Simulating the potential for Carbon Dioxide (CO$_2$) reduction by the application of environmentally friendly transportation (case study: Gatot Subroto Street, Medan City)

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Abstract. Carbon Dioxide (CO$_2$) is one of the greenhouse gases. One source of greenhouse gases comes from the use of fossil fuels in the transport sector. The transportation sector is one of the dominant sectors in contributing to the greenhouse effect. This study aims to calculate the amount of CO$_2$ from transportation activities by using mobile six equations in Gatot Subroto Street, Medan City. A sampling of CO$_2$ concentration was done using Carbon Dioxide Monitor with Non-Dispersive Infra Red (NDIR) Analyzer method. Also, a simulation of the reduction of the number of private vehicles to mass transportation such as BRT gas-fired. The results showed CO$_2$ emissions calculations with mobile six ranged from 47.2 kg CO$_2$ - 978.2 kg CO$_2$. Meanwhile, measurements range from 3,004 ppm - 3,405 ppm. Implementation of the concept of environmentally friendly transportation such as BRT in Gatot Subroto Street, Medan City will be able to reduce the average emissions load CO$_2$ by 42.75% - 78.80%. Based on the calculation simulation in this study is estimated the number of BRT required approximately 71 units.

1. Introduction

The concentration of greenhouse gases (GRK) in the atmosphere has increased as a result of human activities [1]. This condition causes global warming with increasing average earth temperature [2]. Based on data from the [3], Earth's surface temperature has increased by 0.85ºC over the last 100 years, caused by GHGs in the atmosphere. Sources of emissions from carbon dioxide as major pollutants of GHG are from buildings, vehicles, industries and agriculture [4].

The transportation sector is one of the main causes of increasing greenhouse gas emissions, a major factor in global warming and climate change. The emissions generated from the transportation sector come from burning fossil fuels [5;6]. Based on research [7], CO$_2$ emissions in Cameroon comes from transportation activities of 59% of gasoline vehicles and 40% of diesel vehicles. Meanwhile, the mode of transportation that contributes to CO$_2$ emissions in China comes from truck type vehicles of 10-30% [8]. Transportation activities contribute as much as 75% of CO2 emissions in EU Countries [5].

Medan City is a city with a high population density of ± 8,265 people/km$^2$ [9]. Such rapid population growth will bring the consequences of increased use of motor vehicles. CO$_2$ emissions generated from motor vehicles in Medan City amounted to 31.9% [10].
One of the methods used in finding CO\textsubscript{2} emissions is the mathematical model [11]. The mathematical model used in this study is the Mobile 6. Mobile 6 is an air mathematical modeling developed by EPA (Environmental Protection Agency) USA. The parameters used in this Mobile 6 model are the types of vehicles such as cars, trucks, buses, motorcycles according to the fuel.

The purpose of this research is to be measured the ambient air CO\textsubscript{2} concentration in the Gatot Subroto Road, to predicted CO\textsubscript{2} emission by using Mobile 6 equation, to analyzed the relationship and influence between CO\textsubscript{2} emission from Mobile 6 to ambient air CO\textsubscript{2} concentration, to assessed potential CO\textsubscript{2} emission reduction with simulation by using BRT (Bus Rapid Transit).

The research location is in Gatot Subroto Street, Medan City. Selection of Gatot Subroto Street because the road has a V/C ratio of 0.91 [12]. The number of sampling points in this study is 6 (six). These 6 (six) points are intersections of Gatot Subroto Street, because Gatot Subroto Street has a length of 13.3 km and width 33 m. Sampling at the intersection of the road because the intersection is a congestion-prone area caused by the large volume of vehicles.

2. Methodology

2.1. Data Collection
Data collection related research includes primary and secondary data. Primary data collected were vehicle volume and ambient air CO\textsubscript{2} concentration. Measurement of ambient air CO\textsubscript{2} concentration using Carbon Dioxide Monitor tool. The method of analysis of Carbon Dioxide Monitor is NDIR Analyzer. Gas analyzer is a tool capable of analyzing the type of gas in an ambient air sample. Also, it can to provide quantity measurement values in numerical or graphic form [13].

