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Analysis of the Influence of Traffic Flow on Air Pollution at *Simpang Angkatan 66* of Palembang City

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Abstract. The existence of congestion caused by the increase of vehicle volume resulted in the increased level of vehicle exhaust emissions. In Palembang City as a Metropolitan City, congestion is almost evenly distributed throughout the city and one of the intersections that often occurs congestion is *Simpang Angkatan 66*. The study aimed to analyze the intersection performance and its amount of emissions caused by motor vehicles. The analysis of the emission quantity was conducted using EnViVer program supported by Vissim program, and the primary data were done by direct air measurement. The results of the study showed that in the existing condition the amount of the emissions was CO_2 352.499 g / km, NO_x 1.235 g / km, and PM_{10} 0.0055 g / km. The direct measurement produced PM_{10} value of 152 μg / Nm3. Based on the three alternative improvement plans, it showed that the fly over construction was the best alternative in reducing emission value and improving performance of Simpang Angkatan 66.

Keywords: traffic performance, emission, air measurement.

1. Introduction

Transport activities do not always have a positive impact, but they can also have a negative impact. One of the negative impacts of the transportation activity is traffic jam in downtown, including in Palembang City. Congestion causes enormous losses, both on the aspect of travel time which takes long time and gets slow down, financial, health, and environmental aspects as the impacts of air pollution caused by vehicle exhaust emissions.

Based on the RAD-GRK of South Sumatra Province in 2012, greenhouse gas emissions in Palembang City discharged from the transportation sector reached 68,792.50 million tons / year CO_2 [1]. Motor vehicles are a major source of air pollution in urban areas and account for 70% of NO_x emissions, 52% of HC emissions, and 23% particulates [2].

Analysis of traffic performance using Vissim Software on a network of intersections was carried out by comparing the values of queue length and mean delay [3]. There existed several modeling tools which were used to analyze transport CO_2 emissions, transport microsimulation techniques providing insight into the advantages and disadvantages of a program in analyzing emissions [4]. A case study

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showed that Vissim program added by MOVES-Matrix could be effective tools to analyze emission and assessing the air quality planning [5]. Microscopic traffic simulation model (Vissim) combined with emission model (PHEM) was potential to assess better the impacts of traffic, management strategy, and technology implementation [6].

Given the results of the previous study, the concentration of vehicle emission output derived from EnViVer assisted by Vissim was analyzed using direct measurement. This study was focused on analysis of vehicle emission concentration in the form of Carbon Dioxide (CO_2), Nitrogen Oxide (NO_x), and Particulate (PM_{10}). It was conducted at the intersection of Angkatan 66 of Palembang City due to its high congestion particularly during rush hours. The aim of the study was to find out the traffic performance of the existing condition and the condition after the improvement of the intersection of Angkatan 66, as well as analyzing the emission incurred.

