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# Analysis of CO2 Emission from Motorized Vehicle based on Segmentation of Urip Sumoharjo Road at Makassar City

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**ABSTRACT**

This study aims to analyze the amount of $CO_2$ emissions from motorized vehicles through six segments at St. Urip Sumoharjo, and identify relationship between those variables. Segmentation conducted to understand the vehicle volume with the different geometric of road. The method used descriptive quantitative approach by conducting traffic counting that classified into eleven vehicle types and fuel engines (BBM) in peak hour of three time periods. For $CO_2$ emission calculation, there are five factors to consider: number of vehicles, road length, emission factor, density fuel, and fuel economy. In addition, to determine the relationship between vehicle volume and $CO_2$ emission, the result analyzed statistically using SPSS 28 software. As the result, the highest $CO_2$ emission located on Segments: 6, 5, and 1, with a value range of 1,231.1-3,281.4 kg/hour. Those segments are the longest road among other segments with a difference of 0.4-1 km. Furthermore, there are strength relationship with r coefficient of 0.916 between vehicle volume and $CO_2$ emission. However, three type of vehicle: Jeep, Microbus and Bigbus identified has a negative relationship due to different fuel consumption and fuel density.
*Keywords: CO2 Emission; Motorized Vehicle; Segmentation; Fuel Economy*

## 1. INTRODUCTION

Climate change is a global phenomenon that has a significant impact and this is the main focus of world leaders to overcome it. Through the Paris Agreement in 2015, 194 countries around the world deals with the long-term goals of all parties, financial flows, technological problems, and supporting actions to start in 2020 [1]. One of the main actions by making an action plan in an effort to limit the increase in the earth's temperature further than 1.5°C is reducing Greenhouse Gases (GHG) emissions. The portion of $CO_2$ (56%) has contributed the most among the 6 types of GHG and this is regulated in the Kyoto Protocol (IPCC, 2006). Globally, transportation technology mainly on petroleum fuels (95 percent), and the transport sector produces 6.3 tons of $CO_2$ emissions (about 12 percent of the total), and land transportation accounts for 74 percent [2].

In Indonesia, the sectors involved in increasing $CO_2$ production come from energy use, namely industry in construction, manufacturing and operational activities, transportation, housing, commercial and public spaces as well as electricity and heat production sectors. In Indonesia, ESDM presents that GHG emissions in the energy sector [3] were 638,452 Gg $CO_2$e. The largest categories of emission contributors, respectively, are energy producing industries (43.83%), transportation (24.64%), manufacturing and construction industries (21.46%), other sectors (4.13%). This shows that the transportation sector occupies the second highest value in the use of energy in the use of fuel [4][5][6].

Makassar City as a metropolitan city in eastern Indonesia, experienced a population growth rate of 1.29% with a total population of 1,508,154 people. This growth rate will have an impact on the demand for the number of vehicles to mobilize one activity to another. From 2016 to 2019, data recorded from the Traffic Directorate of South Sulawesi (2019) is that the total number of motorized vehicle ownership in Makassar City is 1,425,150 vehicles, 1,505,835 vehicles, 1,563,608 vehicles, and 1,643,653 vehicles. Based on these data, it can be seen that the increase of average vehicle growth rate per year is 4.4%. According to this vehicle rate, the fuel consumption will increase and also have an impact on the amount of emission released from vehicle canals[7]

Among the three classifications in the road network system in Government Regulation No. 34 (2006), primary arterial roads function is to efficiently connect between national activity centers or between national activity centers and regional activity centers [8]. From this function, it can be assumed that the number of vehicles that pass through primary arterial roads is more than other types of roads. In this study, the primary arterial road became a particular object on St. Urip Sumoharjo which also has the longest road length in Makassar City with 4.2. km. This road also connects various activities such as offices, education, commercial goods and services and domestic communities' activities where many people will choose this road. The density of vehicle activity on this road has the potential to increase the amount of $CO_2$ gas emissions emitted into the ambient air so that it will have an impact on urban air quality. Therefore, this study was conducted to analyze the amount of $CO_2$ emissions from motorized vehicles moving in 6 segments at St. Urip Sumoharjo. Furthermore, this study aims to analyze the relationship between vehicle volume and the resulting $CO_2$ emissions. In addition, this study take account into consideration the type of vehicle, road and fuel characteristics, fuel economy which have become the main factors in increasing the number of pollutants emitted into the ambient air.

