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Analysis of Air Pollution due to Vehicle Exhaust Emissions on The Road Networks of Beringin Janggut Area

Achmad Rizki Pratama, Joni Arliansyah*, and Melawaty Agustien

Department of Civil Engineering of Faculty of Engineering of Sriwijaya University, Palembang, Indonesia

*E-mail: joniarliansyah@yahoo.com

Abstract. Vehicle exhaust emission in transportation activities is one of air pollution causes. The increasing number of motor vehicles, lack of space availability on roads, and road side activities can cause congestion. The purpose of this research was to analyze the road network performance and vehicle exhaust emissions on the road networks of *Beringin Janggut* area of Palembang through traffic simulation using *Vissim* software and vehicle exhaust emission calculation using *EnViver* software, and the results were compared with ambient air measurement results at the research location, as well as providing alternative solutions to existing traffic condition. The outputs of *Vissim* software on the existing condition showed a long queue on traffic flow from *Kolonel Atmo 2* street to the *Masjid Lama 2* street with a value of 130.51 m, and there was a long delay on traffic flow from *Kolonel Atmo 1* street to *Rustam TP Effendi* street (Southward) total of 105.37 seconds / vehicle. The *EnViver* software output showed the highest concentration for carbon dioxide (CO₂) pollutant of 181,000 µg / Nm³, the highest concentration for nitrogen oxide (NO_x) pollutant of 534 µg / m³, and the highest concentration for Particulate Matter (PM₁₀) pollutant of 36 µg / Nm³. From the *EnViver* software outputs, the results showed the highest concentration of Particulate Matter air pollutants (PM₁₀) from direct ambient air measurement at the research location had a difference of 79 µg / Nm³. The existing concentrations of air pollutants resulting from *EnViver* software output and ambient air measurements on the road network of *Beringin Janggut* area were still below the ambient air quality standard limits set in Government Regulation No. 41/1999 on Air Pollution Control. Alternative 1 with parking rearrangement was better than alternative 2 with the lanes separation between public and private vehicles in improving road network performance and reducing total emission values due to vehicle exhaust emission from existing conditions.

Keywords : *Vissim software, EnViver software, vehicle exhaust emission, CO₂, NO_x, PM₁₀.*

1. Introduction

The area of *Beringin Janggut* Palembang is one of the commercial center areas that has long been operating in the city of Palembang. Roads in this area are always jammed during rush-hours, due to heavy traffic and high side barriers in the area. Besides Road bodies in the *Beringin Janggut* area used for parking vehicles, it is also used by some traders as a place to conduct trading activities. In the *Beringin Janggut* area there is also a traffic sign intersection which is a joint of the *Kolonel Atmo*



Street and the T.P Rustam Effendi street, therefore, during peak hours there is always a traffic congestion at this junction.

One of the negative effects of traffic congestion is air pollution. Motorist vehicle exhaust emissions using fossil fuel oil are the main causes of air pollution. Pollutants released by motorist vehicles include carbon monoxide (CO), carbon dioxide (CO₂), nitrogen oxide (NO_x) in the form of nitric oxide (NO) and nitrogen dioxide (NO₂), hydrocarbons (HC), sulfur oxides (SO_x) in forms of sulfur dioxide (SO₂) and sulfur trioxide (SO₃), and particulate matter (PM₁₀). Pollutants caused by emissions of these vehicles are harmful pollutants and can have a negative impact on human health if exposed continuously and in the long term.

Several studies on air pollution due to motor vehicle emissions on road traffic activity had been conducted. A study conducted on traffic flows on six Xi'an city streets where the calculation of emission strength using the multiplication formula between emission factor and vehicle travel distance showed that the concentration of NO_x, HC and CO pollutants due to vehicle emissions were 46.43%, 62, 47%, and 51.64% [1].

A research conducted on the traffic of three streets in the city of Medan were Medan-Binjai KM 10 street, Medan-Tg street, Morawa KM 10, and Medan-Tembung street, with emission calculations using the emission factor formula showed that the largest percentage of carbon monoxide emissions were from motorcycles while for nitrogen oxide and sulfur dioxide pollutants were from vehicular trucks [2].

A research on the traffic activity in the traditional market area of Mranggen Semarang through a micro simulation approach with *Vissim* software tool showed that the CO value due to vehicle emission was 474,343 ppm / hour which exceeded the pollutant level of 20 ppm / 8 hours, and the value NO_x due to motorist vehicle emissions of 92.90 ppm / hour that exceeded the pollutant level threshold of 0.05 ppm / 24 hours [3].

