Spatial Patterns of Carbon Monoxide Distribution to Traffic Jam in East Jakarta

A W Ramadhani*, A Wibowo1 and R Saraswati1

1Department of Geography, Faculty of Mathematics and Natural Sciences, Universitas Indonesia, Depok, 16424, Indonesia, ORCID ID: 0000-0002-3946-0026

*argha.wirayuda@ui.ac.id, 1adi.w@sci.ui.ac.id, 1ratna.saraswati@ui.ac.id

Abstract. The rapid growth of cities will certainly also increase traffic jams and emissions in the air. This study aims to analyze the increase in car volume and the CO distribution pattern in East Jakarta. Data for traffic jam patterns were recorded based on Google Maps on weekdays in the morning and evening. The spatial analysis method used to find the CO distribution pattern is the IDW interpolation, and the mathematical model calculates the moving emission based on the distance travelled (VKT). The spatial pattern of CO distribution in 2020 was scattered with high concentrations in Pasar Rebo, Ciracas, Cipayung, Kramat Jati, and Makasar Districts, with CO levels above 4,500 ppm. The spatial pattern of CO distribution from the mobile emission model differs from the air station IDW interpolation. The CO distribution pattern from the mobile emission model is very concentrated in Makassar, and Kramat Jati District was 6,740.91 tons/year. The result concluded that the increase in vehicle volume is not related to the distribution of the CO model from air station IDW interpolation, and on the other hand, the congestion pattern was related to the distribution pattern of the CO model from vehicles from the level of congestion.

1. Introduction

Air pollution is a severe problem because it directly impacts human health conditions [1]. The problem of air pollution in big cities continues to increase due to the increase in population, which increases various sources of pollution [2]. Especially in Jakarta, the center of the economy and government in Indonesia, there is always a movement of people who mainly use vehicles [3]. In Jakarta, sources of air pollution-Jakarta mostly come from human activities that produce Carbon Monoxide (CO), especially from the movement activities using vehicles that account for about 60% - 70% of CO pollutants [4]. The utilization of Geographic Information Systems (GIS) is considered efficient in processing data with a spatial reference used as decision support [5]. GIS can store, manipulate and process spatially-based digital information and provide it in a format that fits the model created [6]. The advantages of GIS, namely easy implementation in analyzing air pollution problems, one of which is a rapid assessment of CO pollution in traffic that was integrated with models that can assist in determining the distribution of CO on roads [7].

The increase in the number of vehicles in Jakarta and its surrounding areas certainly raises several problems such as increasing air pollution, especially CO pollution [8]. In addition, the problem of air pollution, it also causes several traffic problems such as increasing traffic jam [9]. In areas with high levels of traffic jams can create a sharp concentration of air pollution due to motor vehicle exhaust
emissions centered on areas experiencing traffic jams [10]. In particular, in East Jakarta, there are approximately 10 points that often experience traffic jam problems because the East Jakarta area is an area that connects activities between Jakarta, namely Bekasi, Bogor, and Depok [11]. However, the state of activity worldwide, especially in Jakarta, changed when the COVID-19 pandemic occurred in early 2020. In order to reduce the spread of the COVID-19 virus, the DKI Jakarta Government issued a policy of Large-Scale Social Restrictions to regulate restrictions on population activities in an area to prevent the potential for the spread of the virus from being controlled [12]. Based on the problems above, this study was conducted to analyze the traffic jam pattern formed and the distribution of carbon monoxide in East Jakarta. This research is a new study that was created by combining the distribution of carbon monoxide [1] [2] [6], traffic congestion [5] [8] [9], and inventory of carbon emissions from moving vehicles [3] [4] [13]. The result is the relationship of the distribution of carbon monoxide to congestion, which was formed in a spatial model. Thus, the results can provide an overview of the distribution of carbon monoxide and its correlation with congestion in East Jakarta.

2. Method

2.1. Case study location and period
This research was conducted in East Jakarta City, located at 106°49'35'' East Longitude and 06°10'37'' South Latitude. East Jakarta City is one of the administrative areas under the DKI Jakarta Provincial Government. East Jakarta City has an area of 188.03 Km² or 28.37% of the total area of DKI Jakarta Province. The unit of analysis used is the volume of private cars on roads that often experience traffic jams on main roads and toll roads in East Jakarta City, as illustrated in Figure 1. The selection of research areas was based on data from the Jakarta Central Statistics Agency, where the number of passenger car vehicles in 2020 reached 3,365,467 units, which is an increase from 2019. The research is focused on main roads and toll roads in 2020 to make it easier for researchers to calculate the volume of vehicles when traffic jams. In addition, changes in activity in 2020 where there were restrictions on social activities were also the reason for conducting this research.