*Theory*

*a. Traffic Volume*

Traffic volume is the number of vehicles that pass a certain point or line on a cross section of the road. According to Jinca [9], traffic volume shows the number of vehicles crossing one observation point in one unit of time (days, hours, and minutes). The category and type of vehicles used in this study are based on the Indonesian Road Capacity Manual (MKJI, 1997), and the Minister of Environment Regulation No. 12 (PermenLH/No.12, 2010) [10][11]. The classification is as follows: Light Vehicles (LV), Index for motorized vehicles with 4 wheels (passenger cars: Sedan, Mini bus, Taxi, and Public Transportation), Heavy Vehicles (HV), Index for motorized vehicles with more than 4 wheels (Pick up, Jeep, Microbus, 2 axle Trucks, 3 axle Trucks and the appropriate combination), Motor Cycle (MC), Index for motorized vehicles with 2 wheels.

*b. Exhaust Gas Emissions*

Exhaust gas emissions are the residue from the combustion of motorized vehicle engines and will produce compounds such as HC, CO, $CO_2$, and NOx. The impact of exhaust gas emissions that exceed Emission Quality Standards (BME), will affect human health. As the carbon monoxide (CO) content is high, it will reduce oxygen in the blood, causing thinking disorders. For $CO_2$ consequences, it will effect global warming [12]. While the content of hydrocarbons (HC) that exceeds the threshold can cause eye irritation, coughing, drowsiness, skin spots, and changes in the genetic code.

*c. CO2 Emission Load*

Emission load is the amount of emission that emits and enters the ambient air from an human activity in an area during a certain period of time. Based on the Manual of GHG Inventory Implementation [13] and the Report of GHG Inventory and Monitoring, Reporting, Verification [14], the depth of the method used in the GHG inventory is known as the 'tier'. Tier means that the higher the depth of the method used, the calculation results will be more detailed and accurate. In general, the level of accuracy (tier) in the implementation of the GHG Inventory is divided into three, namely: Tier 1, 2, and 3 [15][16].

For calculation of emission load in this study using Tier 2, it is a calculation of emissions and absorption using a more detailed equation. Activity data comes from national and/or regional data sources and uses local Emission Factors (EF) obtained from direct measurements. For the CO2 emission factor, it applies PERMEN LH No. 12 of 2010 which can be seen in table 2.

## 2. METODOLOGY

*A. Location, Time and Data Collection*

This research was conducted on the main arterial road, namely St. Urip Sumoharjo with a road length of 4.2 km. Then this road will be divided into 6 segments (Figure 1) which aims to get a constant volume of vehicles. The factors that must be considered in the division of segment are road openings, intersections, shape of road geometric, and road use activities that have the potential to affect changes in vehicle volume at a certain distance (Table 2). The method used in this research is descriptive quantitative method. In the data collection phases using a quantitative approach, a field survey was conducted by means of traffic counting to obtain primary data consisting of the number and types of vehicles, and type of fuel engine (BBM) used.

Traffic Counting is conducted by counting 11 types of vehicles that pass through the two-way road with two lanes at 6 segments of Urip Sumoharjo to determine the volume of vehicles. Then, the camera is installed at 8 observation points where segments 2 and 4 have 2 points because they have a wider road. For the duration of traffic counting, it is carried out for 1 hour at peak hours of three time periods: 06.50-07.50 (morning), 10.10-11.10 (afternoon), and 17.00-18.00 (afternoon).