2. Experimental Section

2.1 Location of the Study

The survey location was located at the intersection between Basuki Rahmat and R. Sukamto roads, precisely at the intersection between Angkatan 66 and Amphibi roads, commonly called Simpang Angkatan 66. The geometric Intersection of Angkatan 66 is shown in Figure 1 as follows:
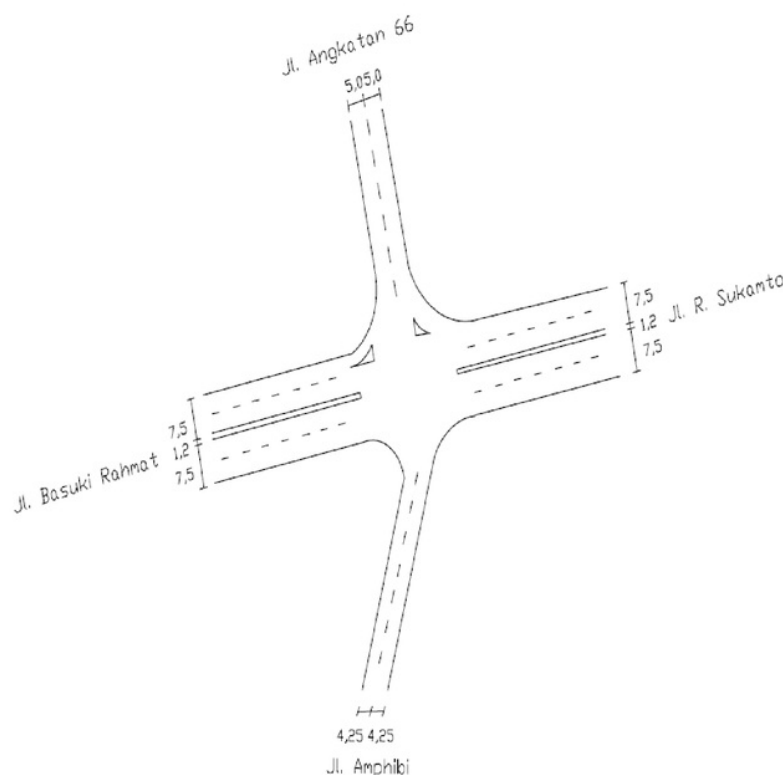

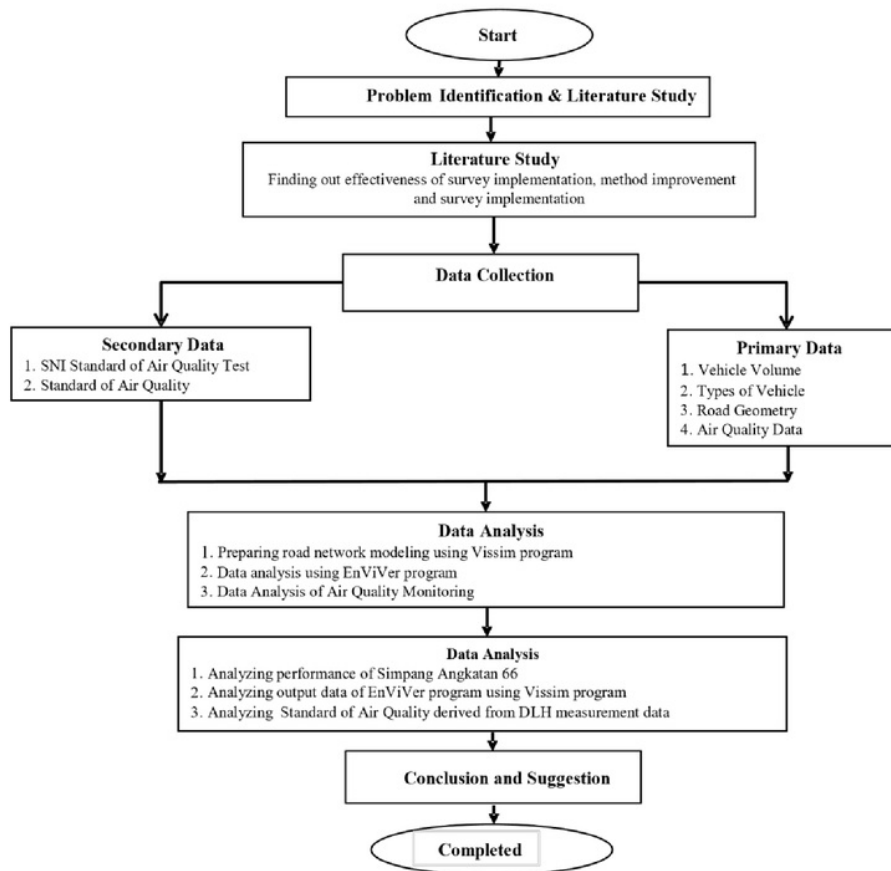**Figure 1.** Geometry of Simpang Angkatan 66

Figure 2. Flow Chart of the Study

2.2. Implementation of Activities

The study flow chart is shown in Figure 2.