A research conducted at the intersection of roads in central and eastern Surabaya aimed to determine fuel need and motor vehicle exhaust emissions. Parameters of motor vehicle exhaust emission research were CO₂, HC, NO, PM, and SO₂, where NO and SO₂ exhaust emission concentrations were calculated using Meti-Lis with gaussian plume model. It was assumed that fuel consumption also produced high CO₂ emission. Calculation of air pollutant concentration from CO₂, HC, NO_x, PM, and SO₂ was conducted to find out whether the air pollutant from existing condition was still in accordance with the air pollutant standard issued by the World Health Organization (WHO). NO and SO₂ exhaust emissions generated by motor vehicles exceeded the secured level suggested by the World Health Organization (2016) [4].

In research conducted by Andres Monzon, Alvaro Garcia Castro, and Cristina Valdes which aimed to measure motor vehicles emissions applying information and communication technology. The research methodology was based on the combination of model simulation variation in micro and macro scale. The research object was a sample vehicle prepared and representative characteristics of vehicles operating in Madrid road traffic. Research location was on M30 road in Madrid. From the data obtained in the location, a micro-scale simulation with *Vissim* software and macro-scale simulation with *Vissim* software were used. The scenarios applied in this research were speed regulation, effective route arrangement, driving method, and traffic management. The result showed that there was a decrease of emission due to motor vehicle by 3% after the implementation of improvement scenario. In this study the calculation of air pollutants as the result of transport activities becoming basic comparison when scenario improvement applied [5].

Frantisek Petro and Vladimir Konecky in their research aimed to calculate emissions from transport activities and using the results to proceed to external cost calculations caused by negative impacts of emissions. It compared three computer softwares used to calculate emissions ie, Map & Guide, NTMCalc Basic 4.0, and EcoTransit. From the comparison result, the most suitable software for emission calculation continued to external cost calculation was Map & Guide because it showed emission factors on route passed [6].

In addition, a research conducted at a two-track roundabout between *the warszawska, marszalkowska, rycerska, and lubelska* roads in *Rzeszow* city through traffic simulation methods with *Vissim* software followed by emissions calculations from motorist vehicles with *EnViver* software showed the emission factors for NO_x and PM₁₀ increased at the peak time traffic. The results of microscopic emission calculations using *EnViver* software compared with mesoscopic model calculations using COPERT 5 software showed that there was a factor difference of NO_x of 7-18% [7].

From several researches conducted above shows that the network performance of a road network will greatly determine the level of pollution occurred due to traffic activities on it. By using *Vissim* software, it can be simulated traffic activities that occur on a road network, from the simulation of traffic through *Vissim* software can be calculated the vehicle exhaust emissions due to traffic activities.

This research was conducted on the road network of *Beringin Janggut* to analyze road network performance of vehicle exhaust emissions through traffic simulation using *Vissim* software and followed by calculation of vehicle exhaust emissions using *EnViver* software, and the results were compared with direct ambient air measurements at the research location, and also to provide alternative solutions to the existing condition.

2. Research Methodology

2.1. Research Location

This research was conducted on the road network of *Beringin Janggut* area of Palembang city which consisted of *Jalan Kolonel Atmo, Jalan T.P. Rustam Efendi, Jalan Masjid Lama, Jalan Segaran and Jalan Kebumen Darat*, and also there were 2 intersections included, *Megahria* intersection and *Pasar Burung* intersection. *Simpang Megahria* is an intersection between *Kolonel Atmo* street and *T. P Rustam Effendi* street while *Simpang Pasar Burung* is an intersection between *Kolonel Atmo* street and *The Masjid lama* street, with a limitation of traffic network area of 1 square kilometer.



Figure 1. Road Network Map of *Beringin Janggut* Area

2.2. Data collection

The data used in this study were the primary data obtained directly in the research location and secondary data obtained from other parties. Primary data in this research included traffic data in form of traffic volume, vehicle speed, and parking event obtained by survey at research location, geometric data of road obtained by direct measurement at research location, and air pollutant data obtained by measurement directly in the location through coordination with Technical Implementing Unit of Environmental Laboratory of Environment and Land Agency of South Sumatera Province. Primary data collection were obtained on the same day on 8 March 2018 starting from 06.00 am until 18.00 pm. Weather at the time of survey for data collection was in bright conditions with air temperature 32^o C .

Traffic data collection included traffic volume, vehicle speed and parking data, surveyors on each road segments on the *Beringin Janggut* road network to record traffic volume, vehicle speed and parking events. The data of traffic volume were recorded per hour for each road segment from 6:00 am to 06:00 pm, the vehicle speed data were measured using a speed gun by taking samples of 30 vehicles for each type of vehicle on the *Beringin Janggut* road network, parking was collected by recording parking events following time of entry and exit of vehicles at the parking point at the *Beringin Janggut* area.

