Alternative study of reducing Carbon Dioxide (CO₂) from the transportation sector in Medan city

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Abstract. Increase of amount greenhouse gas (GHG) emissions from human activities in the form of an increase the number of vehicles indirectly impacting climate change. The purpose of this study is to calculate GHG emissions, namely carbon dioxide (CO₂) generated from the transportation sector and determine the scenario of reducing CO₂ emissions from the sector transportation in Medan City. The method of calculating GHG emissions in this study uses TIER II from IPCC. The study was conducted in 12 locations of sampling points with a traffic counting time of 12 hours per each point with variations in the time of workdays and weekdays. The results showed that CO₂ emissions generated at the twelve sampling locations amounted to 484.41 - 561.16 tons CO₂ / year. The scenario of reducing CO₂ emissions in this study is the application of Bus Rapid Transit (BRT), parking management systems and fuel substitution. Comparison of the average of the three scenarios in reducing CO₂ namely; the application of BRT ± 24.28% with the number of BRT units needed per road segment ranging from 11 - 57 units; fuel substitution of ± 9.16% and parking management system ± 12.08%.

1. Introduction

The occurrence of transportation growth triggers an increase in the amount of greenhouse gas (GHG) emissions that have an impact on global warming and climate change. Transportation is the third-largest source of emissions related to energy and land transportation is the largest outcome of CO₂ emissions, which is about 89% of CO₂ emissions and 91% of energy consumption in this sector. Emissions from the transportation sector will increase seven-fold between 2005 and 2030 to 443 MtCO₂eq [1].

An increase in the number of vehicles that are not accompanied by an increase in road capacity including road width and length will cause traffic congestion. Traffic jams will cause vehicles to pile up at one point, causing an increase in fuel consumption. Increasing the use of fuel will certainly increase the number of emissions produced by each vehicle.

In the transportation sector in North Sumatra Province, the total growth of GHG emission in 2020 is 105% higher than the emissions in 2010. The growth of GHG emission in North Sumatra province is higher than the growth of national GHG emissions, by the result of 68% from 2010 - 2020 [2].

On the Pittsburgh G-20 meeting, the Indonesian government fulfilled its commitment to reducing greenhouse gas emissions up to 26% by their own business and will reach 41% in the case of supported by international assistance in 2020 [2] [3] [4]. Meanwhile, Malaysia has a target to reduce CO₂ emissions on the transportation sector by 9.17 million metric tons per year in 2020 [5].
Following up on the commitment of GHG emission reduction, the government issued Presidential Regulation Number 61 of 2011 that concerning the National Action Plan for Reducing Greenhouse Gas Emissions (RAN-GRK). The regulation mandates all provinces to be responsible for drafting Regional Action Plans for Reducing Greenhouse Gas Emissions (RAD-GRK) no later than 12 months after the enactment of presidential regulations.

This study aims to calculate the greenhouse gas emissions of CO$_2$ from the transportation sector in Medan City and determine the scenario of reducing CO$_2$ emissions from transportation activities.

Calculation of CO$_2$ emissions from the transportation sector requires emission factor data. Emission factors are representative values that connect the number of pollutants released into the atmosphere from an activity related to the source of pollutants [6] [7].

Emissions produced by each vehicle depending on the type of vehicle, fuel used, distance traveled and operating conditions and vehicle maintenance. Every liter of fuel burned will emit about 100 grams of Carbon Monoxide; 30 grams of Nitrogen Oxide; 2.5 kg of Carbon Dioxide and various other compounds including sulfur compounds [8].

2. Method

2.1. Sampling point

This research began with collected secondary data of vehicle growth in Medan City, road physical data and several factors that affected CO$_2$ emission. In this study, the type and the number of vehicles, length of the road, and road coordinates are the primary data that has been collected. The calculation of type and number of vehicles will be conducted in 12 sampling locations, with a duration of sampling time is 12 hours for each point.

Some considerations in choosing 12 (twelve) of these points because based on research [9] [10], some sampling points are points that have an unhealthy air quality index. The selected road segment has a high traffic volume and often experiences congestion, especially during peak hours. V/C ratio at several sampling locations such as V/C Jalan Gatot Subroto is 1.08; V/C Jalan Raja Raja at 1.02 and V/C Jalan A. H. Nasution at 1.36. The traffic jam will cause the vehicle to pile up at one point with the condition still consuming fuel. Increasing BMM consumption will certainly increase pollutant emissions [11]. The 12 sampling points can be seen in Table 1.

