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IDENTIFYING THE INFLUENCE OF TRAFFIC MANAGEMENT ON VEHICLE EMISSIONS AND THE DISTRIBUTION OF AIR DISPERSION IN THE MAKASSAR PORT AREA

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Air pollution in several cities in Indonesia has been increasing significantly over the years. One of the primary triggers is the rise in motor vehicle activity. This increase is due to the improving economic conditions and the decreasing prices of motor vehicles. Vehicles produce various types of pollutants. The pollutants contained in vehicle exhaust gas are carbon monoxide (CO), nitrogen oxide (NO_x), sulfur (SO_x) and dust (PM).

One of the busiest areas for motorized vehicle activity is the Makassar Port Area, which is the largest port in Eastern Indonesia. This area experiences high vehicle activity. The emissions reviewed in this research are CO (carbon monoxide) and NO_x (nitrogen oxide) in the Makassar Port Area which is located on Jalan Nusantara, Jalan Sulawesi, Jalan Siswa Army, Dr. Wahidin Jalan Sudirohusodo, Jalan Sangir, Jalan Kalimantan, Jalan Sarappo, Jalan Banda and Jalan Butung.

This research utilizes historical data on traffic volume, wind speed and direction, air humidity, air temperature, air pressure, solar radiation, cloud cover and surface height. Air dispersion analysis was carried out using AERMOD software. The highest emissions obtained were 67,121 $\mu g/m^3$ for CO and 9,570 $\mu g/m^3$ for NO_x under existing conditions and after implementing traffic management measures, the highest emissions were reduced to 45,737 $\mu g/m^3$ for CO and 7,217 $\mu g/m^3$ for NO_x. These results conclude that traffic management can reduce air pollution. Air dispersion is not only influenced by vehicle volume but also meteorological factors. This can be seen in the dispersion results. Where, the conditions before and after traffic management showed differences in terms of the distribution of air dispersion

Keywords: carbon monoxide (CO), nitrogen oxide (NO_x), AERMOD, traffic management, air dispersion

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1. Introduction

Air pollution in several cities in Indonesia has increased significantly over the years. This increase is largely influenced by motor vehicle activities which contribute almost 80 % of air pollution. During the combustion process, motorized vehicles emit dangerous gases including carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NO_x), sulfur oxides (SO_x), and particulate matter (PM) [1].

In general, among the various sectors that contribute to air pollution, the transportation sector has a much greater role than other sectors [2]. In large cities, motor vehicle exhaust emissions contribute 6070 % of air pollution, while emissions from industrial smokestacks only contribute around 1015 %. Remaining sources of air pollution include residential emissions, waste burning, forest fires, and other sources of combustion [3].

In Makassar City, the number of two-wheeled vehicles increased by 1314 %, and four-wheeled vehicles by 810 %. In 2021, the number of two-wheeled and four-wheeled vehicles in Makassar will reach 2.9 million, with details of motorbikes 1.6 million and cars 1.3 million. This number exceeds the population of Makassar which is approximately 1.7 million people [4]. This unbalanced number of vehicles can create environmental problems, namely air pollution.

One way to reduce air pollution is by carrying out traffic management. Traffic management is a process of regulating and using an existing road system with the aim of meeting a certain goal without the need for additional/creating infrastructure [5].

Therefore, traffic management is needed to reduce pollution produced by motorized vehicles.

2. Literature review and problem statement

The author [6] states that the sector that plays the most role in air pollution is the transportation sector. Research [7] states that the higher the vehicle volume, the higher the emissions produced. However, this research does not discuss air dispersion.

Meteorological factors play an important role in determining air quality in an area. Atmospheric conditions are largely influenced by various meteorological factors, including wind speed and direction, humidity, air temperature, air pressure and surface height. Apart from the quantity of pollutant sources, these meteorological parameters also have an impact on the levels of pollutant gases in the air. Therefore, environmental conditions cannot be ignored [8]. However, it does not discuss the effect of traffic management on the emissions produced.

The sufficient real-time traffic data is necessary, including the fine vehicle (e. g., type, fuel, emission standard), traffic detection information (e. g., traffic volume, vehicle fleet composition, traffic speed), road information (e. g., location, type, length, direction), weather information (e. g., wind, clouds, humidity, temperature, pressure) and other information in urban environments to carry out appropriate control of vehicle emissions [9]. However, this study did not consider surface contour factors.

Therefore, the total pollutant emission load for each network is calculated by adding up the emission load released by the emission sources in the network. To visualize the spatial distribution of emissions, GIS (Geographic Information System) is used. GIS can provide an accurate representation of the spatial distribution of air pollutant emissions over large spatial scales [10]. However, this study did not consider meteorological factors that influence the spread of pollution.

