Investigation of CO emissions on alternative car free day roads in the city of Makassar

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Abstract. Car Free Day is a movement to reduce the level of air pollution in big cities around the world caused by the emission load of vehicles. The event gives motorists and commuters an idea of their locality with fewer cars. Vehicles produce CO emissions from the fuel combustion process. This research was conducted on alternative roads in 3 Car Free Day locations in Makassar City, which are 1) Boulevard with an alternative road Ance Daeng Ngoyo, 2) Sudirman with an alternative road Karunrung and 3) Losari Beach with an alternative road Hj. Saleh Daeng Tompo. Analysis of measurement data using the method of the number of vehicles and Indonesia's emission factors and Indian emission factors. The results of the study show that the CO emission load on Jl. Ance Daeng Ngoyo and Jl. Karunrung, when Car Free Day (Sunday) is smaller than Non Car Free Day (Monday) while on Jl. Hj. Saleh Daeng Tompo when Car Free Day (Sunday) is greater than Non Car Free Day (Monday). The results of statistical tests also showed that there were no significant differences when Car Free Day (Sunday) and Non Car Free Day (Monday).

1. Introduction

Air pollution has become a serious problem in urban areas, including in metropolitan, large, medium, and small cities. Air pollution at a certain level can be a mixture of one or more pollutants, either in the form of solids, liquids, or gases that are dispersed into the air and then spread to the surrounding environment. Most of the air pollutants come from exhaust gases from burning fossil fuels. The main source of pollution comes from motorized vehicles. Other sources of pollution, such as industrial processes, waste disposal, and others [1]. The contribution of motor vehicle exhaust emissions as the biggest source of air pollution reaches 60-70%, compared to the industry, which only ranges between 10-15%. While the rest comes from households, burning trash, forest/field fires and others. Motor vehicles produce CO, HC and NOₓ emissions. In addition, motor vehicles also produce particulates and SO₂, but the content produced is not as much as CO, HC, and NOₓ. Of all exhaust emissions emitted from motor vehicle sources, the percentage of CO (Carbon Monoxide) exhaust emissions is quite significant because it reaches 60% and includes a type of gas that is very dangerous because it can kill for those who inhale it [2].

In Indonesia, the number of vehicles as a producer of emissions is very high, including Makassar City. As the population increases, the need for vehicle ownership is also increasing rapidly, where the
growth rate of motor vehicle ownership in Makassar City has reached 1.252.378 motor vehicles with a 9.9% percentage [3]. The very high number of vehicles clearly produces high exhaust emissions, especially Carbon Monoxide (CO). The blue sky program is an air pollution control program from mobile and stationary sources conducted by the Ministry of Environment. In the application, there are many programs to support the prevention of air pollution. One of them is the Car Free Day (CFD) program. Car Free Day is a campaign activity to reduce the level of air pollution in major cities around the world caused by motorized vehicles. In Indonesia, the Car Free Day Program was first known as the Motor Vehicle Free Day (HBKB) program [4].

The Car Free Day program in Makassar City began on June 7, 2010 along Jl. Penghibur at Losari Coast. On 4 April 2014, the development of the Car Free Day program was carried out on Jl. Sudirman. In addition, on April 23, 2017 Jl. Boulevard was also developed as a place for Car Free Day, which starts at 06.00 WITA - 10.00 WITA. The Car Free Day Program aims to maintain the level of air quality in Makassar City. The Car Free Day Program is not only a vehicle-free location but also a sports and entertainment center. Car Free Day visitors not only the people who live in the area around the location but also the people who live far from the location. So some people who visited Car Free Day brought motorized vehicles and parked it around the Car Free Day location. The existence of the Car Free Day program also causes diversion of the flow of vehicles that will pass through roads that are closed due to Car Free Day. In connection with the implementation of the Car Free Day program, this study was prepared to determine the impact of Car Free Day on the burden of CO emissions on alternative routes in Makassar City. The several objectives to be achieved from this research are as follows: 1) Knowing CO emission load based on motor vehicle emission factors in Makassar City on Car Free Day and on Non Car Free Day, 2) Analyzing the efficiency of reducing CO emissions in Makassar City on Car Free Day and on Non Car Free Day, 3) Analyzing the effect of the number of motor vehicles on CO emissions in Makassar City on Car Free Day and on Non Car Free Day.