![Figure 1. Research Area.](image)

2.2. Materials
Based on Table 1, the data used in this research are obtained directly from the field utilizing surveys such as the volume of vehicles and indirectly or from third parties, such as agencies, organizations, governments, or related institutions. The data from third parties is related to the research in the form of
statistical and other data sourced from scientific publications, research results, and the relevant agencies that have published scientific documents.

## Table 1. Data and Sources of Data.

| Data                          | Source                      |
|-------------------------------|-----------------------------|
| Vehicle Volume Data           | Field Survey                |
| Administrative map of East Jakarta City 1: 25000 | BIG                         |
| Network Road Map of East Jakarta City 1:25000 | Open Street Maps            |
| Traffic Jam Data              | Google Maps                 |
| CO Air Quality                | Environment Agency DKI Jakarta |

### 2.3. Data collection and analysis

The method used in the sample selection is purposive sampling. The sample points determined based on the researcher's criteria are arterial roads and toll roads that experience congestion at 08.00 – 12.00 WIB or 14.00 – 18.00 WIB during weekdays (Monday to Friday) for validation and calculation of the volume of private cars within 30 minutes. Data processing in this study was carried out with the data needed using software such as ArcGIS 10.3 for spatial data processing, Microsoft Excel for tabular data processing, and SPSS for statistical data processing. As for the data, the processing process is as follows.

The road network data obtained from the Open Street Map displayed congestion and correlated with the carbon monoxide distribution model. Road congestion data obtained from Google Maps viewed on weekdays (Monday to Friday) in the morning (08.00 WIB - 12.00 WIB) and afternoon (14.00 WIB - 18.00 WIB) every hour.

Vehicle volume data has been obtained from observations and used to calculate carbon monoxide in East Jakarta. The data from the observations were tabulated in Excel, which was then linked to the spatial data in ArcGIS. CO air quality data was obtained from several sources. Firstly, CO air quality data obtained from the Air Quality Monitoring Station (SPKU) of the DKI Jakarta Environmental Service was used for modelling CO distribution. The modelling was made using the IDW interpolation analysis method in ArcGIS based on the air station point for data estimation based on the air station point. The data was obtained in a tabular form then converted to spatial form. Then, CO air quality data obtained from the calculation of vehicle emissions on the main road uses a moving source emission calculation based on VKT [13]. The formula is in Equations (1) and (2).

\[
VKT_{j, \text{line}} = \sum_{i=1}^{n} Q_{ji} \cdot L_i \tag{1}
\]

\[
E_{cji} = VKT_{ji} \cdot E_{Fc} \tag{2}
\]

\(VKT_{j, \text{line}}\) = VKT in vehicle category \(j\) on-road segment \(i\) which is calculated as source line (km/year);

\(Q_{ji}\) = volume of vehicles in category \(j\) on-road segment \(i\), which was calculated (vehicles/year);

\(L_i\) = Length of road segment \(i\) (km);

\(E_{Fc}\) = Pollutant emission factor (32.4 g/Km);

\(E_{cji}\) = Pollutant emission C for category \(j\) on road \(i\).

The pollutant emission factor value used is a private car with an emission factor value of 32.4 g/Km according to the Regulation of the Minister of the Environment No. 12 of 2010. These calculations were entered into the survey point data, which IDW then interpolates based on each survey point for data estimation. The two CO distribution models to compared with the CO distribution patterns.
3. Results and discussion

3.1. The volume of vehicles and traffic jam
For the volume of vehicles that have been calculated, there are quite various variations, as illustrated in Figure 2. Traffic conditions and road width influence are the most significant factors. Traffic conditions affect the number of moving cars, especially during heavy traffic conditions where vehicles move at low speeds increase the number of moving vehicles. However, when traffic conditions are jammed or obstructed, the number of vehicles does not increase because the flow of cars is blocked. In addition, human activities in land use also affect traffic conditions, which causes the increase of the volume of the vehicle. On roads in areas of activity centers, such as commercial areas, it can hamper traffic conditions. The width road influence of increasing volume of vehicles because the width of the road affects the capacity of the number of vehicles that enter when moving. The wider the road, the greater the vehicle storage capacity, thus increasing the volume of incoming vehicles.