Research conducted by [11] concluded that road transportation is the main source of pollutants such as NO_x (57 %) CO (93 %) NMVOC (96 %) and BC (75 %), with heavy vehicles being the main source of NO_x and BC, and motorbikes being the main source of these pollutants. However, this research does not discuss the influence of traffic management on the air dispersion model.

3. The aim and objectives of the study

The aim of this research is to identify the regularity of vehicle emissions and pollutant distribution. This can help in anticipating the impacts that pollutants will have.

To achieve this aim, the following objectives are accomplished:

– calculate the burden of carbon monoxide (CO) and nitrogen oxide (NO_x) and analyze the distribution of carbon monoxide (CO) and nitrogen oxide pollutants emissions in the area around the Port of Makassar due to motorized vehicles;

– calculate analysis of carbon monoxide (CO) and nitrogen oxide (NO_x) emission loads after traffic management as well as for distribution patterns and concentration levels of carbon monoxide (CO) and Nitrogen Oxide pollutants and analyze the distribution of carbon monoxide (CO) and nitrogen oxide pollutants (NO_x) in the Makassar Port Area using AERMOD.

4. Materials and Methods

This research investigates the effect of traffic management on motor vehicle emissions. This research uses traffic volume to calculate motor vehicle emissions and uses AERMOD to describe pollutant dispersion.

This research was carried out for 2 hours in the morning from 07:30 to 09:30, 2 hours in the afternoon from 12:30 to 14:30, and another 2 hours in the afternoon from 15:30 to 17:30. This research uses traffic volume data to calculate vehicle emissions and uses data on Wind Speed, Wind Direction, Temperature, Air Humidity, Air Pressure, Cloud Cover and Solar Radiation to determine the distribution of CO and NO_x pollutants. The following are the results of the recap of existing traffic volume data.