2.2.1. Vehicle Volume. Traffic surveys are activities conducted to collect data of the number, volume, and compositions of vehicles relating to road traffic conditions.

2.2.2. Vehicle Speed. Spot speed measurement was designed to get speed characteristics at the location, traffic condition, and particular environment during the survey being conducted based on the classification of four-wheeled and two-wheeled motor vehicles.

2.2.3. Direct Air Measurement. Manual method was conducted by way of air sampling on the roadside, and the location of measurement was at a distance of 1 - 5 meters from the edge of the road. The monitored parameters were Carbon Monoxide (CO), Nitrogen Dioxide (NO_2), Sulfur Dioxide (SO_2), Oxidants (O_3) and Particulate (PM_{10}).

2.3. Programs of Vissim and EnViVer

Vissim is a microscopic simulation with time-based and behavior developed for urban traffic models and public transport operations. The program is useful for evaluating a wide range of transportation engineering alternatives and and the most effective level of planning [7].

EnViVer is a program that combines Average Daily Traffic (ADT) with software simulations resulting in modeling of emission forces [8]. This program produces calculations of emission strength of Nitrogen Dioxisa (NO_x), Particulate Matter (PM_{10}) and Carbon Dioxide (CO_2).

2.4. Research Instrument
In this study, the instrument was divided into two parts, namely:
1. Measurement of traffic flow included volume, composition, and average speed of each type of vehicle. This measurement used several helping tools for field data collection comprising counter device (hand counter), survey form, stationery, stopwatch, and speed gun for vehicle speed survey.
2. Direct air measurement was conducted using Impinger to measure SO_2, Ozon, NO_2, CO *analyzer*, HVAS *(High Volume Air Sampler)* for PM_{10} and other supporting tools.

2.5. Data Analysis
Data analysis was conducted using Vissim and En ViVer programs to get the values of traffic performance and emission at the Intersection Angkatan 66.

2.5.1. Vissim Data Analysis. Vissim Data Analysis started from preparing road network modeling of the existing condition at the study location. The analysis was done by inserting the data of vehicle volume previously collected from the survey results which had been put into the Vissim program. Then, the running of Vissim program resulted in the queue length and vehicle delays for road performance analysis.

2.5.2. EnViVer Data Analysis. EnViVer Data Analysis started from analyzing the file *fzp derived from the Vissim program contained in theEnViVer program. After the file of Vissim was inserted into the program, the EnViVer would show the emission total value and description of emission distribution at the location of the study.

The result of Vissim and EnViVer outputs were planned for alternative improvement to increase road performance and decrease emission rate as follows:

• Geometric Widening of the Road
 Planning of the Road Geometric Widening is shown in the following table:

Table 1. Width of Road Geometric Plan

Street Names	Existing Condition (meter)	Planned Width (meter)
Jl. BasukiRahmat	15	22
Jl. Angkatan 66	10	12
Jl. R. Sukamto	15	22
Jl. Amphibi	8.5	12.5

• Traffic Cycle Time Optimization
 In this alternative, planning of rearranging traffic lights was conducted by using Optimize All Fixed Time Signal Controles contained in the PTV Vissim, that is automatically optimizing the red lamp cycle of the existing condition by adjusting the data previously inputted.
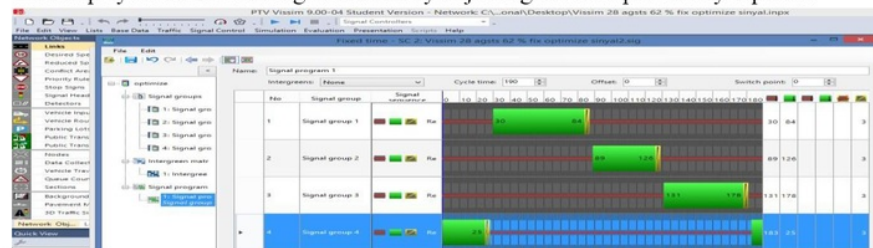

Figure 3. The appearance of Opimize Signal inVissim Program

- Fly Over Construction Planning
  This alternative planning was done by constructing a fly over or overpass connecting Jalan Basuki Rahmat and Jalan R. Sukamto. Having the fly over, the flow of vehicles from and to Jalan Basuki Rahmat to Jalan R. Sukamto or vice versa will switch through the fly over.