*B. Data Analysis*

For the calculation of $CO_2$ emissions, it used the volume of vehicles generated from traffic counting with 11 types of vehicles. The equations of $CO_2$ emission calculation are adopted by Pasaribu (2015), as follows:

$$E_k = \frac{n \times L \times f \times p}{F} \quad (1)$$

Table 1. Vehicle Exhaust Emission Factors for Metropolitan Cities and Big Cities in Indonesia Determined by Vehicle Category and Sub-Category in Car Category

| Category for Calculation of Air Pollution Load | $CO_2$ (g/kg Engine Fuel) | Sub-Category for Calculation of Air Pollution Load | $CO_2$ (g/kg Engine Fuel) |
|---|---|---|---|
| Motorcycle | 3180 | Public Transportation | 3180 |
| Car (petrol) | 3180 | Taxi | 3180 |
| Car (diesel) | 3172 | Pick-up | 3178 |
| Car | 3178 | Jeep | 3178 |

| Category for Calculation of Air Pollution Load | $CO_2$ (g/kg Engine Fuel) | Sub-Category for Calculation of Air Pollution Load | $CO_2$ (g/kg Engine Fuel) |
|---|---|---|---|
| Bus | 3172 | Van/Minibus | 3178 |
| Truck | 3171 | Sedan | 3180 |

Tier 2 methodology used for emission factors has been developed and written in the Minister of Environment Regulation No. 12/2010. In addition, other factors that are considered in calculating $CO_2$ emissions are the density of each engine fuel (Table 3) and its economic factor (Table 4). Then to determine the relationship between vehicle volume and CO2 emissions, it will be analyzed statistically using SPSS 28 software.

## 3. RESULT AND DISCUSSION

### A. *Identifying the Number of Vehicles on the Main Arterial Road on St. Urip Sumoharjo*

Figure 2. describes the comparison of results between vehicle volume and vehicle type in each segment of St. Urip Sumoharjo. From this graph, it is clear that the dominant types of vehicles are Motorcycle (a), Sedan (b), Public Transportation (e) and Pick-Up (f), with a percentage of 71% (116,508 units), 23% (37,782 units), 2.3% (3,795 units), and 2.14 % (3,519 units) respectively.


Graph 1. Study Location in St. Urip Sumoharjo, Makassar City

Table 2. Location of Measurement Points and Area Boundaries in Each Segment

| Segment | Length (km) | Territory Restrictions | |
|---|---|---|---|
| | | West | East |
| 1 | 1,015 | Start from St. Bawakareng until St. Masjid Raya | West edge of St. Flyover |
| 2 | 0,325 | West edge of St. Flyover | Signaled Intersection on St. A.P. Pettarani, St. Urip Sumoharjo, and St. Barawaja |
| 3 | 0,627 | West edge of St. *Flyover* | East edge of St. *Flyover* |
| 4 | 0,302 | Signaled Intersection on St. A.P. Pettarani, St. Urip Sumoharjo, and St. Barawaja | East edge of St. *Flyover* |

| Segment | Length (km) | Territory Restrictions | |
|---|---|---|---|
| | | West | East |
| 5 | 1,181 | East edge of St. *Flyover* | St. Prof. Abdur Rahman Basalamah in front of the Governor's Office |
| 6 | 1,992 | St. Prof. Abdur Rahman Basalamah in front of the Governor's Office | T-junction of St. Urip Sumoharjo, St. Perintis Kemerdekaan, and St. Dr. Leimena |

Table 3. Density of each engine fuel

| Type of Engine Fuel | Density (Kg/liter) |
|---|---|
| Petrol | 0,63 |
| Diesel | 0,7 |

While the lowest number of vehicle types is Big Bus (i) 0.03% (42 units), Microbus (h) 0.04% (72 units), and Taxi (d) 0.06% (103 units).