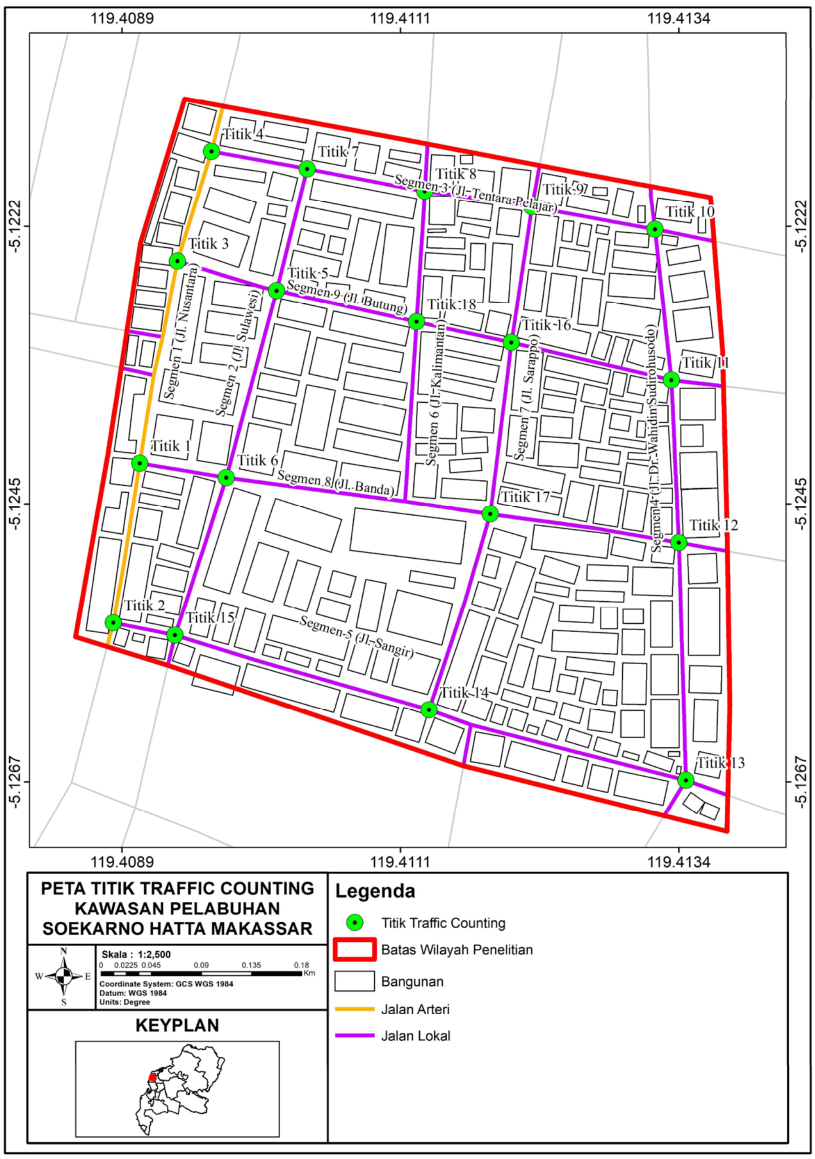

Fig. 1. Location map study

Previous research used CALINE 4. This research uses AERMOD. AERMOD, introduced by the US EPA in 2004, is a stabilized plume model. The modeling system consists of one main program (AERMOD) and two preprocessors (AERMET and AERMAP). AERMET's main function is to calculate layer parameters for use by AERMOD, while AERMAP functions as a pre-processor. In general, AERMOD models plumes as a combination of two restricted cases: horizontal dispersion (collision with the terrain) and dispersion following the contour of the terrain. Consequently, in all scenarios, the total concentration at the receptor is limited by the predicted concentration of these conditions. This is true even for flat terrain. By incorporating the discharge height, the AERMOD model calculates the total concentration as the weighted sum of the relevant concentrations of two finite cases or terrain contours [12]. AERMOD is a spatial air quality distribution model designed to comply with regulations and is capable of predicting air quality distribution from up to 50 different sources (point, area or volume). Apart from that, it can estimate the movement of air quality from various sources [13].

This research uses the traffic enumeration method. Enumeration of traffic volume was carried out by recording vehicles passing at each location for 6 hours. 2 hours in the morning from 07:30 to 09:30, 2 hours in the afternoon from 12:30 to 14:30, and another 2 hours in the afternoon from 15:30 to 17:30. This research uses traffic volume data to calculate vehicle emissions and uses data on wind speed, wind direction, temperature, air humidity, air pressure, cloud cover and solar radiation to determine the dispersion of CO and NO_x pollutants.

Calculation emission vehicle use equation (1):

$$Ep = \sum_{i=1}^{n} L \times Ni \times Fpi, \quad (1)$$

where E – intensity emission from something section (g/hour/km);

p – type of pollutant estimated;

N – number vehicles motorized type i who passed by segment road (vehicles /hour);

I – type vehicle motorized based on type material burn;

L – length of the road under study (km);

F – emission factor vehicle motorized type i (g/km).

Unlike most previous studies, which solely calculate air pollution without considering meteorological factors and air dispersion, this research aims to quantify emissions and develop a dispersion model.

The steps taken by the author to obtain and analyze data are shown in Fig. 2.

Fig. 2 illustrates the data collection process and the steps for analyzing the data. The first step involves calculating the traffic volume and cross. Afterward, vehicle emission calculations are performed, followed by the collection of meteorological data obtained from the Indonesian Agency for Meteorological, Climatological, and Geophysics. Subsequently, wind rose diagrams are generated using WRPLOT, and topographic data is processed using AERMAP. The final step involves inputting emission data into AERMOD.

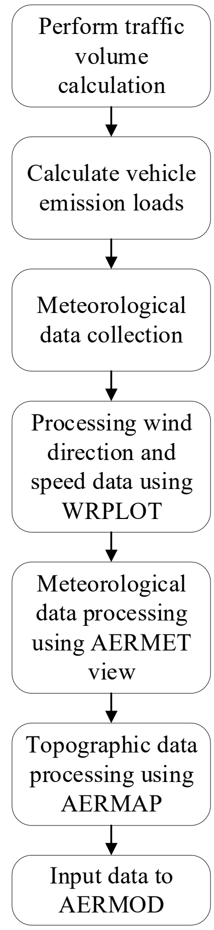

Fig. 2. Flow diagram

5. Research results of AERMOD dispersion model

5. 1. Calculation of emission condition existing and analyze the distribution of carbon monoxide and nitrogen oxide pollutants

Table 1 presents traffic volume data at the research location.

Table 1

Traffic volume data for existing conditions

Street Name	Vehicle volume, vehicles/hour			
	Motor vehicle	Light vehicle	Heavy vehicle	Total
Nusantara	3892	3913	777	8582
Sulawesi	4081	1214	183	5478
Tentara Pelajar	5856	2163	362	8381
Dr. Wahidin Sudirohusodo	3199	1439	185	4823
Sangir	3296	535	52	3883
Kalimantan	397	113	31	541
Sarappo	1180	253	74	1507
Banda	146	76	6	228
Butung	697	242	34	973

The highest traffic volume is on Nusantara Street with a total vehicle volume of 8582 vehicles/hour and the lowest total traffic volume is on Banda Street 228 vehicles/hour.