The pollutant data collection on ambient air was carried out by placing the air quality measuring device in form of Non-Dispersive Infrared device for measuring CO pollutant concentration, impinger tube for measurement of NO₂, SO₂ and O₃ pollutants, High Volume Air Sampler (HVAS) device used for pollution concentration measurement of PM₁₀. The air pollutant concentration in ambient air were placed at the *Beringin Janggut* intersections where its location was the congestion point and the largest emissions of motor vehicle exhaust on the *Beringin Janggut* road network. Data collection of pollutant concentration in ambient air was conducted from 08.10 am to 05.15 pm. The secondary data used in this research were aerial photographs taken using Google Earth software that will be used as the background for the road network in data processing by using *Vissim* software.

2.3. Data Analysis

Data analysis were conducted by entering data of existing traffic condition and geometric data of road network at research location to *Vissim* software. In this process, to produce the desired value then it required a trial and error process that will be done several times. The calibration and validation process will be carried out to achieve a simulation of traffic flow of *Vissim* software output that was in accordance with the existing condition in the research location. Traffic simulation data of *Vissim* software output according to the existing condition were processed using *EnViver* software to obtain emissions from vehicle exhaust emissions in form of carbon dioxide (CO₂), nitrogen oxide (NO_x), and particulate matter (PM₁₀). The concentration of air pollutants in form of particulate matter (PM₁₀) of *EnViver* software output will be compared with the result of direct measurement of ambient air in the research location to find out the suitability between air pollution calculation as result of activity by using software and reality in the research location. From the existing traffic conditions data, a simulation scenario for handling parking rearrangement will be made on the research location with *Vissim* software and will be followed by air pollution calculation with *EnViver* software, the total emission value of the existing will be compared with the total emission value of the parking rearrangement scenario.

3. Results and Discussion

3.1. Road Network Modeling Using *Vissim* Software

Traffic modeling on the *Beringin Janggut* road network was conducted using *Vissim* software. The data obtained directly from surveys and field measurements were entered into the *Vissim* software. Traffic modeling began with input data base in form of type, class, and vehicle category, driving behavior, followed by making the road network according to the original condition in the field, and then were input the vehicle volume and its composition. The next step was to do the calibration

process by changing average standstill distance value and additive part safety distance value on the driving behavior in the traffic model by trial and error. Validity model was conducted by comparing vehicle volume on existing traffic with vehicle volume in traffic simulation model using *Vissim* software, and then statistical test was conducted using Geoffrey E. Havers (GEH) formula to determine whether or not the simulation model using *Vissim* software was acceptable. The validity of simulation test using *Vissim* software can be seen in table below.

Table 1. Validity Test of Traffic Simulation Models on Existing Conditions Using *Vissim* Software

No	Roads	Existing Vehicle Volume	Vehicle Volume on <i>Vissim</i> Model	Percentage	Statistical Test Value (GEH)	Note
1	<i>Jl. Kolonel Atmo</i>	1607	1423	88,55 %	4,73	Accepted
2	<i>Jl. T.P. Rustam Effendi (Selatan)</i>	1504	1337	88,90 %	4,43	Accepted
3	<i>Jl. T.P. Rustam Effendi (Utara)</i>	240	178	74,17 %	4,29	Accepted
4	<i>Jl. Kebumen Darat</i>	630	519	82,38 %	4,63	Accepted
5	<i>Jl. Masjid Lama</i>	473	376	79,49 %	4,71	Accepted
6	<i>Jl. Segaran</i>	366	278	75,96 %	4,90	Accepted

The road network performances that need to be analyzed using *Vissim* software on the road network were the queue length (Qlen) and delay (Veh Delays). In existing traffic simulations using *Vissim* software, node points to analyze traffic performance were located at *Megahria* intersection and *Pasar Burung* intersection. From the results of existing data processing using *Vissim* software obtained results in form of vehicle volume, queue length (Qlen) and delay (Veh Delays). Recapitulation of data output from *Vissim* software for existing traffic conditions on the road network of *Beringin Janggut* area can be seen in the table below.

Table 2. Existing Road Network Performance Outputs from *Vissim* Software

No.	Vehicle Flows	Vehicle Volume (Veh /hour)	Queue Length (m)	Delays (sec/veh)
1.	<i>Jl. Kolonel Atmo 1 – Jl. Kolonel Atmo 2</i>	1423	52,39	86,67
2.	<i>Jl. Kolonel Atmo 1 – Jl. T.P. Rustam Effendi (South)</i>	1337	53,71	105,37
3.	<i>Jl. Kolonel Atmo 1 – Jl. T.P. Rustam Effendi (North)</i>	178	52,39	61,09
4.	<i>Jl. Kolonel Atmo 2 – Jl. Kebumen Darat</i>	519	126,29	99,26
5.	<i>Jl. Kolonel Atmo 2 – Jl. Masjid Lama 2</i>	376	130,51	99,51
6.	<i>Jl. Masjid Lama 1 – Jl. Masjid Lama 2</i>	278	55,39	46,70

3.2. Calculation of Air Pollution Using *EnViver* Software

The calculation of air pollution was conducted using *EnViver* software. The result of traffic running simulation of the road network of *Beringin Janggut* area using *Vissim* software was in form of a *file.fzp* than imported into *EnViver* software. The results obtained from the *EnViver* software were the

total value of the calculation of vehicle exhaust emissions in form of carbon dioxide (CO₂), nitrogen oxide (NO_x), and particulate matter (PM₁₀) and the color gradient display for each pollutant concentration on the road networks of *Beringin Janggut* area .