![Figure 2. Vehicle Volume Map.](image)

3.2. Distribution of carbon monoxide in East Jakarta
Distribution of carbon monoxide in 2020 in East Jakarta resulted from the IDW spatial interpolation technique from five Air Quality Monitoring Stations (SPKU) in DKI Jakarta, then used the East Jakarta Area. The distribution pattern of CO in 2020 from the southern region to the central part of East Jakarta in Pasar Rebo District, Ciracas District, Cipayung District, and half the area of Makassar District and Kramat Jati District have high CO levels, which are above 4,500 ppm in a year. Then, in the central part of East Jakarta, parts of Makasar District, Kramat Jati District, Duren Sawit District, and Jatinegara District have CO levels of 4,000 ppm to 4,500 ppm in a year. Then, in the northern part of East Jakarta, half the Jatinegara and Duren Sawit sub-districts and Matraman, Pulo Gadung, and Cakung sub-districts have CO levels below 4,000 ppm in a year. The total CO emission resulting from the calculation of vehicle emissions in East Jakarta is 6,740.91 tons/year. The highest CO emission value is 2,326.38 tons/year, located on the Jagorawi Toll Road with a car volume of 9,702,936 units/year. Then, the lowest CO emission value is 23.41 tons/year, located on Jalan Raya Pondok Gede, Cipayung District. The CO concentration distribution pattern model from the vehicle emission calculation model saw in Figure 3.
The spatial pattern of carbon monoxide distribution in 2020 from the mobile emission model is significantly different from the spatial pattern of carbon monoxide distribution from the IDW interpolation model from five points of the Air Quality Monitoring Station (SPKU). The spatial pattern of carbon monoxide distribution from the 2020 mobile emission model was concentrated in Makassar District, Kramat Jati District, Ciracas District, and Cipayung District. The location often experiences traffic congestion, especially on the Jakarta Outer Ring Road Toll Road. Meanwhile, the spatial pattern of carbon monoxide distribution from the 2020 air station IDW model was more evenly distributed with high levels in the south towards the center in Pasar Rebo District, Ciracas District, and Cipayung Kramat Jati District, and Makassar District. The spatial pattern is due to the different sources of CO emissions, where CO from moving emissions is calculated only from vehicle emission sources on the road, while CO from air stations was calculated from various sources. For a comparison map of the distribution pattern of carbon monoxide from the mobile emission model and the IDW air station interpolation model, see Figure 4.

3.3. Relationship of vehicle volume to carbon monoxide distribution
The relationship between increased volume and distribution of carbon monoxide in East Jakarta using 30 points. The volume of vehicles calculated during the survey at 30 points has been processed into vehicle volume/year. The vehicle volume is then related to the carbon monoxide value from the air station IDW interpolation model and the mobile emission model, whose values were extracted according to the location of the survey point. The correlation used is the Pearson correlation in Table 2.
Table 2. Correlation result of vehicle volume with air station CO distribution and CO moving emission.

|                           | Vehicle Volume to CO Distribution Air Station | Vehicle Volume to CO Moving Emission |
|---------------------------|---------------------------------------------|-------------------------------------|
| Correlation               | Pearson 0.244                               | Pearson 0.933                       |
| Sig                       | 0.193                                       | Sig 0.001                           |

Based on Table 2, the congestion correlation test of vehicle volume on the distribution pattern of carbon monoxide in 2020 from the IDW air station interpolation model resulted in a significance value of 0.193. So H0 is accepted, meaning that there is no relationship between the increase in vehicle volume and the distribution pattern of CO in East Jakarta, which comes from the IDW interpolation of air stations. This distribution pattern based on the source of CO calculated from stations is not only sourced from vehicle emissions. Based on Table 2, the congestion correlation test from the volume of vehicles on the distribution pattern of carbon monoxide emissions in motion produces a significance value of 0.001 or less than 0.05, respectively. So that H1 is accepted, meaning that there is a relationship between increased vehicle volume and the distribution pattern of CO in East Jakarta, which comes from the mobile emission model with a relationship of 0.933, which means that the relationship is very strong. Thus, worsening congestion due to increased vehicle volume can increase the distribution of CO, mainly from vehicle emissions.