Table 2 presents the results of calculating carbon monoxide (CO) and nitrogen oxide (NO_x) emissions under existing conditions.

The highest CO emissions were on Tentara Pelajar street at 10,812 μg/m^3, and the highest NO_x emission on Nusantara Street at 1,551 μg/m^3.

CO dispersion results were obtained taking into account Wind Rose (Fig. 3) using AERMOD under conditions existing.

The dominant wind direction moves from Southeast to South. Wind speed ranges from 2–4 *m/s*. Wind frequency is most often in the range 2–4 m/s, which is 51.6 % (Fig. 4).

Fig. 5 illustrates that the highest CO concentration recorded was 42.714 μg/m^3 which is depicted in red, while the lowest concentration shown in light purple was 427 μg/m^3.

Fig. 6 depicts the results of NO_x pollutant dispersion in existing conditions.

Fig. 6 illustrates that the highest NO_x concentration recorded at 5.864 μg/m^3 is depicted in red, while the lowest concentration, shown in light purple, is 59 μg/m^3.

Table 2

Total emission calculation results for existing conditions

Street Name	Segment length, km	Total emissions CO, grams/second	Total emissions NO_x, grams/second
Nusantara	0.434	10.637	1.551
Sulawesi	0.438	7,999	0.559
Tentara Pelajar	0.393	10.812	0.925
Dr. Wahidin Sudirohusodo	0.461	6.900	0.602
Sangir	0.231	3.222	0.222
Kalimantan	0.283	0.550	0.049
Sarappo	0.466	2.521	0.148
Banda	0.478	0.323	0.030
Butung	0.304	0.985	0.094