Emission		
CO ₂	NO _x	PM ₁₀
548.224 kg	1659.392 g	103.159 g
548.254 kg/h	1659.484 g/h	103.165 g/h
359.645 g/km	1.089 g/km	67.674 mg/km

Figure 2. The Total Value of Vehicle Exhaust Emissions on The Road Networks of *Beringin Janggut* Area

From Figure 2 above, the first line represents the total emission value of vehicle exhaust emission on *Beringin Janggut* road network, the second line shows the value of vehicle exhaust emissions per hour on the road network of *Beringin Janggut* area, and the third line shows the value of vehicle exhaust emissions motor per kilometer on the road network of *Beringin Janggut* Area. From figure 1 can be seen the total value of motor vehicle exhaust emissions on the road network of *Beringin Janggut* area for carbon dioxide (CO₂) pollutant of 548.224 kg, nitrogen oxide (NO_x) pollutants of 1659.392 gr, and particulate matter (PM₁₀) pollutants of 103.159 gr. For the highest concentration of each type of pollutant from the results of *EnViver* software output can be seen in the table below .

Table 3. Highest Concentration of Pollutants Output from *EnViver* Software on Existing Traffic Condition

No	Pollutants	The Highest Concentration
1	Carbon dioxide (CO ₂)	181,000 µg/Nm ³
2	Nitrogen Oxide (NO _x)	534 µg/Nm ³
3	Particulate Matter (PM ₁₀)	36 µg/Nm ³

3.3. Pollutant Concentration on Ambient Air

Data collection for the amount of pollutant concentration in ambient air was conducted on the research location at the measuring point which was considered most representative and held on 08 March 2018 from 08.10 am until 17.15 pm along with the implementation of traffic data survey, where the air sampling process and data processing were conducted under supervision of Technical Implementing Unit of Environmental Laboratory of the Environment and Land Agency of South Sumatra Province.

The data of air pollutant concentrations on ambient air due to traffic activity in the road networks of *Beringin Janggut area* can be seen in the table below.

Table 4. Pollutant Concentrations of Ambient Air on the Road Networks of *Beringin Janggut Area*

	Measurement Time	Pollutant Concentrations					Unit
		CO	NO ₂	SO ₂	O ₃	PM ₁₀	
1	08.10 - 09.10	2,290	97.4	75.8	-	78.8	µg/Nm ³
2	09.20 - 10.20	5,726	98.8	115	-	95.2	µg/Nm ³
3	10.25 - 11.25	10,307	175	131	-	115	µg/Nm ³
4	11.30 - 12.30	9,162	148	129	122	111	µg/Nm ³
5	12.50 - 13.50	6,871	99.2	116	-	92.9	µg/Nm ³
6	14.00 - 15.00	4,581	98.7	115	-	91.5	µg/Nm ³
7	15.10 - 16.10	4,581	147	153	-	102	µg/Nm ³
8	16.15 - 17.15	2,290	98.2	76,4	-	90.1	µg/Nm ³

The comparison between the pollutants concentration in the ambient air on the road network of *Beringin Janggut area* with the threshold of air quality standard based on Government Regulation No. 41 year of 1999 on Air Pollution Control can be seen in the table 5 below.

Table 5. The Comparison of Pollutant Concentrations of Ambient Air on the Road Networks of *Beringin Janggut Area* toward the Threshold of Air Quality Standard

No	Pollutants	Concentrations	Threshold Air Quality Standard
1	Carbon monoxide (CO)	10,307 µg/Nm ³	30,000 µg/Nm ³
2	Nitrogen dioxide (NO ₂)	175 µg/Nm ³	400 µg/Nm ³
3	Sulfur dioxide (SO ₂)	131 µg/Nm ³	900 µg/Nm ³
4	Oxidants (O ₃)	122 µg/Nm ³	235 µg/Nm ³
5	Particulate Matter (PM ₁₀)	115 µg/Nm ³	150 µg/Nm ³

From table 5 it can be seen that the concentration of air pollutants on the road networks of *Beringin Janggut area* is still below the threshold of air quality standard set under Government Regulation No. 41/1999 on Air Pollution Control, but the concern is the PM₁₀ pollutant concentration quite high, so it is necessary to take measurement of air quality improvement especially from the transportation sector as one of contributors to air pollution due to vehicle exhaust emissions.