Based on MKJI classification, the dominant mode of vehicles crossing each segment on Jalan Sumoharjo are MC and LV types. Although the one type of vehicle classified as HV (Pick Up) occupied in 3rd high percentage. In addition, the value of vehicles categorized as HV has a significant number through this road. The situation caused by this road have function to link between the Western region to the Eastern region of Makassar city as well as an alternative road from the Southern region of Makassar to go Western and Eastern. Western region is the area that will central to the border between Makassar City and other regencies in Sulawesi.

The highest volume of vehicles is located at segment 6, 5 and 1 with 38,558 units, 36,971 units and 33810 units respectively. Road users are denser than other segments due to Segment 1 connecting City and Provincial Government Offices, Health Facilities, Houses of Worship, and various business activities. While in segment 5, road users are mostly used to access the Governor's Office of South Sulawesi Province, Nipah Mall, educational facilities such as Bosowa University and Indonesian Muslim University, as well as business activities such as coffee shops and restaurants.

The Segment 6 is widely used by road users to access Pertamina Racing gas stations, Police Dormitory, Hasanuddin XIV Military Command, Cemetery, Panaikang Market, Bulog Warehouse, and the Litha Bus Terminal.

While the lowest value of vehicle volume is in segment 2 (15,306 units), 4 (19,100 units), and 3 (20,620 units). This is because segment 2 is only an access road connecting toll roads, Jalan A.P Pettarani, and segment 4, and contrariwise for segment 4. For segment 3, it only connects segments 1 and 5 which are flyover roads.

*B.* $CO_2$ *emission characteristics based on road segmentations, time periods and vehicle types*

*1. Road Segmentations*

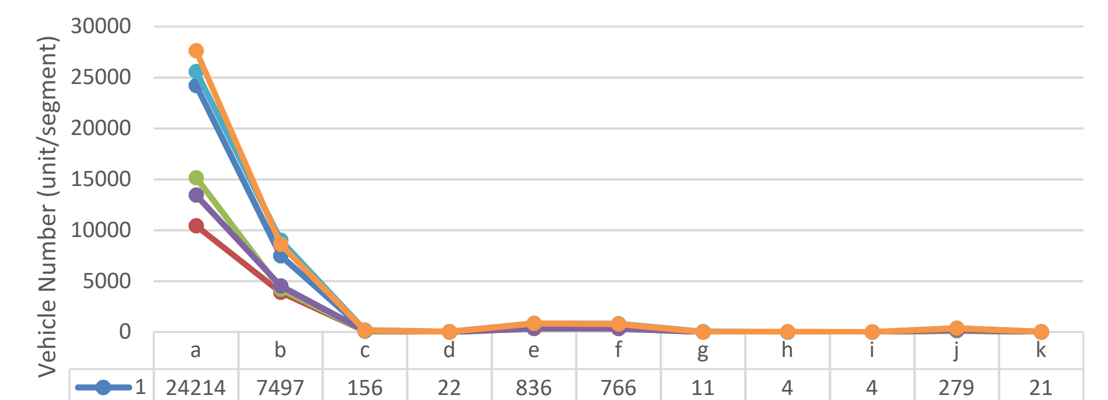
From the calculation of $CO_2$ emissions (Figure 3) based on the six segments on Jalan Sumoharjo, the largest values are in Segment 6, Segment 5, and Segment 1, with a value range of 1,231.1-3,281.4 kg/hour. While the lowest values are in the order: Segment 3, Segment 4, and Segment 2 with a amount of $CO_2$ emission value with range 182.4-543.9 kg/hour.