2. Methodology

2.1 Magnitude of motor vehicle emission factors

The emission factor value used is the vehicle exhaust emission factor for metropolitan cities and big cities in Indonesia, which is determined based on the vehicle category based on the Regulation of the Minister of Environment No. 12 of 2010 concerning the Implementation of Air Pollution Control in the Regions [5]. The emission factor values can be seen in table 1.

| Category for calculation of air pollutants loads | CO  | HC  | NO2  | PM10 | CO2  | SO2  |
|-----------------------------------------------|-----|-----|------|------|------|------|
| Motorcycle                                    | 14  | 5.9 | 0.29 | 0.24 | 3180 | 0.008|
| Car (Gasoline)                                | 40  | 4   | 2    | 0.01 | 3180 | 0.026|
| Car (Diesel)                                  | 2.8 | 0.2 | 3.5  | 0.53 | 3172 | 0.44 |

The number of emissions can be determined through the following equation based on the regulation of the Minister of Environment number 12 of 2010.

\[ E = \text{Vehicle Volume} \times \text{VKT} \times \text{FE} \times 10^{-6} \] (1)

The above equation models the emission load (ton/year) where vehicle volume is the number of vehicles (vehicles/year), VKT is Total length of trip (km) and FE is emission factor (g/km/vehicle). In addition, Indian emission factor values are also used (table 2).
Table 2. Indian’s emission factor values [6].

| Velocity (km/hours) | 2W4S CO (g/km) | 3W4S CO (g/km) | 4WG CO (g/km) | Bus/Truck CO (g/km) |
|---------------------|----------------|----------------|---------------|---------------------|
| 0                   | 0              | 0              | 0             | 0                   |
| 10                  | 1.6            | 5.4            | 16            | 6.1                 |
| 20                  | 1.1            | 0.9            | 11.5          | 4.6                 |
| 30                  | 1.0            | 0.434          | 10.33         | 4.6                 |
| 40                  | 1.4            | 0.575          | 29.75         | 3.8                 |
| 50                  | 3.3            | 1.6            | 39            | 3.9                 |
| 60                  | 3.2            | 18             | 52            | 4                   |

2.2 Research time and location
This research was conducted for 3 weeks during Car Free Day (Sunday) and Non Car Free Day (Monday) on alternative routes at 3 Car Free Day locations, which are Jl. Ance Daeng Ngoyo on August 5, 2018 and August 6, 2018, Jl. Karunrung on August 12, 2018 and August 13, 2018 and Jl. Hj Saleh Dg Tompo on August 19, 2018 and August 20, 2018, which every day of measurement was held at 06.00 - 10.00 WITA. The point of measurement location can be seen in figure 1 to figure 3.

2.3 Data collection methods
Data collection techniques used in this study used two ways, first was direct measurement (primary data) and indirectly (secondary data). Primary data collection is done by a direct survey method in the field. A field survey conducted was recording traffic flow using camcorders and vehicle speed...
measurements using Speed Gun. While secondary data are the supporting data to complete the needs of the data in measurement. The secondary data in this study are the coordinates of measurement points, journals, and books as a reference.

2.4. Data processing and analysis methods
To analyze the volume of vehicles carried out by the extraction method. The method is carried out by playing back the recorded video, then measuring the amount, composition, and time. The recording is done for each type of vehicle. At this stage, a CO emission load analysis is carried out based on motor vehicle emission factors generated based on vehicle volume data. This analysis uses the emission load calculation method based on the Minister of Environment Regulation No. 12 of 2010 (table 1). After obtaining vehicle volume data per year using the extraction method, Car Free Day length data, and emission factors based on the vehicle category, the vehicle CO emission load calculation is calculated using equation 1.

In this analysis, the amount of CO emission factors (g / km) (table 2) is based on vehicle speed (0 - 60 km/hour) and the type of vehicle. Based on the values of the emission factors in table 2, for the CO parameters with vehicle speeds not listed, the interpolation formula is the solution. For example, the average CO speed on Jl. Aceh Daeng Ngoyo on Sunday 2W4S is 28 km/hour. For the calculation of CO emission loads with Indian emission factors, the same as the formula for calculating emission loads with Indonesian emission factors.

3. Results and discussion
3.1. Vehicle volume
The volume of the vehicle prediction in one year in each location can be seen in table 3 to table 5.