3.4. The Comparison of Highest Air Pollutant Concentration Output of *EnViver* Software and Concentration of Pollutants on Ambient Air

The same parameter between *EnViver* software output and ambient air measurement results is particulate matter (PM₁₀) concentration. The comparison between PM₁₀ concentration from *EnViver* software output and ambient air measurement on the road network of *Beringin Janggut area* can be seen in the table below.

Table 6. The Comparison between Highest PM₁₀ Concentration Output of *EnViver* Software and Ambient Air Measurements

Particulate Matter (PM ₁₀) Concentration	
<i>EnViver</i> Software Output	Ambient Air Measurement Results
36 µg/Nm ³	115 µg/Nm ³

From table 6 above, the concentration of particulate matter (PM₁₀) of ambient air measurements has a difference of 79 µg/Nm³ from the *EnViver* software output, the PM₁₀ concentration measured on the ambient air above the highest PM₁₀ concentration value of the *EnViver* software output. The highest concentration of PM₁₀ for ambient air measurement occurred for 1 hour from 10:25 am to 11:25 am and almost simultaneously with peak traffic volumes on the road network of *Beringin Janggut* area that occurred at 11.00 am until 12.00 pm which was simulated with the *Vissim* software device on time interval of 3600 seconds, where the simulation results of *Vissim* software were used to measure PM₁₀ concentration by using *EnViver* software. The difference of PM₁₀ concentration occurred because the *EnViver* software calculated the concentration of air pollutants based only on emissions from transport activities while the ambient air measurement calculated the concentration of air pollutants from all sources of pollutants where in this research location sites there were grocery stores and materials warehouses. When the measurement of ambient air was conducting, the loading and unloading activities occurred in time at 11:00 am to 12:00 pm.

Another possible cause of the different air pollutant concentrations was the lack of accuracy of the *Vissim* software traffic model on existing traffic conditions in the field, and also occurred due to errors during ambient air measurements caused by wind and humidity pressures.

3.5. Alternative 1 Scenario by Rearrangement Parking Points

At the research location there are parking spots along the road network of *Beringin Janggut* area. On the T.P Rustam Effendi street, there are several parking spots disturbing the traffic flow, especially during peak hours and cause congestion for transportation to *Kolonel Atmo* street. On *Beringin Janggut* street has been closed completely because it is used as a trading place and will be planned to be re-arranged, so that the parking point that disrupts the traffic flow in T.P. Rustam Effendi street can be partially transferred to *Beringin Janggut* street. The road network performance results from *Vissim* software output with alternative 1 scenario parking rearrangement can be seen in the table below.

Table 7. Road Network Performance using Alternative 1 Scenario Output from *Vissim* Software

No.	Vehicle Flow	Vehicle Volume (veh/hour)	Queue Length (m)	Delays (sec/veh)
1.	<i>Jl. Kolonel Atmo 1 – Jl. Kolonel Atmo 2</i>	1,438	31.75	15.14
2.	<i>Jl. Kolonel Atmo 1 – Jl. T.P. Rustam Effendi (South)</i>	1,340	31.75	14.48
3.	<i>Jl. Kolonel Atmo 1 – Jl. T.P. Rustam Effendi (North)</i>	184	30.88	10.90
4.	<i>Jl. Kolonel Atmo 2 – Jl. Kebumen Darat</i>	524	123.30	88.83
5.	<i>Jl. Kolonel Atmo 2 – Jl. Masjid Lama 2</i>	393	123.76	89.79
6.	<i>Jl. Masjid Lama 1 – Jl. Masjid Lama 2</i>	297	48.87	38.11

After modeling using *Vissim* software, emission calculation values from vehicle exhaust emission were input into *EnViver* software for traffic simulation model of parking rearrangement. The results obtained from *EnViver* software showing there were a lot of rearrangements on the road networks of *Beringin Janggut* area as shown in the figure below.

Emission		
CO ₂	NO _x	PM ₁₀
393.715 kg	1069.236 g	82.302 g
393.781 kg/h	1069.414 g/h	82.315 g/h
275.037 g/km	746.936 mg/km	57.493 mg/km

Figure 3. The Total Value of Vehicle Exhaust Emissions on The Road Networks of Beringin Janggut with The Parking Rearrangement Scenario

From Figure 3 it shows the total value of motor vehicle exhaust emission on road network of *Beringin Janggut* area with implementation of parking rearrangement scenario for carbon dioxide (CO₂) pollutant of 393.715 kg, nitrogen oxide (NO_x) of 1069.236 gr, and Particulate Matter (PM₁₀) of 83.302 gr. For the highest concentration of each type of pollutants the results from *EnViver* software can be seen in the table below

Table 8. The Highest Concentration of Pollutants Output from *EnViver* Software on Traffic Conditions with Implementation of Parking Rearrangement Scenario

No	Pollutants	The Highest Concentration
1	Carbon dioxide (CO ₂)	166,000 µg/Nm ³
2	Nitrogen Oxide (NO _x)	577 µg/Nm ³
3	Particulate Matter (PM ₁₀)	32.1 µg/Nm ³

3.6. Alternative 2 Scenario Separating Lane between Public Vehicle and Private Vehicles

Kolonel Atmo street in the road network of *Beringin Janggut* area is passed by public transportation from Lemabang and KM 5 area, these public transportation often stop to wait for passengers so it affects the traffic flow on these street. In alternative 2, it will be planned to lane separation between public transportation and private vehicles, public transportation is on the left lane of Kolonel Atmo street. The road network performance from *Vissim* software output for alternative 2 scenario with lanes separation between public and private vehicles can be seen in the table below.