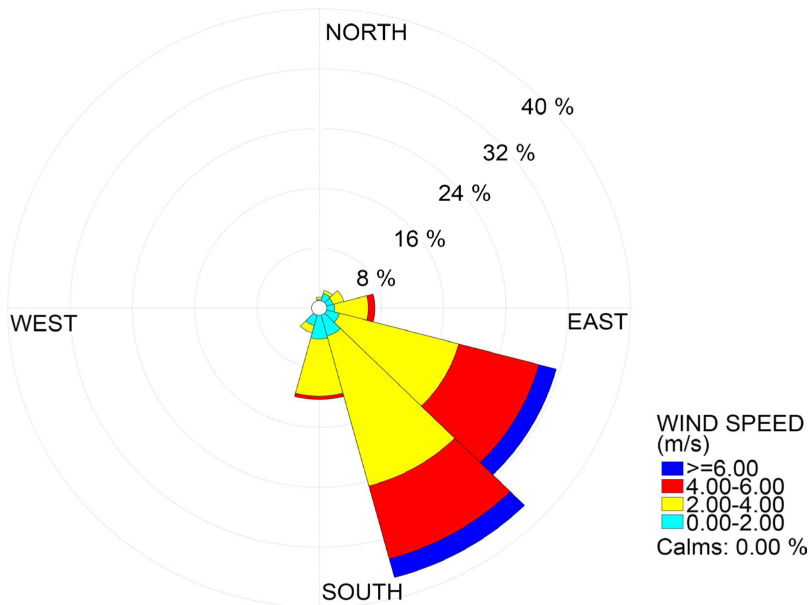

Fig. 3. Windrose

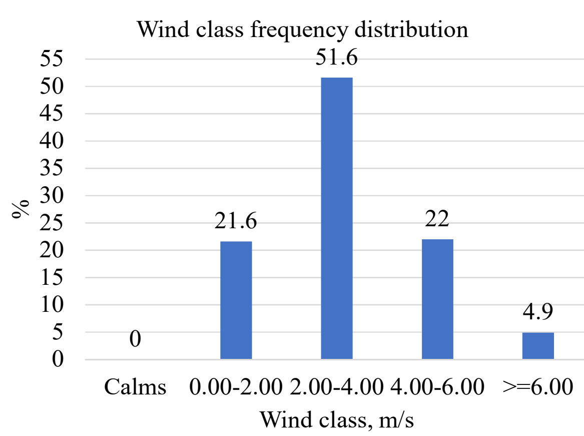

Fig. 4. Distribution frequency wind

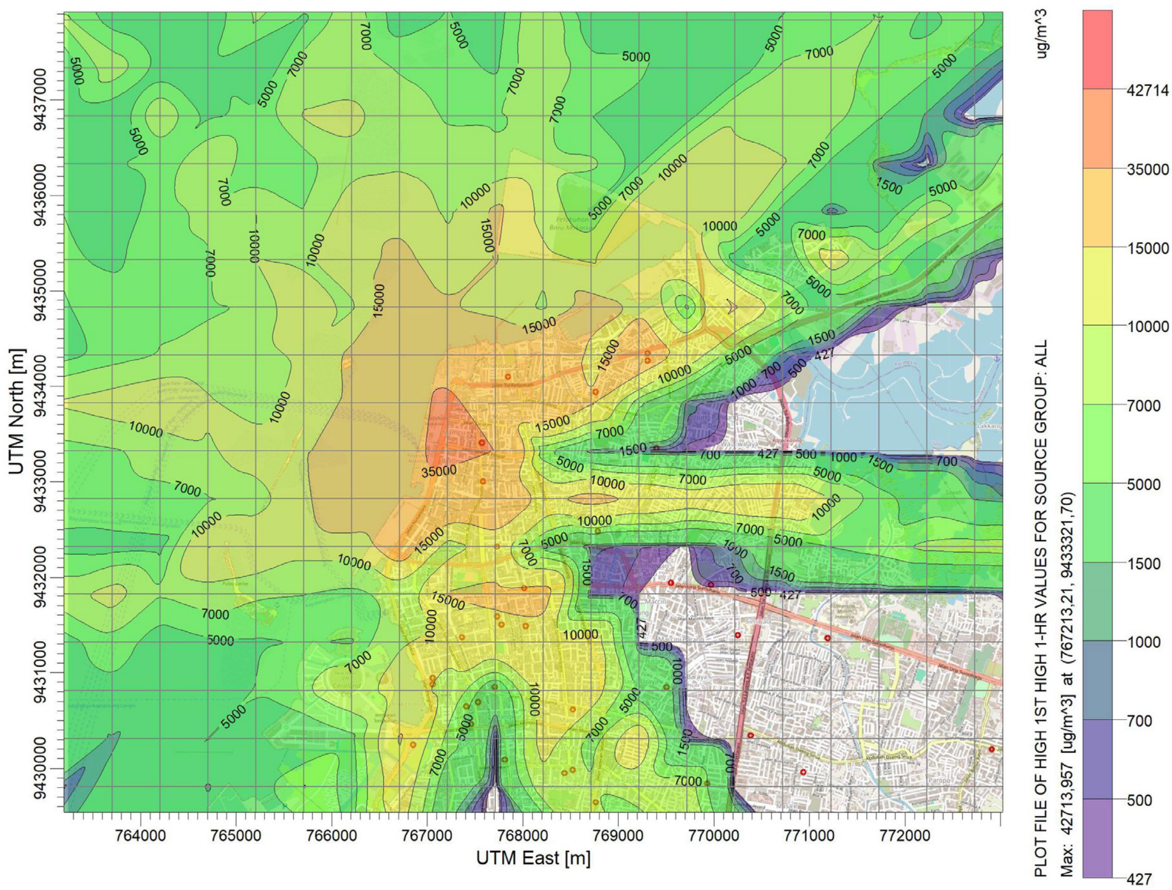

Fig. 5. CO pollutant dispersion in existing conditions

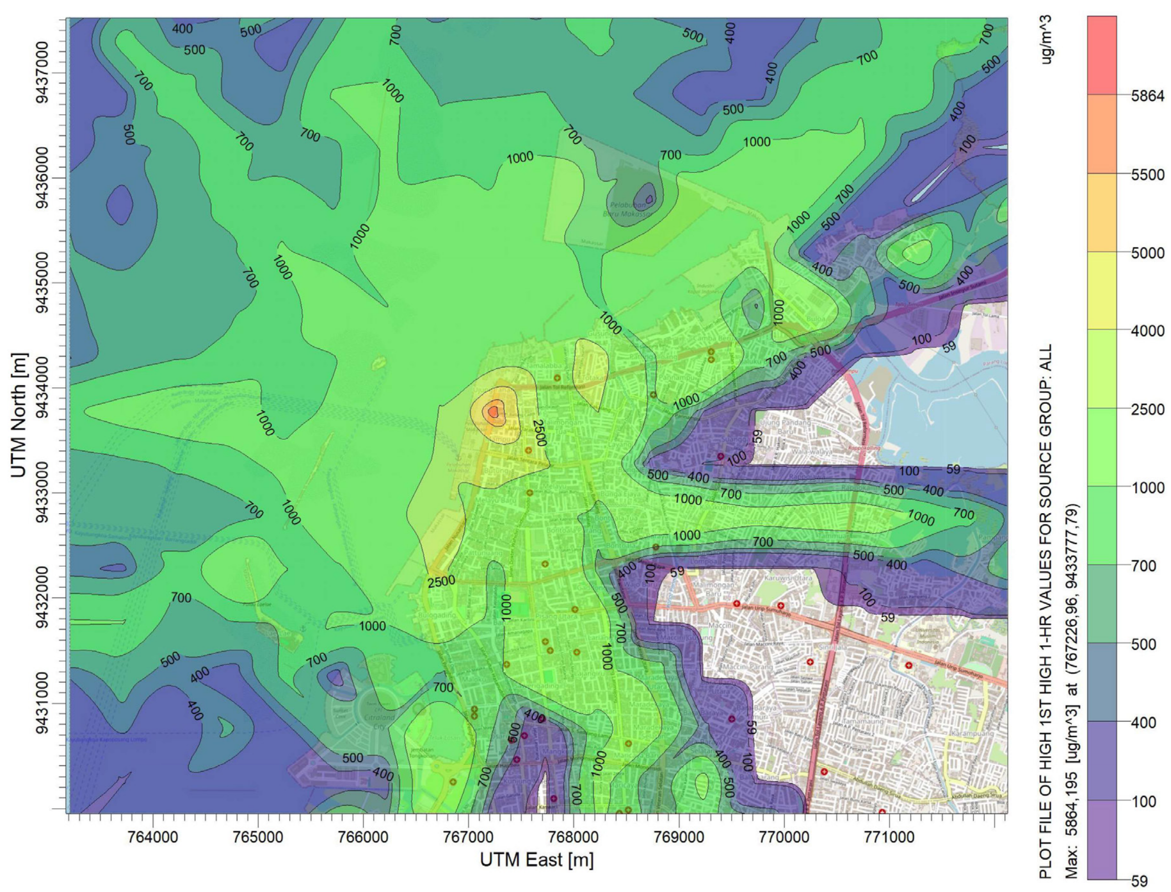

Fig. 6. NO_x dispersion conditions existing conditions

5. 2. Calculation emission vehicle after traffic management and analyze the distribution of carbon monoxide and nitrogen oxide pollutants

Table 3 presents traffic volume data after traffic management.

The highest traffic volume is on Nusantara street with a total vehicle volume of 46.355 vehicles/hour and the lowest total traffic volume is on Kalimantan street, namely 7.621 vehicles/hour.

Table 4 presents the results of calculating carbon monoxide (CO) and nitrogen oxide (NOx) emissions after traffic management.

The highest CO emissions were on Tentara Pelajar street at 9,555 μg/m^3, while the highest NO_x emissions were on Nusantara Street at 7,217 μg/m^3.

Table 4

Calculation results of total emissions after traffic management

Street name	Segment length, km	Total emissions CO, grams/second	Total emissions NO_x, grams/second