Table 3. Vehicle volume data per years at Aceh Daeng Ngoyo street

| Time       | Car Free Day (Sunday) | Non Car Free Day (Monday) |
|------------|-----------------------|--------------------------|
| MC | LV | HV | MC | LV | HV |
| 06.00 – 07.00 | 435.802 | 100.339 | 0 | 467.251 | 60.653 | 1.498 |
| 07.00 – 08.00 | 631.238 | 126.547 | 2.246 | 965.952 | 135.533 | 0 |
| 08.00 – 09.00 | 538.387 | 131.040 | 2.246 | 917.280 | 180.461 | 2.995 |
| 09.00 – 10.00 | 610.272 | 140.026 | 1.498 | 832.666 | 149.760 | 2.995 |
| Total       | 2,215,699 | 497,952 | 5.990 | 3,183,149 | 526,406 | 7.488 |

Table 4. Vehicle volume data per years at Karunrun street

| Time       | Car Free Day (Sunday) | Non Car Free Day (Monday) |
|------------|-----------------------|--------------------------|
| MC | LV | HV | MC | LV | HV |
| 06.00 – 07.00 | 747.302 | 286.042 | 2.246 | 856.627 | 545.126 | 5.990 |
| 07.00 – 08.00 | 1,020.614 | 499.450 | 4.493 | 1,331.366 | 793.728 | 3.744 |
| 08.00 – 09.00 | 1,098.490 | 669.427 | 5.242 | 1,058.054 | 521.914 | 11.232 |
| 09.00 – 10.00 | 1,015.373 | 864.115 | 2.995 | 899.309 | 693.389 | 17.971 |
| Total       | 3,881,779 | 2,319,034 | 14.976 | 4,145,357 | 2,554,157 | 38.938 |

Table 5. Vehicle volume data per years at H. Saleh Daeng Tompo street

| Time       | Car Free Day (Sunday) | Non Car Free Day (Monday) |
|------------|-----------------------|--------------------------|
| MC | LV | HV | MC | LV | HV |
| 06.00 – 07.00 | 568.339 | 226.889 | 0 | 287.554 | 286.042 | 2.246 |
| 07.00 – 08.00 | 992.909 | 346.694 | 4.493 | 640.973 | 351.936 | 2.246 |
3.2. Vehicle Emission Loads with Indonesian Emission Factors

Emission loads on each Alternative Car Free Day Road on Car Free Day (Sunday) and Non Car Free Day (Monday) in Ance Dg. Ngoyo street can be seen in figure 2 below.

From figure 2a, it can be seen that the highest emission load occurs at 07.00-08.00 both Car Free Day (Sunday) and Non Car Free Day (Monday). This happens because the hours of 7:00 to 8:00 are the highest number of vehicles as shown in table 3 where the hours are indeed the peak hours. Based on figure 2b, it can be seen that the highest emission load occurs at 08.00-09.00 both during Car Free Day (Sunday) and Non Car Free Day (Monday). This happens because the highest light vehicle volume occurs at 08.00-09.00. In addition, on Car Free Day (Sunday), there is an increase in emissions load every hour. While on Non Car Free Day (Monday), there was also an increase in emissions load except at 09.00 - 10.00. From figure 2c, it can be seen that the highest emission load occurs during Car Free Day (Sunday) at 08.00 - 09.00 and 09.00 - 10.00. Whereas the Non Car Free Day (Monday) happens at 07.00 - 08.00 and 08.00 - 09.00 has the same emission burden. There is even a zero
emission load value (none), which is at 06.00-07.00 during Car Free Day (Sunday) and 07.00 - 08.00 during Non Car Free Day (Monday). This happens because the vehicle volume at that hour is zero (none), as shown in table 3. Emission Loads on each Alternative Car Free Day Road on Car Free Day (Sunday) and Non Car Free Day (Monday) at Karunrung street can be seen from figure 3.

![Figure 3](attachment:emission_loads.png)

**Figure 3.** Emission loads at Karunrung (a: Motorcycle, b: Gasoline car, c: Diesel car)

From figure 3a, it can be seen that the highest emission load when Car Free Day (Sunday) is at 08.00-09.00. This is in accordance with table 7 that shows the highest vehicle volume at 07.00 - 08.00. Whereas on Non Car Free Day (Monday), the highest emission load is at 07.00-08.00. Based on Figure 3b, it can be seen that the highest emission load during Car Free Day (Sunday) is at 09.00-10.00. This happens because the highest volume of light vehicles occurs at 09.00-10.00, as shown in table 7. In addition, during the Non Car Free Day (Sunday), there is an increase in emissions load every hour. Whereas during the Non Car Free Day (Monday), the highest emission load occurs at peak hours, namely at 07.00 - 08.00. Figure 3c shows that the highest emission load during Car Free Day (Sunday) occurs at 08.00 - 09.00. While Non-Car Free Day (Monday) occurs at 09:00 to 10:00. This happens because at that hour is the highest volume, as shown in table 4.