Table 9. Road Network Performance with Alternative 2 Scenario Results from *Vissim* Software Output

No.	Traffic flow	Vehicle Volume (veh/hour)	Queue Length (m)	Delays (sec/veh)
1.	<i>Jl. Kolonel Atmo 1 – Jl. Kolonel Atmo 2</i>	1,418	52.41	81.64
2.	<i>Jl. Kolonel Atmo 1– Jl. T.P. Rustam Effendi (South)</i>	1,328	52.10	80.91
3.	<i>Jl. Kolonel Atmo 1 – Jl. T.P. Rustam Effendi (North)</i>	181	52.41	60.99
4.	<i>Jl. Kolonel Atmo 2 – Jl. Kebumen Darat</i>	536	73.14	36.11
5.	<i>Jl. Kolonel Atmo 2 – Jl. Masjid Lama 2</i>	382	73.32	26.13
6.	<i>Jl. Masjid Lama 1 – Jl. Masjid Lama 2</i>	304	35.74	18.23

After modeling using *Vissim* software then vehicle exhaust emissions will be computed using *EnViver* software for traffic simulation models as alternatives of lane separation between public and private vehicles. Results obtained from *EnViver* software can be seen in the figure below.

Emission		
CO ₂	NO _x	PM ₁₀
447.136 kg	1304.450 g	93.568 g
447.161 kg/h	1304.522 g/h	93.573 g/h
312.042 g/km	910.335 mg/km	65.298 mg/km

Figure 4. Total Vehicle Exhaust Emissions with Alternative Lane Separation between Public Vehicles and Private Vehicles

From Figure 4 can be seen that the total value of vehicle exhaust emission on road network of *Beringin Janggut* area for carbon dioxide (CO₂) is 447.136 kg, nitrogen oxide (NO_x) is 1034.450 gr, and Particulate Matter (PM₁₀) is 93.568 gr. For the highest concentration of each type of pollutants, the results of *EnViver* software can be seen in the table below

Table 10. The Highest Concentrations of Pollutants Outputs from *EnViver* Software Traffic by Implementing Scenario of Lanes Separation between Public Vehicles and Private Vehicles

No	Pollutants	The Highest Concentration
1	Carbon dioxide (CO ₂)	184,000 µg/Nm ³
2	Nitrogen Oxide (NO _x)	657 µg/Nm ³
3	Particulate Matter (PM ₁₀)	35.1 µg/Nm ³

3.7. Analysis of Road Network Performance Comparison

Comparison between road network performance on the road networks of *Beringin Janggut* area for existing condition, alternative 1 with parking rearrangement and alternative 2 with lane separation between public vehicle and private vehicle traffic simulation result using *Vissim* software are presented in table 11. below.

Table 11. The Comparison of Road Network Performance from *Vissim* Software Output

Traffic Flow	Vehicle Volume (veh/hour)	Queue Length (m)	Delays (sec/veh)
Existing Condition			
<i>Jl. Kolonel Atmo 1 – Jl. Kolonel Atmo 2</i>	1,423	52.39	86.67
<i>Jl. Kolonel Atmo 1 – Jl. T.P. Rustam Effendi (South)</i>	1,337	53.71	105.37
<i>Jl. Kolonel Atmo 1 – Jl. T.P. Rustam Effendi (North)</i>	178	52.39	61.09
<i>Jl. Kolonel Atmo 2 – Jl. Kebumen Darat</i>	519	126.29	99.26
<i>Jl. Kolonel Atmo 2 – Jl. Masjid Lama 2</i>	376	130.51	99.51
<i>Jl. Masjid Lama 1 – Jl. Masjid Lama 2</i>	278	55.39	46.70