Table 4. Motor Vehicle Fuel Economy in Metropolitan Cities and Big Cities in Indonesia

| Code | Category/Sub-Category | Fuel Economy (km/liter) |
|---|---|---|
| a | Motorcycle | 28 |
| b | Sedan | 9,8 |
| c | Van/Minibus | 8 |
| d | Taxi | 8,7 |
| e | Public Transportation | 7,5 |
| f | Pick-up | 8,5 |
| g | Jeep | 8 |
| h | Microbus | 4 |
| i | Big Bus | 3,5 |
| J | 2 axle Trucks | 4,4 |
| k | 3 axle Trucks | 4 |

The segments that produce the highest $CO_2$ emission are the longest road compared to the segment with low classification with a difference of 0.4-1 km, with a large range of vehicle volume. Furthermore, the distance traveled by the vehicle has a direct effect on the amount of fuel (BBM) burned by motorized vehicles to move the driver's destination. This shows that the longer the travel distance, the more fuel is converted into motion energy and produces $CO_2$.

In addition to the traveled length or distance of the road, the amount of $CO_2$ emission load is also strongly influenced by the volume of the vehicle. This can be seen from Segment 2 and Segment 4. The length of the road in Segment 4 is shorter when compared to the length of the road in Segment 2. However, the amount of $CO_2$ emissions in Segment 4 is highest than in Segment 2. This is because the volume of vehicles in Segment 4 is higher, compared to the vehicle volume through in Segment 2.




| | a | b | c | d | e | f | g | h | i | j | k |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 24214 | 7497 | 156 | 22 | 836 | 766 | 11 | 4 | 4 | 279 | 21 |
| 2 | 10448 | 3906 | 96 | 2 | 342 | 341 | 24 | 5 | 2 | 132 | 8 |
| 3 | 15163 | 4206 | 84 | 17 | 509 | 441 | 9 | 3 | 5 | 175 | 8 |
| 4 | 13464 | 4520 | 120 | 11 | 388 | 344 | 10 | 3 | 11 | 212 | 17 |
| 5 | 25593 | 9036 | 192 | 23 | 858 | 827 | 25 | 10 | 8 | 375 | 24 |
| 6 | 27626 | 8617 | 146 | 28 | 862 | 800 | 13 | 47 | 12 | 384 | 23 |

Figure 2. Traffic Volume in 6 segments of St. Urip Sumoharjo

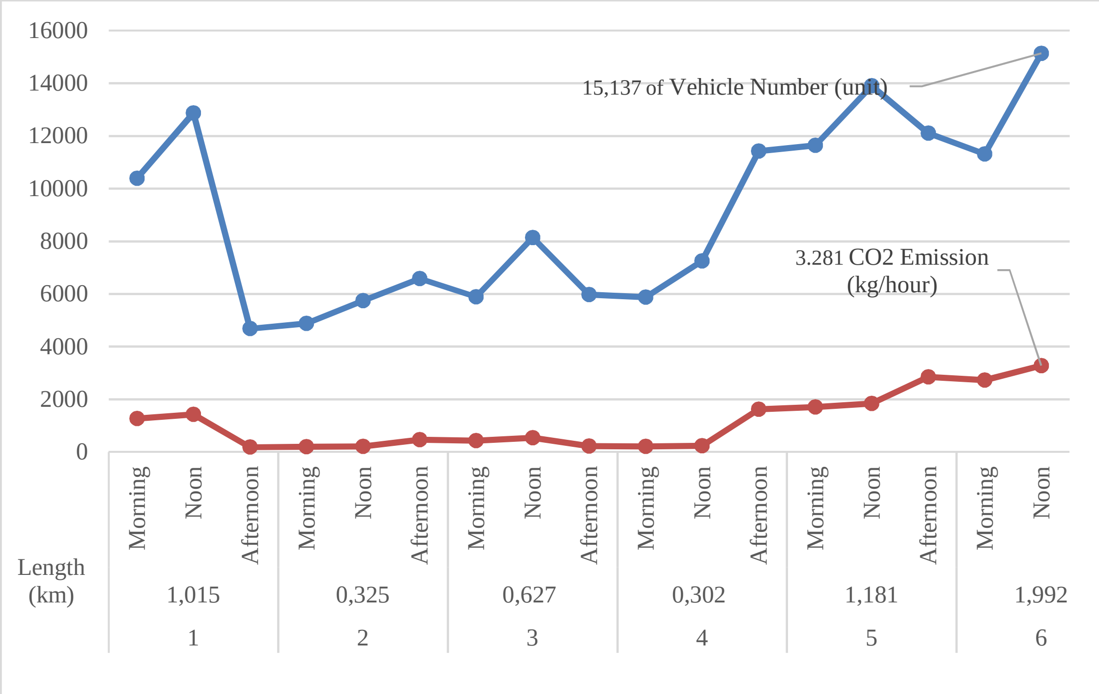



Figure 3. The amount of $CO_2$ Emission based on the segmentation of the Urip Sumoharjo road