Emission Loads on each Alternative Car Free Day Road on Car Free Day (Sunday) and Non Car Free Day (Monday) at H. Saleh Dg. Tompo street can be seen in figure 4.
From figure 4a, it can be seen that the highest emission load during Car Free Day (Sunday) is at 08.00 - 09.00. This is in accordance with table 11 that the highest vehicle volume at 08.00 - 09.00. While on Monday, the highest emission load is at peak hours at 07.00-08.00. Based on figure 4b, it can be seen that the highest emission load during Car Free Day (Sunday) is at 09.00-10.00. This happens because the highest light vehicle volume occurs at 09.00-10.00 as shown in table 11. In addition, during Car Free Day (Sunday), there is an increase in emissions load every hour. Whereas during the Non Car Free Day (Monday), the highest emission load occurs at peak hours, which at 07.00 - 08.00. From figure 4c, it can be seen that the highest emission load during Non Car Free Day (Sunday) occurs at 09.00 - 10.00. Whereas the Non Car Free Day (Monday) occurs at 06.00 - 07.00 and 07.00 - 08.00 with the same emission load. This happens because at that hour is the highest volume, as shown in table 5.

3.3. Vehicle emission loads with Indian emission factors emission loads
Indian Emission Factors Emission loads, 2W4S (Motorcycles), 4WG (gasoline-fueled cars) and Buses / Trucks (diesel-fueled cars) in Makassar City which has been calculated based on equation 1, the results can be seen in the figure below.
Based on figure 5, 2W4S emission loads on Car Free Day (Sunday) at Ance Daeng Ngoyo is 1.4867 tons/year at a speed of 28 km/hour, at Karunrung 1.0481 tons/year at a speed of 31 km/hour and at H. Saleh Daeng Tompo 0.8443 tons/year at a speed of 23 km/hour. Whereas the Non Car Free Day (Monday) was 2.1359 tons/year at 28 km/hour, 1.1192 tons/year at 31 km/hour and 0.3479 tons/year at 32 km/hour.

In figure 6, it can be seen that the 4WG emission load during Car Free Day (Sunday) at Ance Daeng Ngoyo is 3.4931 tons/year at a speed of 25 km/hour, at Karunrung 7.2006 tons/year at a speed of 29 km/hour and at H. Saleh Daeng Tompo 3.4310 tons/year at a speed of 20 km/hour. Whereas the Non Car Free Day (Monday) was 3.6927 tons/year at a speed of 26 km/hour, 7.9307 tons/year at a speed of 25 km/hour, and 2.3675 tons/year at a speed of 25 km/hour.

Based on figure 7, it can be seen that the emission loads of Bus / Truck on Car Free Day (Sunday) at Ance Daeng Ngoyo is 0.0168 tons/year at a speed of 21 km/hour, at Karunrung 0.0186 tons/year at a speed of 23 km/hour and at Hj Saleh Daeng Tompo 0.0098 tons/year at a speed of 24 km/hour. Whereas the Non Car Free Day (Monday) is 0.0210 tons/year at a speed of 21 km/hour, 0.0484 tons/year at a speed of 25 km/hour, and 0.0017 tons/year at a speed of 18 km/hour. The speed and number of vehicles greatly affect the burden of emissions with Indian emission factors. Where the higher the speed and number of vehicles, the higher the vehicle's emissions burden.
Based on emission load in each location on Car Free Day (Sunday) an non car free day can be seen that CO emissions has no significant difference, this shows that in Makassar City Car Free Day is not efficient in reducing the loads of CO emissions. This result has the same result in Pekanbaru, which is car free day and non car free day has no significant difference [7]. In Semarang, the results also show that Car Free Day is not efficient in reducing loads of CO emissions [8].

4. Conclusions
CO emission loads in Makassar City based on the Indonesian Emission factors of Motorcycle and Car with Solar Fuel on Car Free Day (Sunday) is smaller than Non Car Free Day (Monday) with a difference of 3.04% and 0.02%. While for the Gasoline Cars on Car Free Day (Sunday) is greater than Non Car Free Day (Monday) with a difference of 2.08%. CO emission load in Makassar City based on Indian Emission factors is 2W4S (Motorcycle) and Bus / Truck on Car Free Day (Sunday) is smaller than Non Car Free Day (Monday) with a difference of 0.63% and 0.15%. Meanwhile, for 4WG (Gasoline Car) on Car Free Day (Sunday) is greater than Non Car Free Day with a difference of 21.45%. CO emission load is greatly influenced by the number of vehicles where the higher the number of vehicles, the higher the emission load produced. CO emissions in Makassar City on Car Free Day and Non Car Free Day showed no significant difference. This shows Car Free Day is not efficient in reducing loads of CO emissions.

5. References
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Figure 7. Bus/truck emission load
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