2.2. Processing and Data Analysis
Equation Mobile 6 to determine CO\textsubscript{2} emissions from the transportation. CO\textsubscript{2} emission calculation steps using Mobile 6 method as follows. [14];

The first step is to convert the number of vehicles to the Passenger Car Unit (SMP), the second step is to calculate the vehicle fraction of each type of fuel (TG\textsubscript{n}) with the formula:

\[
TG_n = \frac{\text{The number of one type of vehicle}}{\text{total of the same fueled vehicle}}
\] (1)

The third step is to calculate the emission factor (ER\textsubscript{n}), by the formula:

\[
ER_n = \text{Emission factor} \times \text{density}
\] (2)

The fourth step is calculating CO\textsubscript{2} emissions for 1 liter of the vehicle (e), by the formula:

\[
e = \sum_{n=1}^{N} (TG_n \times O \times ER_n)
\] (3)

Total CO\textsubscript{2} emissions (kg), by the formula:

\[
Fuel = \frac{\text{Amount of Fuel (liter)}}{\text{Number of vehicles per fuel (smp)}}
\] (4)

\[
E = e \times Fuel
\] (5)

Where: Emission factor (g / Kg BBM) = KLH, 2010, gasoline density = 0.63 kg / L, solar density = 0.7 kg / L, O = total number of vehicles (SMP) and N = vehicle type


The calculation to forecast vehicle emission reduction is a scenario for transfer of car passenger to mass transportation. Determination of percentage of transportation mode transfer based on previous research is TransJakarta ± 20% [15] and target for Mebidang in Medan City is ± 32% [12], so in this research will be done transfer of car passenger to mass transportation as much as ± 30% with the type of fuel used is CNG (Compressed Natural Gas).

Data were analyzed statistically. The statistical test performed is regression and correlation test using SPSS. The size of the correlation number determines the strength or weakness of the relationship between the two variables. The benchmark numbers are as follows; if the $R^2 = 0-0.25$, it is mean the correlation is very weak; $R^2 > 0.25 -0.5$, it is mean correlation is enough; $R^2 > 0.5 -0.75$, it is mean strong correlation and $R^2 > 0.75-1$, it is mean very strong correlation.

3. Results and Discussions

3.1. Number of motor vehicles on Gatot Subroto Street

The study conducted at 6 (six) points along Gatot Subroto Street. The result of the volume of motor vehicles in Gatot Subroto Street segment presented in Figure 1.

![Figure 1. Number of motor vehicles on Gatot Subroto Street.](image)

The most dominant type of vehicle presented in Figure 1 is a motorcycle. Most vehicle volume located at point 1, namely Bundaran Intersection. The large number of vehicles at the Bundaran Intersection due to Monday is the beginning of community activity to be restarted after the weekend holiday to the office, campus or shopping center located at the research location. High economic density affects the volume of passing vehicles [16].
3.2. CO₂ emissions using mobile 6

Based on the volume of vehicles from the observation results by using the Mobile 6 equation obtained data CO₂ emissions. Mobile fuel data by assuming average fuel consumption spent per 1 liter per kilometer of the road for each type of motor vehicle.

The selected mileage for the car is 10 km, the motorcycle is 48 km, the bus and truck are 4 km [17]. In calculating the consumption of fuel oil is also required data length of the road. The data obtained by using the coordinate point of the Global Positioning System (GPS) device [18].

Results of data processing volume of motor vehicles using Mobile 6 method, then obtained CO₂ emissions at each point as shown in Figure 2.

![Figure 2. Total CO₂ emissions based on vehicle fuel.](image)

The contribution of CO₂ on Wednesday is high due to the exit and entry activity of city transport in Pinang Baris terminal. The number of vehicle around the terminals will affect CO₂ emissions caused by several activities, such as the movement of existing vehicles at the terminal with a speed of 7-30 km/h and idle time vehicle activity [19]. It is mean the result in the engine's engine being unable to work optimally at operating temperatures, resulting in fuel residues in the exhaust gases that make greenhouse gas emissions increase [20]. Parking management is a policy that needs to be implemented in crowded traffic terminals to reduce congestion. According to [21], on-street parking is an illegal parking activity that can disrupt traffic and can cause more stop-start conditions.