*2. Observation Times*

Based on Figure 4, it can be seen that from the three time periods of data collection, the highest value of $CO_2$ emissions is the densest in the afternoon at 17.00-18.00 in each segment, with a value range of 209-3,281 kg/hour. Furthermore, the highest time period after the afternoon occurs in the morning (06.50-07.50) and the smallest is in the afternoon 10.10-11.10 with a $CO_2$ emission load value of respectively: 182-2.847 $CO_2$ kg/hour and 200-2.723 $CO_2$ kg/hour. This is because the afternoon and morning are the busiest hours for vehicle mobilization when starting daily activities and returning from work.

In addition, the amount of $CO_2$ value will be influenced by the number of vehicles that are more dominant across St.Urip Sumoharjo during rush hour in the afternoon with a total of 5,739-15,137 vehicles, compared to the daytime with a total of 4,886-11,542 vehicles.

*3. Vehicle Types*

From the figure 5, the total value of $CO_2$ emissions has a linear trend with the total volume of vehicles on St. Urip Sumoharjo, where Motorcycle (MC), Sedan (LV) contributed the highest with a percentage value of 43.9% (9,071.8 kg/hour) and 40.28 % (8,322.9 kg/hour).

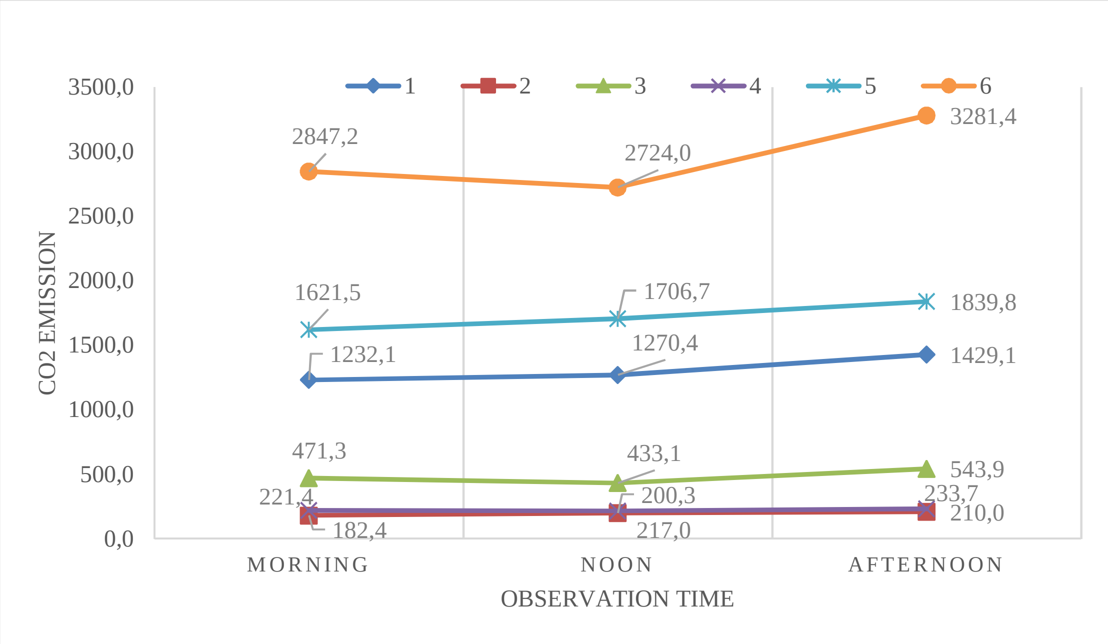



Figure 4. $CO_2$ Emission based on observation time in 6 segments of St. Urip Sumoharjo

