coordination of traffic movements and the demand initiatives like road pricing, parking restrictions and entirely movement reversals. Economic efficiency is one of road transport management consideration to reduce traffic congestion in large scale. The road pricing is an example of this approach. A study in Yogyakarta Indonesia focused on application of congestion pricing showed that congestion pricing of motorcycle to the City of Yogyakarta was IDR 881 per trip. When the congestion pricing for motorcycles users applied, this situation will increase the vehicle speeds between 0.42-6.32% and decreases the generalized cost.

Traffic congestion causes great expense and inconvenience for many businesses and companies, especially companies that require high levels of transport activity per unit of production. Since, the mid-1990's until today, economic activity has faltered. In addition, the impact of congestion also causes a reduction in investment of transport infrastructure (O'Mahony and Finlay, 2004). Congestion causes loss of vehicle operating costs were great and a lot of time wasted in traveling for

Corresponding Author: Ahmad Husain, Graduate School of Environmental Sciences, University of Brawijaya, Mayjen Haryono, 65145 Malang, Indonesia

weaving at the crossroads (Said, 2011). There are a lot of factors have caused congestion, indiscipline of road user, weak law enforcement and the increase of two-wheeled vehicles at a rate of 13-14% per year and four-wheeled vehicle at a rate of 8-10% per year. This increased are ironically not supported by the development of new roads in the urban area. In Makassar City, South Celebes, from 2009-2014 data, the roads only increased by 0.01% km per year (Anonymous, 2015) which ideally should increase from 10-15 km per year. Another problem is the gridiron structure of the intersection which is decelerate the vehicle speed. This situation can be solved with geometric widening at the intersection.

Previous study showed that without any actions (do nothing) the intersection performance in will experience high Degree of Saturation (DS) of all the arms, fell at 0.9 and severe degradation in which level of service fall at F level with DS>1 (poorest service conditions). When geometric widening is developed at intersections, level of service will be of a very high that increasing at the level of A and C (high services). The projecting data on road geometric modification showed that acceleration increased in the middle of the period where vehicle speed on the roads may reach twofold. This modification enhances of road capacity and may accelerate the movement of vehicles. However, there is no information about travel cost efficiency with using the geometric modification.

The objectives of this study are to analyze change in travel time values, efficiency of vehicle operating costs and carbon dioxide emission efficiency with applied geometric widening intersection in Makassar.

MATERIALS AND METHODS

The sampling technique in this study was accidental sampling, direct field observation, survey and in-depth interviews of 80 respondents. The study sites were located at an intersection in Makassar, South Celebes Indonesia (Fig. 1). The intersection consisted of 4 arms as follows Veteran Utara (VU) Street Veteran Selatan (VS) Street with Sungai Saddang (SS) Street-Sungai Saddang Baru (SSB) Street.

At each arm, vehicle volume was counted from 10.30-15.00 with period of 15 min. Data of vehicle was used to estimate the variables. There were three

Fig. 1: Study site in Makassar, Indonesia study sites this study was conducted in Veteran Utara (VU) Street-JL. Veteran Selatan (VS) Street, Sungai Sadang (SS) Street and Sungai Sadang Baru (SSB) Street in Makassar, South Sulawesi

parameters used in this study, time, cost and fuel. These parameters depend on performance measures in the intersection which can be expected are:

Traffic volume: It is defined as the number of vehicles that pass a point of road (transverse) in one time written in point/hour/lane, divided into three classes of vehicles, namely low vehicle, heavy vehicle and motorcycle.

Speed: Speed is defined as the total distance traveled divided by the total time it took to travel that particular distance in km/h m/sec.

Capacity: Saturation flow (s) is the maximum number of vehicles that can run. The proportion of green time (g) with the cycle time (c) is called the green time ratio (u). Capacity (Q) has the same unit with saturated flow, i.e., vehicles/h.

Degree of saturation: Degree of saturation (x) is the ratio of inflows (q) compared with a capacity.

Delay: Delay is the average vehicle delay during the current specified period including delay after the end of the period.

Level of services: Based on Sidra Intersection 5.1 user guide in measuring the level of service, method of delay and degree of saturation must be used. This method uses the average delay and the degree of saturation as the basis for setting the level of service.

Change in travel time values was calculated using approach that is associated with per capita income of the population known as the income approach where it is assumed that the time value is determined based on the difference in income for this type of vehicle. The following calculations based on assumptions of income approach:

- Per capita income IDR 1,670,000
- Disposable income amounted to 85% of income per capita per month
- The monthly working hours to 200 h
- Wages riders Class IIA and IIB 75% of the average wages
- Wages riders Class 1 was 5 times the wages of the rider Class 2A
- The business trip = wages
- The value of non-business trip = 25% wages
- Percentage of trips Class 1: 25%, Class 2A: 10% Class 2B: 5% for the entire trip
- The number of passengers Class 1: 8 people, a bus 30 people and multi-purpose vehicle 4 people

Data analysis: Analysis can be performed with a traffic evaluation device with an advanced microanalysis analyzing lane by lane with a recurrent approximation method to obtain capacity and performance statistics such as delay, the degree of saturation and service levels. This analysis evaluates the signalized intersection. The calculation is performed for two conditions, namely the existing linear condition and turning conditions at intersections. The results of the analysis are in the form of intersection performance parameters such as traffic volume, speed, capacity, degree of saturation, delays and service levels. Change in travel time values was projected by using to determine the time value growth projections for the future (from 2015-2025), it can be calculated using an exponential equation by first determining growth factor (r) of the function of income per capita of the population. Results of analysis for these two conditions are then compared to determine the effect of the geometric design at the intersections.