Table 11. Continue

Traffic Flow	Vehicle Volume (veh/hour)	Queue Length (m)	Delays (sec/veh)
Alternative 1			
<i>Jl. Kolonel Atmo 1 – Jl. Kolonel Atmo 2</i>	1,438	31.75	15.14
<i>Jl. Kolonel Atmo 1 – Jl. T.P. Rustam Effendi (Selatan)</i>	1,340	31.75	14.48
<i>Jl. Kolonel Atmo 1 – Jl. T.P. Rustam Effendi (Utara)</i>	184	30.88	10.90
<i>Jl. Kolonel Atmo 2 – Jl. Kebumen Darat</i>	524	123.30	88.83
<i>Jl. Kolonel Atmo 2 – Jl. Masjid Lama 2</i>	393	123.76	89.79
<i>Jl. Masjid Lama 1 – Jl. Masjid Lama 2</i>	297	48.87	38.11
Alternative 2			
<i>Jl. Kolonel Atmo 1 – Jl. Kolonel Atmo 2</i>	1,418	52.41	81.64
<i>Jl. Kolonel Atmo 1 – Jl. T.P. Rustam Effendi (South)</i>	1,328	52.10	80.91
<i>Jl. Kolonel Atmo 1 – Jl. T.P. Rustam Effendi (North)</i>	181	52.41	60.99
<i>Jl. Kolonel Atmo 2 – Jl. Kebumen Darat</i>	536	73.14	36.11
<i>Jl. Kolonel Atmo 2 – Jl. Masjid Lama 2</i>	382	73.32	26.13
<i>Jl. Masjid Lama 1 – Jl. Masjid Lama 2</i>	304	35.74	18.23

From table 11 can be seen that there was a decrease in the queue length and delays time when applied alternative 1 scenario or alternative 2 scenario. On vehicle flow from *Jl. Kolonel Atmo* to *T.P. Rustam Effendi* (south) with the highest delay time in the existing condition was 105.37 sec/veh decreased to 14.48 sec/veh when applied alternative 1 scenario, it became 80.91 sec/veh when applied alternative 2 scenario. On vehicles flows from *Jl. Kolonel Atmo 2* to *Jl. Masjid Lama 2*, the highest queue length in the existing condition was 130.51 m decreased to 123.76 m when applied alternate 1 scenario, and it became 73.32 m when applied alternative 2 scenario.

3.8. Comparison Analysis of Vehicle Exhaust Emission Value

The Comparison between the total value of vehicle exhaust emissions and the highest concentration value of each pollutant in *Beringin Janggut* area for existing condition, alternative 1 scenario with parking rearrangement and alternative 2 scenario with separating lane between public vehicle and private vehicles, the calculation result from *EnViver* software can be seen in table and picture below.

Table 12. The Comparison of Total Emission Values

No.	Conditions	Pollutants		
		CO ₂	NO _x	PM ₁₀
1.	Existing	548.224 kg	1659.392 gr	103.159 gr
2.	Alternative 1 Scenario Parking Rearrangement	393.715 kg	1069.236 gr	82.302 gr
3.	Alternative 2 Scenario Lanes Separation between Public Vehicles and Private Vehicles	447.136 kg	1304.450 gr	93.568 gr

From table 12 it can be seen that there is a decrease in the total value of vehicle exhaust emission for carbon dioxide (CO₂) from the existing condition of 207.485 kg at alternatives 1 and 154.064 on

alternative 2. For nitrogen oxide (NO_x) there is a decrease in total emission value from the existing condition of 562.601 gr on alternative 1 and 327.387 gr on alternative 2. For Particulate Matter (PM₁₀) there is a decrease in total emission value of 38.765 gr from the existing condition in alternative 1, whereas in alternative 2 there is a decrease in total emission value of 27.499 gr from the existing condition.

Among the three types of air pollutants mentioned above, carbon dioxide (CO₂) is the most dangerous pollutant for humans when exposed for long periods of time, the scenario of parking rearrangement is considered quite effective in reducing air pollution on the road networks of *Beringin Janggut* Area.

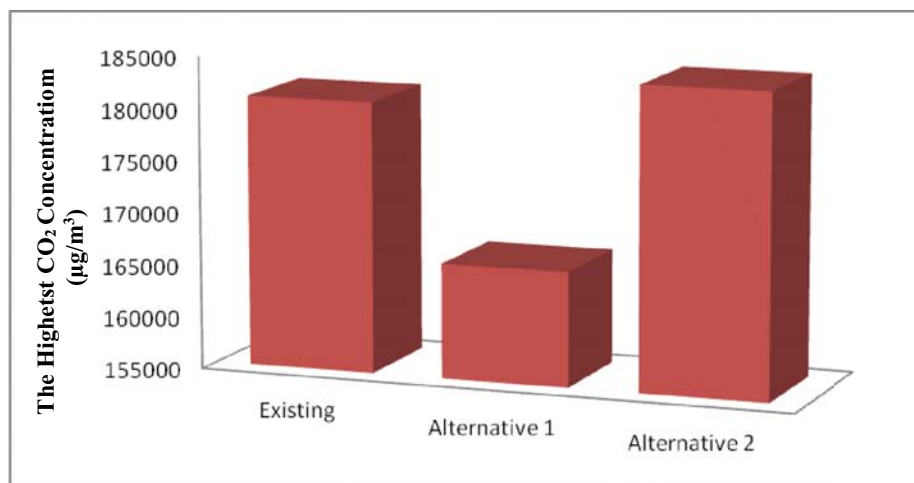


Figure 5. The Comparison of The Highest Concentration of Carbon Dioxide (CO₂) from *EnViver* Software