Nusantara	0.434	7.659	1.223
Sulawesi	0.438	7.292	0.481
Tentara Pelajar	0.393	9.555	0.786
Dr. Wahidin Sudirohusodo	0.461	6.146	0.519
Sangir	0.231	3.115	0.210
Kalimantan	0.283	0.472	0.041
Sarappo	0.466	2.216	0.115
Banda	0.478	0.298	0.027
Jl. Butung	0.304	0.894	0.084

Table 3

Traffic volume after rraffic management

Street Name	Traffic volume, vehicles/hour		Vehicle volume, vehicle/hour
	MC	LV	
Nusantara	23308	23047	46355
Sulawesi	21636	8214	29850
Tentara Pelajar	30530	15100	45630
Dr. Wahidin Sudirohusodo	24582	10519	35101
Sangir	22627	6243	28870
Kalimantan	5810	1811	7621
Sarappo	13130	3079	16209
Banda	10978	4532	15510
Butung	11402	3366	14768

Fig. 7 depicts the results of CO pollutant dispersion after traffic management.

Fig. 7 illustrates that the highest CO concentration recorded was 36.199 μg/m^3, depicted in red, while the lowest concentration, shown in light purple, was 362 μg/m^3.

Fig. 8 depicts the results of CO pollutant dispersion after traffic management.

Fig. 8 illustrates that the highest NO_x concentration was recorded at 3.560 μg/m^3, depicted in red, while the lowest concentration, shown in light purple, was 45 μg/m^3.