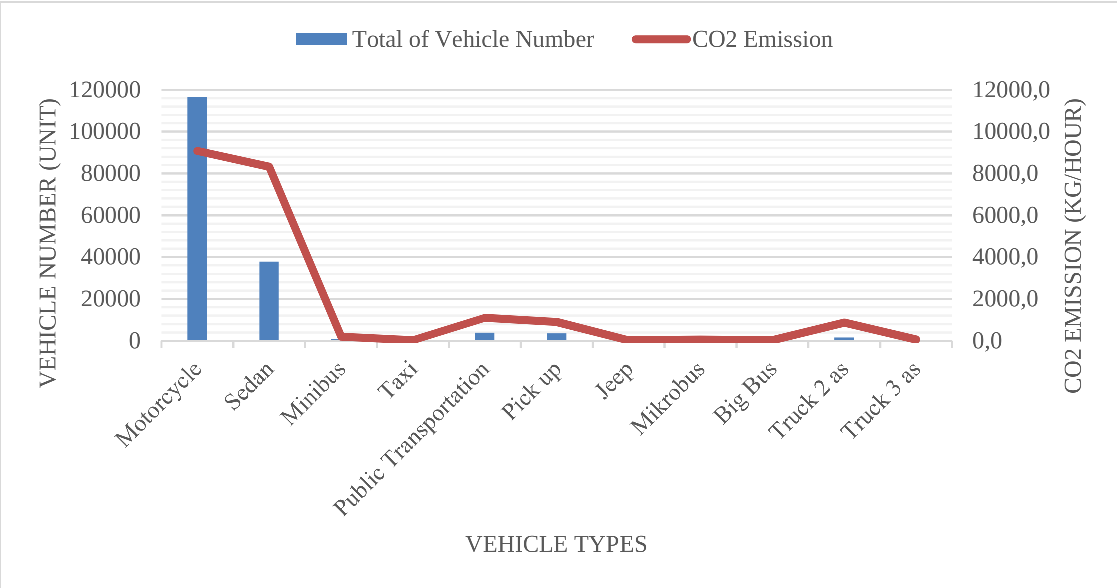



Figure 5. Distribution of $CO_2$ emissions and vehicle volume by vehicle type on Jalan Urip Sumoharjo

Then followed by quite large values, namely Public Transportation (1102 kg/hour) and Pick Up (904.2 kg/hour).

While the values with low classification are Taxi (LV), Jeep, and Big bus (HV) with a percentage of 0.13% (27.6 kg/hour) with a percentage value of 0.31% (28.2 kg/hour) and 0.10% (20.9 kg/hour). From the order of magnitude of $CO_2$ emissions by vehicle type, it can be concluded that the highest value of $CO_2$ emissions is dominant in the MC and LV vehicle types.

*C. Correlation Test The relationship between vehicle volume and* $CO_2$ *emissions*

The output in the Test of Normality table with the Kolmogorov-Smirnov test obtained p-values for the micro bus variable, and big bus = 0.000-0.028, <0.05, it can be concluded that only the data are not normally distributed. From this value, the two variables will be tested using the Spearman correlation, while the other variables will use the Pearson correlation test.