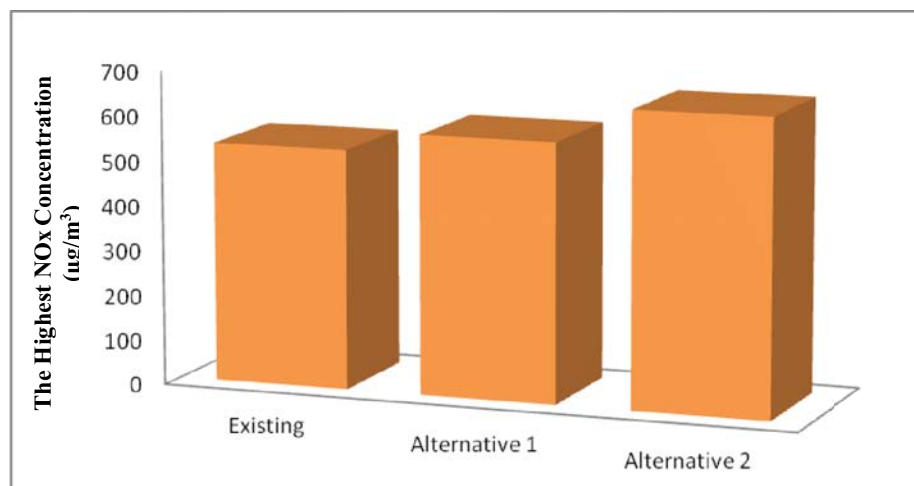


Figure 6. The Comparison of The Highest Concentration of Nitrogen Oxide (NO_x) from *EnViver* Software

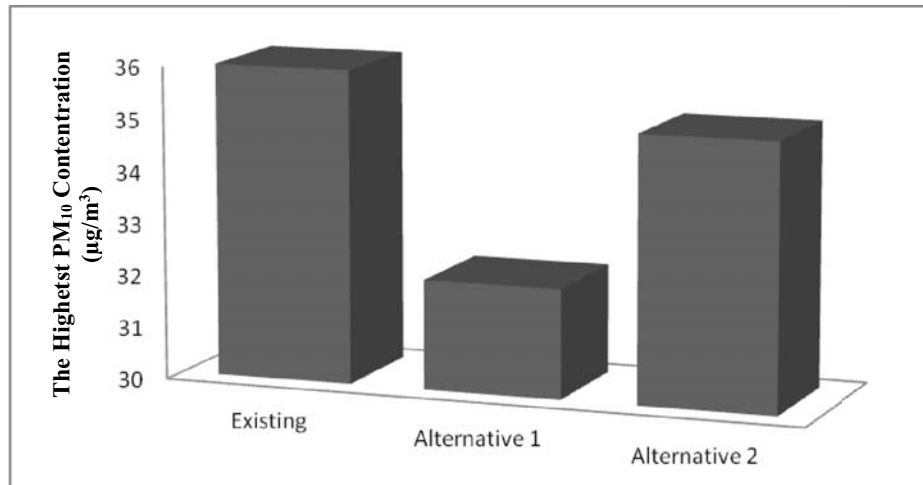


Figure 7. The Comparison of The Highest Concentrations of Particulate Matter (PM₁₀) from *EnViver* Software

From Figure 5, Figure 6, and Figure 7. It can be seen that alternative 1 is better than alternative 2 in reducing air pollutant concentration due to vehicle exhaust emission on the road network of *Beringin Janggut* area.

4. Conclusions

Based on the results of data analyses, it can be concluded as follows:

1. The highest concentration of air pollutants due to vehicle exhaust emissions in the road networks of *Beringin Janggut* area from *EnViver* software output were 181,000 µg/Nm³ of CO₂, 534 µg/Nm³ of NO_x, and 36 µg/Nm³ of PM₁₀ concentration.
2. From *EnViver* software output obtained a difference of 79 µg/Nm³ of particulate matter (PM₁₀) from ambient air measurement
3. Particulate matter concentration (PM₁₀) of ambient air measurements from *EnViver* software output on the road networks of *Beringin Janggut* area was still below the ambient air quality standard as specified under Government Regulation No. 41 of 1999 on Air Pollution Control.
4. The alternative 1 scenario for parking rearrangement was better than the alternative 2 for the lane separation scenario between public and private vehicles as it was quite effective in reducing air pollution on the road networks of *Beringin Janggut* Area.
5. The results of this research are in line with the research conducted on the M30 road in Madrid City [5] where there is a decrease in the total value of vehicle exhaust emissions when applied improving scenarios to existing traffic conditions using simulation software.

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