RESULTS AND DISCUSSION

This study showed that, the density of vehicles that cross the intersection was varied by the arm. The highest volume of vehicles was occurred at SSB Street (155-390 vehicles) while the lowest was in the VU Street (55-85 vehicles) (Fig. 2). The intersection is a meeting place between (2) or more roads that meet or intersect, so that, contributing to the delay of time (60-70%) of the total travel time (travel time) that cause congestion on the urban road network system (Tamin, 2008).

Performance roads intersection was associated with the delay and travel time to get through the intersection.

Based on the result, value of time for each class of vehicles was determined. The result of the calculation of the value of time for each class of vehicles can be seen in Table 1.

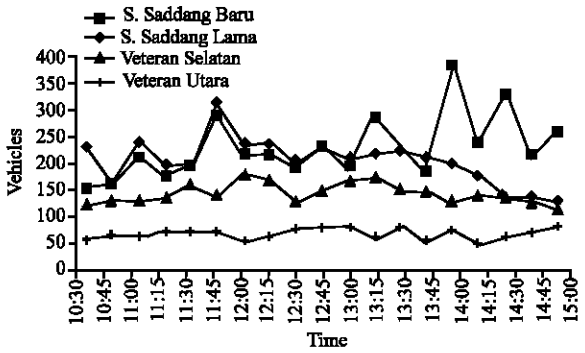

Fig. 2: Volume of vehicles at the intersection (results survey, August 2015 and August 2016)

Table 1: Travel time values of vehicle Class 1, 2A and IIB

Variables	Class 1	2A	2B
Percapita income (IDR/month)	1,670,000	1,670,000	1,670,000
Disposable income (IDR/month)	1,569,500	1,569,500	1,569,500
Average wages (IDR/h)	10,678	2,136	2,136
Business travel values (IDR/h)	10,678	2,136	2,136
Non-business travel values (IDR/h)	2,670	534	534
Business travel time values (IDR/h)	2,670	214	107
Non-business travel time values (IDR/h)	2,002	481	507
Total	4,672	694	614
Time value (IDR.vehicle/ h)	10,278	20,822	2,456

Table 2: Projection of time value growth

Years	Income growth (%)	Exponential	Time value (IDR.vehicle/h) Class 1	Class 2A	Class 2B
A	B	$c = (1+b)^n$	$d = c \times d_n$	$e = c \times e_n$	$f = c \times f_n$
2015			10.278	20.822	2.456
2016	0.121727	1.121727	11.529	23.357	2.755
2017	0.121727	1.121727	12.932	26.200	3.090
2018	0.121727	1.121727	14.506	29.389	3.466
2019	0.121727	1.121727	16.272	32.967	3.888
2020	0.121727	1.121727	18.253	36.980	4.362
2021	0.121727	1.121727	20.475	41.481	4.893
2022	0.121727	1.121727	22.967	46.531	5.488
2023	0.121727	1.121727	25.763	52.195	6.156
2024	0.121727	1.121727	28.899	58.548	6.906
2025	0.121727	1.121727	32.417	65.675	7.746

Without any effort to change the road geometry, volume of vehicle will increase and the road can no longer be tolerated while passenger car which passes through the capacity limit of the ability to pack roads to channel the direction of the drive. One way of solving this clutter is to parse both continuous pile vehicle and that will do that is by forming super-elevation deflection as steps to improve the road geometry. The growth of time value will also increase in the future. The time value for the year can be calculated in the following Table 2.

Calculation results showed that an increase in the value of the significant time each year. Seen in the initial year (2015) the value of time for each vehicle of Class 1 was IDR 10,278 mph and an increase of IDR 32,417 mph in 2025. This situation was similar to the vehicle Class 2A and 2B.

If the value obtained when each type of vehicle associated with travel time, efficiency obtained in previous calculations, it can also be calculated efficiently obtained from any reduction in travel time as a direct influence on the development of geometric design. The efficiency of each segment can be seen in the following (Table 3).

The most advantaged vehicles are Class 1 because using a little lubricant, this may improve vehicle acceleration. Automatically wear auto parts can be controlled though on one hand the cost of the insurance will be great with the awareness level higher than public transport users. The highest vehicle operating cost was goods vehicles through weight tonnage of the vehicle as their function. This calculation excluded the destruction of the road.