3. Result and Discussion

3.1. Road Performance Analysis

Analysis of the intersection performance was carried out by the help of PTV Vissim Program to obtain the calibration of network simulation model with the existing condition equal to 63%. The calculation using Vissim Program produced volume, queue length and vehicle delay at the intersection. Then, alternative improvements were planned for road performance. The recapitulation of volume, queue length and vehicle delays on the existing conditions and alternative improvements at the intersection of Angkatan 66 is given in Table 2.

Table 2. Recapitulation of Volume, Queue Length, and Vehicle Delays
at the Intersection of Angkatan 66

Approach	Attribute	Existing	Alternative 1 (Geometric Widening)	Alternative 2 (Signal Optimization)	Alternative 3 (Construction of *Fly Over*)
Jl. Basuki Rahmat	Volume (v/hour)	3217	3749	3125	3821
	Queue Length (m)	209.42	235.41	208.58	4.31
	Delay (s/v)	82.3	61.48	82.35	9.98
Jl. Angkatan 66	Volume (v/hour)	1720	1811	1652	2269
	Queue Length (m)	92.55	33.09	93.49	89.21
	Delay (s/v)	133.84	117.27	138.67	94.28
Jl. R. Sukamto	Volume (v/hour)	3786	4055	3660	4096
	Queue Length (m)	179.38	209.9	178.39	6.59
	Delay (s/v)	63.90	72.07	63.31	14.33
Jl. Amphibi	Volume (v/hour)	1363	1443	1310	1877
	Queue Length (m))	117	124.9	118.77	109.61
	Delay (s/v)	123.41	138.40	127.18	82.32

The above table shows that the output of the highest volume total of the vehicles by simulating the alternative 3, namely the fly over construction. From the simulation result, the total volume of vehicles passing through Simpang Angkatan 66 at the peak hour was 12,063 vehicles where the total existing condition of the vehicles was only 10,085 vehicles.

Based on the plan of alternative 3, the result of the smallest queue length was by conducting the plan of alternative 3 in which the highest queue length was 109.61 meters occurring at the approach of Jalan Amphibi. Meanwhile, the result of the smallest vehicle delay value was 9.98 v/s and it was also obtained by conducting the alternative 3, that is fly over construction.

The output result of Vissim in the forms of vehicle volume, queue length, and vehicle delay showed that the best alternative of road performance improvement was by constructing a fly over. This is due to the resulted output value in which the total volume of the vehicles passing through Simpang Angkatan 66 was larger than the other 2 alternatives, while the queue length and delay were smaller than the other alternatives.

3.2. Analysis of Vehicle Exhaust Emissions

The calculation using EnViVer Program produced the output of the emission total value of the existing condition and the repair alternative at Simpang Angkatan 66. The modeling using Vissim and EnViVer programs produced the output of the emission total value of the existing condition shown in Figure 4 as follows:

CO_2	NO_x	PM_{10}
366.999 kg	1285.539 g	58.018 g
1692.539 kg/h	5928.694 g/h	267.568 g/h
352.499 g/km	1.235 g/km	55.725 mg/km