**Table 1. Sampling points for traffic counting.**

| No | Name of Sampling Point | Name of Street | Coordinat | Representative |
|----|------------------------|----------------|-----------|----------------|
| 1  | TS1                    | Pulau Jawa Street | N 03°40'08,4" : E 098°40'12,2" | Industrial Area |
| 2  | TS2                    | Kapt. Sumarsono Street | N 03°36'55,9" : E 098°38'31,6" | Inter City Crossing |
| 3  | TS3                    | Gatot Subroto Street | N 03°35’24,3” : E 098°39’19,1” | Shops Area |
| 4  | TS4                    | S. Parman Street | N 03°35’22,9” : E 098°40’06,7” | Education Area |
| 5  | TS5                    | Balai Kota Street | N 03°35’26,3” : E 098°40’39,5” | Government Area |
| 6  | TS6                    | H. M Yamin Street | N 03°35’51,4” : E 098°41’21,4” | Trading Area |
| 7  | TS7                    | Brigjen Katamso Street | N 03°34’05,3” : E 098°41’14,2” | Settlement |
| 8  | TS8                    | Dr. Mansyur Street | N 03°34’03,1” : E 098°39’28,3” | Hospital Area |
| 9  | TS9                    | SM. Raja Street | N 03°32’16,1” : E 098°42’27,9” | Terminal Area |
| 10 | TS10                   | A. H. Nasution Street | N 03°32’30,8” : E 098°40’23,2” | Government Area |
| 11 | TS11                   | Bunga Sakura Street | N 03°32’31,2” : E 098°36’16,1” | Local Market |
| 12 | TS12                   | Letjen Jamin Ginting Street | N 03°30’08,5” : E 098°36’44,0” | Tourist Area |

2.2. Analysis of calculation of CO$_2$ emission from transportation sector

In this study, CO$_2$ emissions from the transportation sector are calculated using the IPCC Tier 2 method [7]. Tier 2 method is a calculation of the emission and uses more detailed equations in which the activity data was taken from national and/or regional data sources. The local emission factors were
obtained from direct measurement results. The calculation steps of CO$_2$ emissions from the transportation sector can be seen in the flow chart (Figure 1).

\textbf{Figure 1.} The calculation step of CO$_2$ emissions on transportation sector

Equation (1) is used to calculate the CO$_2$ emissions from the transportation sector \[7\].

\[
\sum CO_2 = L \times V \times \sum_{i=1}^{n} P_i C_{ij} \times F_{BBM}
\]

Where $\sum CO_2$ is emission load (g/hour), $L$ is the length of the road section observed (Km), $V$ is the total volume of vehicles passing through a road (vehicle/hour), $P_i$ is the fraction probability of distribution of type $i$ vehicles, $C_{ij}$ is emission factor (g/Km) and $F_{BBM}$ is fuel consumption (l).

2.3. The alternative scenarios for reduction of GHG emission

In this study, the action strategy that will be applied in the transportation sector can be divided into avoiding, shift, and improve. Avoid/reduce means to avoid or to reduce the trips or the necessity for travel (especially in urban areas) through land spatial-planning, regulation, and so on. Next, the shift means switching to more environmentally friendly modes of transportation (from personal to public transportation and non-motorized transportation). For the last, improve means to improve the energy efficiency of transportation modes and vehicle technology. The scenario for the reduction of GHG emissions from the transportation sector in Medan City is shown in Figure 2.

The CO$_2$ emission reduction scenario in this study consists of parking management, fuel substitution and the implementation of Bus Rapid Transit (BRT). Emission reduction is calculated by subtracting the total emissions from the load with the emission load after the scenario is applied. Equation (2) is used to calculate the reduction in emissions.

\[
BE_r\% = \left(\frac{BE_e - BE_{si}}{BE_e}\right) \times 100\%
\]

Where $BE_r$ is reduction of emissions burden, $BE_e$ is existing emission load and $BE_{si}$ is emission scenario.
3. Results and discussions
The results of this study will be discussed in 4 sub-topics, namely type and number of vehicles, GHG emissions from the existing transportation sector, GHG emissions from the transportation sector from each scenario of GHG emission reduction and alternative GHG emission reduction options.

3.1. Types and number of vehicles in the sampling location
Traffic counting or calculation of the number of vehicles based on the type of vehicle is carried out in 12 (twelve) research locations, carried out at one research location calculated on weekdays and weekends, each day is 12 hours. The results of the recapitulation of types and numbers of vehicles on weekdays and weekends at sampling points can be seen in Figure 3 and Figure 4.

Figure 3. Type and number of vehicles at sampling location on weekdays.
Figure 4. Types and number of vehicles at sampling locations on weekends.

In Figures 3 and 4, it can be seen that motorcycle is the highest number of vehicles on the 12 sampling points (measured on a weekday), which ± 57.02% of the total vehicles. Based on the results of traffic counting, Balai Kota Street is the most heavy road that traversed by vehicles on weekdays with the total number of vehicles is 124,448 units. It happened because Balai Kota Street is located on government area, trade area, hotel and culinary center of Medan City (namely Merdeka Walk), which is also one of an iconic place in Medan City.