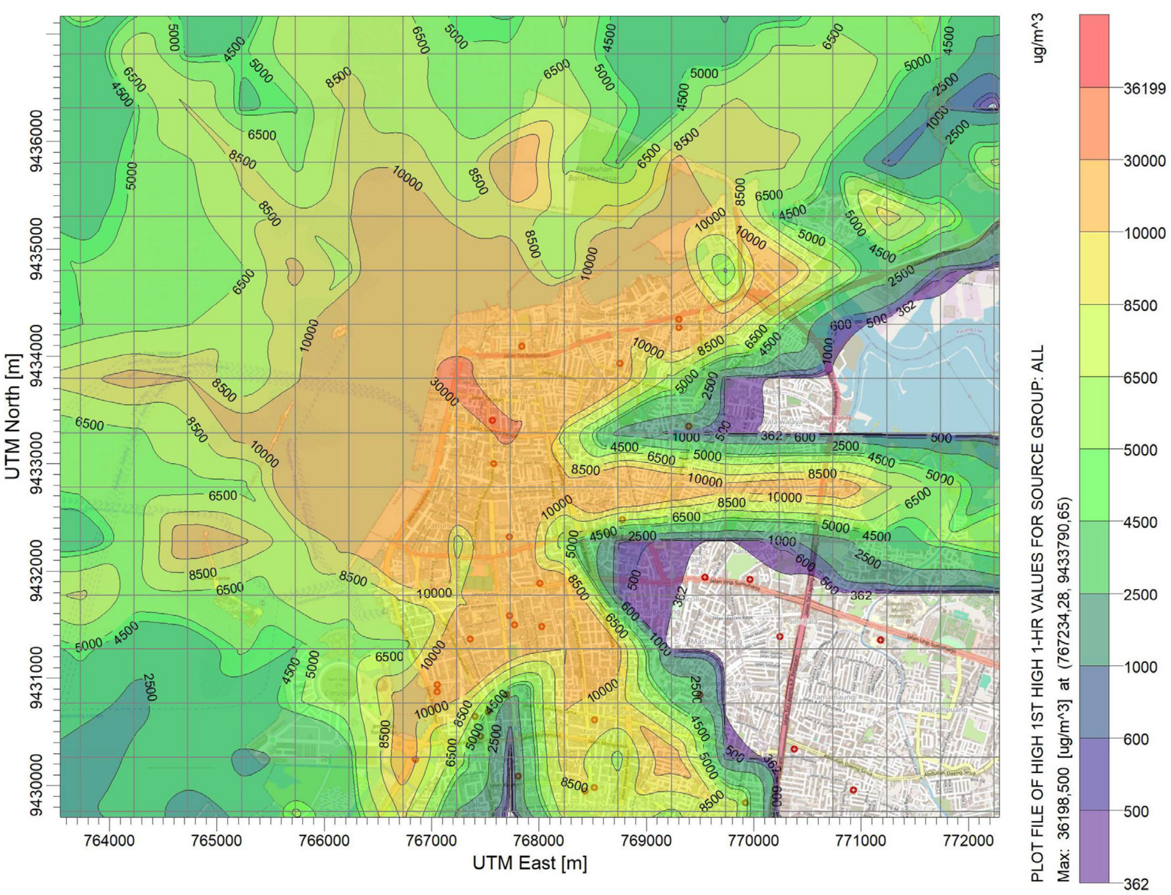

Fig. 7. Dispersion of CO after traffic management

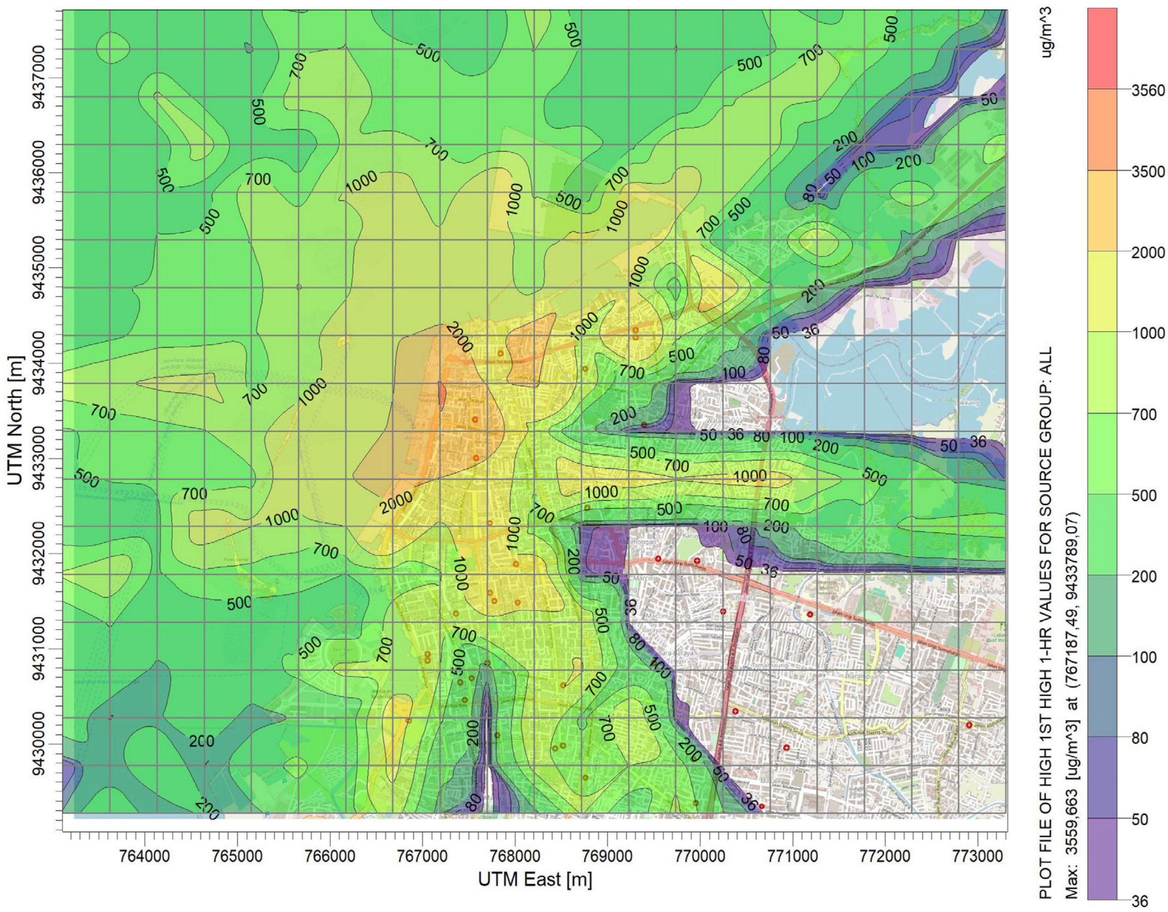

Fig. 8. NO_x dispersion after traffic management

6. Discussion of CO and NO_x dispersion model results

Based on the modeling results, it was found that traffic volume influences the amount of vehicle emissions. Where after implementing Traffic Management, it is seen that there is a reduction in the resulting emissions. Before implementing traffic management, the highest CO emission concentration was recorded at 10,637 μg/m^3, the highest NO_x concentration was 1,551 μg/m^3 (Table 2). Dangerous areas from the modeling results are symbolized in red. The radius of spread of carbon monoxide pollution gas on Jalan Nusantara, Student Army, Jalan Sarappo, and Jalan Dr.Wahidin Sudirohusodo. This is caused by windrose which shows that the wind is moving from the Southeast towards the South. This results in the distribution of CO and NOx pollutants in this study, namely that as you move towards the south the concentration will increase to the highest concentration point at that location. These results indicate that the distribution of air dispersion is not only influenced by vehicle emissions but is also influenced by meteorological factors.

After implementing traffic management, the highest CO decreased to 7,659 μg/m^3. Likewise, NOx emissions fell to 1,223 μg/m^3 after traffic management was implemented (Table 4). Dangerous areas from the modeling results are symbolized in red. Radius of spread of carbon monoxide pollution gas on Jalan Nusantara, Jalan Kalimantan and Jalan Sarappo. These results indicate that after traffic management there was a shift in air distribution.

Therefore, traffic management is needed to reduce pollutant emissions caused by motorized vehicles. It is also necessary to know the wind rose so it is possible to understand the spread of air dispersion.