Figure 4. Emission Total of EnViVer Output

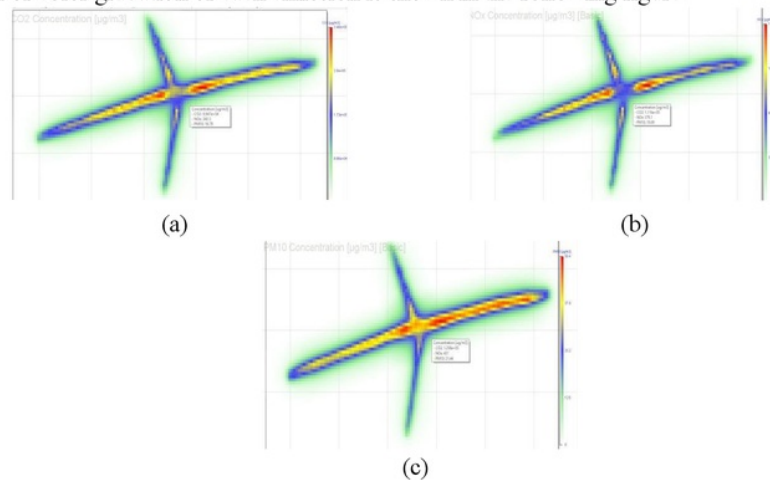The level of color gradation of each emission is shown in the following figure:

(a)   (b)

(c)

Figure 5. Concentration Gradation (a). CO_2 (b). NO_x (c). PM_{10} Existing Condition

The highest CO_2 gas emission is shown by the red gradation of 346,000 $\mu g/m^3$ which means the value belongs to the high category, the yellow gradation was 260,000 $\mu g/m^3$, the blue gradation was 173,000 $\mu g/m^3$, and the green gradation was 86,600 $\mu g/m^3$. The highest NO_x gas emission is shown by the red gradation of 1,340 $\mu g/m^3$, the yellow gradation of 1,000 $\mu g/m^3$, the blue gradation of 669 $\mu g/m^3$, and the green gradation of 334 $\mu g/m^3$. While the highest PM_{10} gas emission is shown by the red gradation of 50,4 $\mu g/m^3$, the yellow gradation of 37,8 $\mu g/m^3$, the blue gradation of 25,2 $\mu g/m^3$, and the green gradation of 12,6 $\mu g/m^3$. All output results of EnViVer program on the emission total value with several repair alternatives are given in Table 3.

Table 3. Recapitulation of Emission Total Value using EnViVer Program

Condition	CO_2		NO_x		PM_{10}	
Existing	352.499	g/km	1.235	g/km	0.055725	g/km
Alternative 1 (Road Geometric widening)	272.65	g/km	0.967287	g/km	0.049056	g/km
Alternative 2 (Optimizing Traffic Signs)	333.236	g/km	1.235	g/km	0.056501	g/km
Alternative 3 (Fly Over Construction)	264.424	g/km	0.915316	g/km	0.050973	g/km

Table 3 shows the comparison between the total emission value of EnViVer output indicating that the total emission value on alternative 3 was better than other road performance improvement alternatives. Because at alternative 3 the total emission values for CO_2, NOx and PM_{10} decreased significantly from the other repair alternatives. This means that if the planning of alternative improvement 3 constructing the Fly Over was completed then total value of CO_2, NOx and PM_{10} emission would decrease.

3.3. Analysis of Vehicle Exhaust Emissions Derived from Direct Measurement. Measurement of vehicle exhaust emission value at Simpang Angkatan 66 was carried out by Air Sampler Implinger analysis. Measurement of vehicle exhaust gas parameters was done on the same day by measuring the vehicle volume. The type of vehicle exhaust gas measured at the time of research was CO, NO_2, SO_2, O_3, and PM_{10}. Here are the results of the measurement:

Table 4. Vehicle Gas Emission Data by Direct Vehicle Measurement

No.	Time of Sampling	Parameter				
		CO ($\mu g/Nm^3$)	NO_2 ($\mu g/Nm^3$)	SO_2 ($\mu g/Nm^3$)	O_3 ($\mu g/Nm^3$)	PM_{10} ($\mu g/Nm^3$)
1.	06.00 - 07.00	2290	336	149	233	73.5
2.	07.00 - 08.00	2290	283	132	259	40.9
3.	08.00 - 09.00	2290	284	132	206	51.1
4.	09.00 - 10.00	3436	341	94.7	269	80.7
5.	10.00 - 11.00	2290	171	94.8	117	60.2
6.	11.00 - 12.00	3436	286	114	181	39.3
7.	12.00 - 13.00	3436	287	127	109	46
8.	13.00 - 14.00	2290	285	108	132	62.6
9.	14.00 - 15.00	2290	341	108	140	104
10.	15.00 - 16.00	3436	397	125	140	152
11.	16.00 - 17.00	2290	282	131	130	42
12.	17.00 - 18.00	3436	280	149	250	101