Table 5. Correlation test results between vehicle volume and $CO_2$ emissions

| Vehicle Categories | Vehicle Type | P-Value | r Coefficient |
|---|---|---|---|
| MC | Motorcycles[a] | 0,01* | 0.916 |
| LV | Sedan[a] | 0,013* | 0.904 |
| | Minibus[a] | 0,07* | 0.77 |
| | Taxi[a] | 0,023* | 0.87 |
| | Public Transportation[a] | 0,016* | 0.894 |
| | Pick up[a] | 0,015* | 0.89 |
| | Jeep[a] | 0,33** | 0.47 |
| HV | Microbus[b] | 0.06** | 0.78 |
| | Bigbus[b] | 0.11** | 0.714 |
| | 2 axle Trucks[a] | 0,011* | 0.913 |
| | 3 axle Trucks[a] | 0,046* | 0.819 |

[a] = Pearson Correlation * Correlated
[b] = Spearman Correlation ** Uncorrelated

Table 6. Result of $CO_2$ emissions and vehicle volume on Jalan Urip Sumoharjo

| Vehicle Type | Fuel Economy (km/liter) | Total of Vehicle Number | Vehicle Emission |
|---|---|---|---|
| Motorcycle | 28 | 116508 | 9071.8 |
| Sedan | 9.8 | 37782 | 8322.9 |
| Minibus | 8 | 794 | 202.6 |
| Taxi | 8.7 | 103 | 27.6 |
| Public Transportation | 7.5 | 3795 | 1102.1 |
| Pick up | 8.5 | 3519 | 904.2 |
| Jeep | 8 | 92 | 20.8 |
| Microbus | 4 | 72 | 63.2 |
| Big Bus | 3.5 | 42 | 28.2 |
| 2 axle Trucks | 4.4 | 1557 | 861.6 |
| 3 axle Trucks | 4 | 101 | 60.1 |

From the results of the Pearson correlation test, it shows that vehicle volume has a relationship with $CO_2$ emission with a positive or directly proportional relationship pattern which means that if the value of vehicle volume increases, the value of $CO_2$ emissions will also increase, with the strength of the relationship (r coefficient) of 0.916, which means it has a correlation. These results are in accordance with previous studies where the volume of light vehicles is directly proportional to CO2 emissions on arterial roads in the city of Makassar (Aly et al., 2021). However, the Jeep variable is included in the uncorrelated value with p value = 0.33, > 0.005. In addition, the Microbus and Big bus variables using the Spearman correlation test also remained uncorrelated with p values = 0.06 and 0.11. This indicate that three of vehicle types has negative relationship between its vehicle volume and $CO_2$ emission.

According to Table 6, the volumes for types of vehicles: Taxi and truck 3 axles, Mini Bus and Truck 2 axles, and Jeeps and Mikrobus tend to be non-linear with the value of $CO_2$ emissions emitted by these vehicles. This is caused by different fuel consumption, where Taxi, Mini Bus, and Jeep use efficient fuel. Value of fuel economy used: 1 liter of fuel can be used for a trip of 8-8.7 km. Meanwhile, the types of vehicles that are also classified as HV (Truck 3 axles, Truck 2 axles, and Microbuses) consume more wasteful fuel with a mileage of 4 meters/liter. This factor can emit greater $CO_2$ emissions. The other factors is the type of fuel. Vehicles classified as HV use diesel fuel with a higher specific gravity: 0.7 kg/liter compared to gasoline (0.63 kg/liter). These two factors also make the type of vehicle: Jeep, Microbus and Big bus not correlated between the volume of vehicles through on Jalan Urip Sumojarjo with the amount of emissions emitted.

## 4. CONCLUSIONS

$CO_2$ emission was estimated by using Tier-2 method for accurate emission factor. As the result the correlation of vehicle volume and $CO_2$ emission relied on the length of the road, fuel consumption and fuel density. It found that the highest $CO_2$ emission was located at Segments identified as longest roads than other roads. Furthermore, distance traveled by the vehicle has a direct effect on the amount of fuel (BBM) burned consumption by motorized vehicles. Moreover, volume of HV classification has dominant the negative relation among $CO_2$ emission. This indicated that fuel economy and fuel density of HV impacted to the contribution emitting $CO_2$ emission. Therefore, in the further study, it should take into consideration using the Tier-3 method that have more variables to obtain more accurate emission factors.

## ACKNOWLEDGEMENT

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