3.3. CO₂ concentration on Gatot Subroto Street

In addition to traffic counting at the location of the study also carried out the CO₂ ambient air concentration using the CO₂ monitor. The result of measurement of ambient air CO₂ concentration presented in Figure 3.
Measurement of CO$_2$ concentration at 6 (six) points along Gatot Subroto Street presented in figure 3 that CO$_2$ concentration measured in the morning and afternoon obtained highest in 3$^{rd}$ location i.e. Darussalam Intersection compared to the total measurement of other intersection.

The concentration of CO$_2$ at Darussalam Intersection is higher than other intersections along Gatot Subroto Street influenced by several other sectors: energy (37%), industry (22.2%), household (11%), others (2.6%) [22]. The transport sector accounts for 19.2% of total CO$_2$ emissions [23].

3.4 Analysis of vehicle volume effect on CO$_2$ concentration
The effect of vehicle on CO$_2$ concentration is obtained from regression and correlation test using SPSS. The result of the statistical from table shows that the correlation value is 0.179, it means that the relation between vehicle volume and CO$_2$ concentration is very weak. The coefficient of determination (R$^2$) is 0.032. The value of R$^2$ states that the number of the vehicle influences the concentration of CO$_2$ by R$^2$ = 0.032 or 3.2%. While 96.8% influenced by other factors, such as a large number of residents around the study site. This condition caused the increase of land woke up in Medan Petisah District and reduced green space. The population density has a positive correlation to CO2 emissions derived from household electrical appliances by 63%, 21% gasoline use and cooking activities using LPG by 16% [24].

3.5. Analysis of the effect of CO$_2$ emissions on ambient CO$_2$ concentration
The effect of CO$_2$ emission load on CO$_2$ concentration obtained from the result of regression and correlation test using SPSS. The result of the statistical from the table shows that the correlation value is 0.265, meaning that the relationship between CO$_2$ emission and CO$_2$ concentration is enough. The coefficient of determination (R$^2$) is 0.070 or 7%. While 93% is influenced by other sectors such as the commercial, industry, transportation, household, mining because some of the energy needs using premium, diesel, coal, LPG, and electricity resulted in increased CO$_2$ emissions [25].
3.6. Simulation of CO\textsubscript{2} emission load decrease with implementation of BRT (Bus Rapid Transit)
If the planned transfer of private transportation (motorcycles and cars) to mass transportation in the form of BRT then obtained the CO\textsubscript{2} emissions load as in Figure 4.

![Figure 4. CO\textsubscript{2} emissions before and after BRT simulation.](image)

Based on figure 4 presented if there is a transfer of transport mode from car passenger to BRT, the CO\textsubscript{2} emission decrease by BRT ranges from 42.75% - 78.80%. The amount of BRT needed to meet the CO\textsubscript{2} emission reduction is around 71 units. BRT is a high-quality bus based transit system that is fast, convenient and cost-effective. According to [26], the two most efficient strategies for reducing CO\textsubscript{2} emissions are improving motor vehicle fuel efficiency and improving BRT accessibility. Therefore, the provision of adequate mass transport and low-carbon transport infrastructure is better than expanding roads [27].

4. Conclusion
Based on sampling result of CO\textsubscript{2} concentration with NDIR Analyzer method obtained the highest CO\textsubscript{2} concentration at Jalan Darussalam 3,225 ppm for morning sampling time and 3,130 ppm for daytime. The correlation results show that if the CO\textsubscript{2} emission load is high, CO\textsubscript{2} concentration is also high. While the regression test results obtained that each addition of the CO\textsubscript{2} emission load value, than an increase in CO\textsubscript{2} concentration of 19.862 ppm. If the simulation of transport mode transfer from motor and car to BRT obtained, the decrease of CO\textsubscript{2} emission ranges from 42.75% - 78.80% with the required BRT amount ± 71 units.

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