This study utilizes AERMOD due to its capability as a high-quality spatial dispersion model designed to meet regulatory standards. AERMOD can predict the dispersion of air quality from up to 50 different sources, including point, area, or volume sources. Additionally, it can forecast the movement of air quality from one source to another. A notable advantage of AERMOD over other models is its ability to predict ground-level concentration (GLC) consequences resulting from the influence of the Planetary Boundary Layer (PBL) [14].

The limitation of this research is that it only carries out one traffic management scenario, namely limiting heavy vehicles at certain hours. Future research should explore various traffic management scenarios and calculate other pollutant emissions caused by motorized vehicles to obtain optimal results in reducing air pollution.

7. Conclusions

1. The highest CO calculation results occurred on Indonesian highways at 10,637 μg/m^3 and NO_x at 1,551 μg/m^3.

2. The highest CO concentration was 7,659 $\mu g/m^3$ and the highest NO_x was 1,551$\mu g/m^3$. These results indicate that management was a reduction in emissions after traffic management was carried out. From these results, it can be seen that traffic management can be carried out to reduce emissions produced by motorized vehicles.

Conflict interest

The writers state that they no own conflict of interest about the study, fine financial, personal, related authorship, or others, which may influence research and results presented in this paper.

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Data availability

Data will be available based on reasonable request.

Use intelligence artificial

The writers confirm that they do not use technology intelligence artificial moment to make work this moment.

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