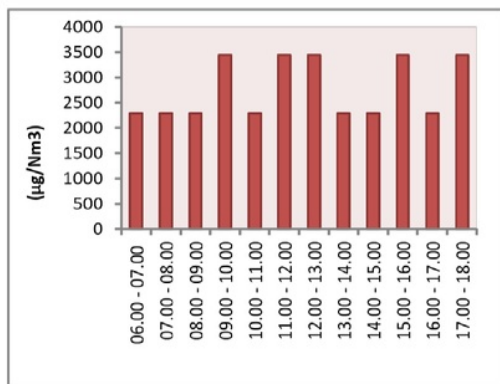Here is a graph of vehicle exhaust emissions obtained from direct measurement:
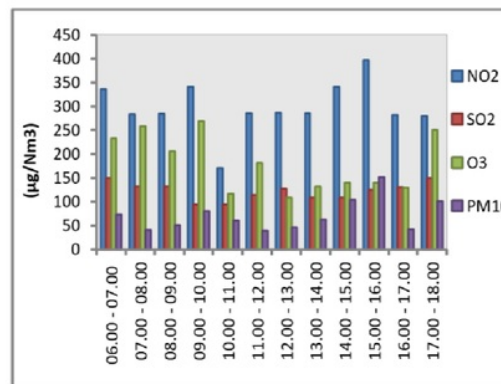

Figure 6. CO Value Obtained from Direct Measurement

Figure 7. Values of NO_2, SO_2, O_3, and PM_{10} Obtained from Direct Measurement

The National Ambient Air Quality Standard No. 41 of 1999 states that the quality standard for CO gas parameters within an hour measurement time is 30,000 $\mu g/Nm^3$ whereas NO_2, SO_2, O_3 and PM_{10} were 400 $\mu g/Nm^3$, 900 $\mu g/Nm^3$, 235 $\mu g/Nm^3$, and 150 $\mu g/Nm^3$. The results of measurement of the highest value of CO gas obtained at Simpang Angkatan 66 was 3,436 $\mu g/Nm3$, NO_2 of 397 $\mu g/Nm^3$, SO_2 of 149 $\mu g/Nm^3$, O_3 of 269 $\mu g/Nm^3$, and PM10 152 $\mu g/Nm^3$. In conclusion, the parameters of NO_2, O_3, and PM_{10} were already in a high level.

4. Conclusion

Based on the previous description, the following is the conclusion:

a. In the existing condition, Simpang Angkatan 66 is not able to serve the traffic properly because the simulation of PTV Vissim showed that the queue length was 209.42 meters and the delay was 133.84 s/v. Of the three planned improvement alternatives, the planned alternative 3 constructing a fly over- produced the smallest queue length and delay.

b. The total emission value of the EnViVer program under the existing condition for CO_2 gas amounted to 352.499 g/km, NO_2 1.235 g/km and PM_{10} of 0.0055 g/km. Of the three planned alternatives, the alternative 3- constructing a fly over- was the best alternative of decreasing emission value.

c. The direct air measurement results showed that the highest value of CO_2 gas was 3,436 $\mu g/Nm^3$, NO_2 of 397 $\mu g/Nm^3$, SO_2 of 149 $\mu g/Nm3$, O_3 of 269 $\mu g / Nm^3$, and PM_{10} 152 $\mu g / Nm^3$. In conclusion, the parameters of NO_2, O_3, and PM_{10} were already in a high level because the value obtained exceeded the quality standard value stipulated by the Government Regulation No. 41 of 1999 on the National Ambient Air Quality Standard.

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