After a geometric design applied Vehicle Operating Cost (VOC) savings was obtained varied. By using constant prices VOC savings obtained in 2025. At SSB Street, VOC savings in 2015 were lowest in Class IIA (13.29%) while the highest was in Class 1 (21.67%). The same trend was projected in 2025 when the lowest was in the former (25.43%) while the highest was in the latter (58.25%). At VS Street, VOC savings in 2015 were lowest in Class 2A (10.66%) while the highest was in Class 1 (16.95%). The same trend was projected in 2025 when the lowest was in the former (19.43%) while the highest was in the latter (37.89%). At SS Street, VOC savings in 2015 were lowest in Class 2A (7.50%) while the highest was in Class 1 (11.30%). The same trend was projected in 2025, when the lowest was in the former (14.26%) while the highest was in the latter (26.52%). At VU Street, VOC savings in 2015 was lowest in Class 2A (1.93%) while the highest was in Class 1 (4.06%). The same trend was projected in 2025, when the lowest was in the former (6.74%) the highest was in the latter (10.75%).

In the Makassar City, the ratio of private vehicle ownership in comparison to the number of public

Table 3: Efficiency of vehicle operating cost with geometric design

		Vehicle operating cost (IDR.Km) Efficiency								
		Do nothing			NWith geometric design			VOC efficiency		
Arm	Years	1	11A	11B	1	11A	11B	1	11A	11B
SSB	2015	1,311.98	2,237.48	3,996.59	1,078.28	1,974.34	3,396.34	233.70	262.52	600.25
	2025	1,823.44	2,590.62	5,264.72	1,152.27	2,065.43	3,287.68	671.17	525.19	1,677.04
	Efficiency						2015	21.67%	13.29%	17.67%
	-						2025	58.25%	25.43%	46.74%
VS	2015	1,265.30	2,190.59	3,877.72	1,081.90	1,979.53	3,405.72	183.39	211.06	472.00
	2025	1,572.77	2,450.19	4,650.33	1,140.56	2,051.55	3,557.46	432.21	398.65	1,092.86
	Efficiency						2015	16.95%	10.66%	13.86%
							2025	26.52%	14.26%	21.66%
SS	2015	1,172.73	2,089.29	3,640.40	1,053.66	1,943.47	3,332.45	199.07	145.82	307.95
	2025	1,481.03	2,384.34	4,422.28	1,170.56	2,086.79	3,634.83	310.47	297.55	787.45
	Efficiency						2015	11.30%	7.50%	9.24%
	-						2025	26.52%	14.26%	21.66%
VU	2015	792.11	1,588.63	2,659.24	761.22	1,558.52	2,588.36	30.89	30.11	70.88
	2025	854.73	1,671.85	2,816.74	771.79	1,566.30	2,611.15	82.93	105.55	205.58
	Efficiency						2015	4.06%	1.93%	2.74%
	-						2025	10.75%	6.74%	8.08%

transport was 67.50% (Anonymous, 2016). This trend will be formulated to get a good economic value either direct or indirect values. All of which will be used as the optional value to obtain a greater cost benefit compared to the social cost caused by intersection geometric improvements. Value cumulative loss rate in the form of lost cost trip multiplication ratio values obtained from the travel time, delay, time effectiveness, so that, the total economic value of the geometry improvement and left deflection directly obtained travel time efficiency value of IDR 18,343 vehicle/h while Vehicle Operating Costs (VOC) of was IDR 1,152 vehicle/km with the number of delay IDR 3,214 vehicle/h, effectiveness 24 h/day. Those were used to calculate the environment economic value or cost benefit value by multiplying the ratio and obtained IDR 88,904,175/day. A study conducted in in Surabaya, Indonesia showed that proposed design of geometric access implemented, the intersection capacity estimated to be increase up to 46.6%, degree of saturation reduce up to 31.9%, intersection delay reduce up to 57% and queue probability reduce up to 50.9%; compared with the existing access conditions till the year 2020 (Setiawan, 2011). Another study conducted Semarang, Indonesia showed that the Vehicle Operating Costs (VOC) with circle road was more efficient compared to existing road. The value of VOC vehicle Class I was IDR 415.11 (3.09%); Class IIA was IDR 2321.46 (4.01%) while Class IIB was IDR 3383.27 (8.49%) (Subandriyo *et al*., 2014).

CONCLUSION

This study showed that travel time values was highest on Class 2A vehicle and lowest on Class 2B vehicle. Projection data showed that in 2025 the travel time values were tripled. Overall, VOC efficiency in all arms was lowest in Class 2A while the highest was in Class 1. In the analysis of intersection improvement through geometric design may increase vehicle speed and thus more benefit in VOC in order to accelerate the movement of goods and people. The total economic value of the geometry improvement and left deflection directly obtained travel time efficiency value was IDR 18,343 vehicle/h while Vehicle Operating Costs (VOC) of was IDR 1,152 vehicle/km. The environment economic value or cost benefit value by multiplying the ratio and obtained IDR 88,904,175/day.

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