4. Conclusion
The spatial pattern of carbon monoxide distribution in 2020 was scattered with high concentrations in Pasar Rebo, Ciracas, Cipayung, Kramat Jati, and Makasar Districts with CO levels above 4,500 ppm. The spatial pattern of carbon monoxide distribution formed from the mobile emission model has a different value form from the air station IDW interpolation model. The CO distribution pattern from the mobile emission model is very concentrated in Makassar, and Kramat Jati District, regarding the mobile emission in East Jakarta, was 6,740.91 tons/year. The result concluded that the increase in vehicle volume is not related to the distribution of the CO model from air station IDW interpolation, and the other hand, the congestion pattern was related to the distribution pattern of the CO model from vehicles from the level of congestion.

Acknowledgements
The research and publication were support by a Research Grant from the Directorate of Research and Development Universitas Indonesia year 2020 based on contract number: NKB-2003/UN2.RST/HKP.05.00/2020.

References
[1] Arista F, Saraswati R, and Wibowo A 2019 Pemodelan Spasial Distribusi Karbon Monoksida di Kota Bandung (Spatial Modeling of Carbon Monoxide Distribution in Bandung) *JGLITrop* 3 21-31
[2] Safarianzengir V, Sobhani B, Yazdani M H, and Kianian M 2020 Monitoring, Analysis Spatial and Temporal Zoning of Air Pollution (Carbon Monoxide) Using Sentinel-5 Satellite Data for Health Management in Iran, Located in The Middle East Air Qual Atmos Health 13 709–719
[3] Azaria L, Wibowo A, Shidiq I P A, and Rohmatuloh 2018 The 3rd Int. Conf. on Energy, 73 4–8
[4] Ismiyati, Marlita D, and Saidah D 2014 Pencemaran Udara Akibat Emisi Gas Buang Kendaraan Bermotor (Air Pollution Due to Motor Vehicle Exhaust Emissions) *J. Manaj. Transp. Logist.* 1 241–248.
[5] Wang X 2005 Integrating GIS, Simulation Models, and Visualization in Traffic Impact Analysis *Comput Environ Urban Syst* 29 471–496.
[6] Dalvi M, Beig G, Patil U, Kaginalkar A, Sharma C, and Mitra A P 2006 A GIS-Based
Methodology for Gridding of Large-scale Emission Inventories: Application to Carbon-monoxide Emissions Over Indian Region Atmos. Environ 40 2995–3007

[7] Azeez O S, Pradhan , and Shafir H Z M 2018 Vehicular CO Emission Prediction Using Support Vector Regression Model and GIS Sustainability 10 1-18

[8] Salean S and Hadyan M 2019 Analisis Kemacetan Lalu-Lintas Di Jalan Matraman Raya-Jalan Bekasi Barat , Jakarta Timur (Analysis of Traffic Jam on Jalan Matraman Raya-Jalan Bekasi Barat, East Jakarta) J. Ilm. Plano Krisna 13 40-48

[9] Handoyo S S and Afriansyah S 2008 Optimalisasi Pengaturan Lalu Lintas Jalan Pemuda di Wilayah Dki Jakarta Timur (Optimizing Traffic Management on Jalan Pemuda in East Jakarta, DKI Jakarta) LOGISTIK 1 51–64

[10] Soleiman N 2008 Model Sistem Dinamis Untuk Estimasi Pencemaran Udara dari Emisi Kendaraan Bermotor di Jakarta (Dynamic System Model for Estimating Air Pollution from Motor Vehicle Emissions in Jakarta) JMST 9 1–10

[11] Pusparini N 2018 Penanganan Kemacetan di Jalan Raya Bogor Kawasan Cililitan – Pekayon Jakarta Timur (Priority Analysis of Congestion Management Policies on Jalan Raya Bogor Cililitan – Pekayon, East Jakarta) Bachelor Thesis (Universitas Dipenogoro)

[12] Indriyani S, Hasandy L R, and Dewantoro E B 2021 Dynamics of Gas Emission Concentration of Monoxide (CO) during PSBB Period Using Cloud Computing Based on Google Earth Engine, Case Study of Dki Jakarta Province, Indonesia Majalah Ilmiah Globe 23 35–42

[13] Maulana Q, Sofyan A, and Frazila B 2016 Simulasi Pemodelan Jaringan Jalan untuk Memprediksi Pengurangan Emisi CO, NOx, PM_{10}, dan SO_{2} dari Rencana Pembangunan Bus Rapid Transit di Kota Tangerang (Road Network Modeling Simulation to Predict the Reduction of CO, NOx, PM_{10}, and SO_{2} Emissions from the Bus Rapid Transit Development Plan in Tangerang City) J. Tek. Lingkungan. 22 63–72.