Meanwhile, the average vehicles in 12 sampling locations are dominated by motorcycle, which result is ± 53.69% on weekends. The results of traffic counting indicated that SM Raja Street is the highest traffic road. Furthermore, it has road section and categorized as a primary arterial a road segment which is an inter-provincial inter-area. Hence, it passed by various types of vehicles especially on weekends, because the public generally will travel out of Medan City.

3.2. CO\textsubscript{2} emission from the transportation sector in Medan city

The type and number of vehicle data were converted to passenger car units according to the applicable road capacity manual. After the passenger car unit from the twelve road segments was taken, it was continued by calculating the CO\textsubscript{2} emission load. It has done by multiplying the length of the road (that corresponds to the road segment) and CO\textsubscript{2} emission factor (that corresponds to various types of vehicles), then multiplied by fuel consumption using Equation 1. The results of the calculation of CO\textsubscript{2} emission load from vehicle activities in Medan City on weekdays are shown in Figure 5.
Based on Figure 3, the sampling point that produces the highest CO$_2$ emissions is TS 9, SM Raja Street at 2.86 million tons of CO$_2$/year. The dominant type of vehicle emitting CO$_2$ is on SM Raja Street is a truck of 1.32 million tons of CO$_2$/year. This happened because the number of trucks that passed SM Raja Street on weekdays was 6,039 units for 12 hours of sampling.

**Figure 5.** CO$_2$ emissions on the transportation sector in Medan City on weekday.

**Figure 6.** CO$_2$ emissions from the transportation sector in Medan City on weekend.
Figure 6 shows that TS9 (SM Raja Street) is also the sampling point that produced the highest CO\textsubscript{2} emission load on weekend days, with the car being the largest emitter of CO\textsubscript{2} emission in 12 sampling points (unlike the weekday in Figure 3). This happened due to the limited transportation of goods transport vehicles, such as trucks following Law No. 20 of 2009 concerning Road Traffic and Transportation [12].

The results of the study by the research on [13], CO\textsubscript{2} emissions in Denpasar City have calculated by using the TIER II method, which produced 20,339.17 tons of CO\textsubscript{2}/year. Several factors that affect CO\textsubscript{2} emissions are road conditions and travel speed. Poor road conditions will slow down the speed of the vehicle and furthermore will increase the fuel consumption, whereas directly proportional to the increase of amount in CO\textsubscript{2} emissions [14].

In Yogyakarta City, emissions generated from the calculation of Tier 2 have the highest equivalent CO\textsubscript{2} emissions from motorized vehicles, which reached 581,568 tons/year. The factor that affected CO\textsubscript{2} emissions (in addition to the number of vehicles) is the process of burning fuel (combustion process) on a motorcycle in idle conditions. If the process is continued, the CO\textsubscript{2} emissions will remain out of the vehicles’ exhaust [8].

3.3. The scenario for reduction of CO\textsubscript{2} emission on the transportation sector in Medan City

Based on the calculation, the total amount of greenhouse gas emissions in the twelve research sites is 7.01 million tons of CO\textsubscript{2} / year for weekdays and 4.28 million tons of CO\textsubscript{2}/year for holidays. When compared with the average emission burden from the transportation sector in the city of Yogyakarta at 283,481 tons / year [8], the Surabaya area at 2.2 million tons CO\textsubscript{2}e / year [15] then the emission burden generated from the land transportation sector in Medan City is higher.

Some efforts to reduce GHG emissions due to the land transportation sector include: traffic management programs, BRT systems, parking management, car-free days, smart driving, improving fuel quality, raising Euro standards, hybrid vehicles and electricity, limiting the use of private vehicles [2; 3; 4]. The scaling down in this study was carried out for 3 (three) scenarios, namely the application of BRT, parking management and fuel substitution.

The reduction of CO\textsubscript{2} emission load using the Bus Rapid Transit (BRT) system is calculated using the same method as the calculation of the greenhouse gas emission load. In this calculation, it is assumed that ± 30% of private vehicles (cars and motorbikes) turn to BRT. The reduction in GHG emissions under the BRT system is calculated using the formula for reducing the emission load. The application of BRT can reduce the average CO\textsubscript{2} emission load is around ± 18.23% - 24.28% with the amount of BRT needed as much as ± 11 -57 units.

The second scenario is the application of a parking management system. The application of parking management is done by diverting the large number of private vehicles such as motorbikes and cars so that there is a decrease in the use of parking by 25% of private vehicles and cars [12]. The results of this study indicate that the application of parking management can reduce the burden of CO\textsubscript{2} emissions ranging from 8.47% - 12.08%.

Meanwhile, the third scenario is fuel substitution. The type of fuel substituted is gasoline to gas fuel. The types of vehicles to be substituted for fuel are trucks and buses as a mode of public transportation. Research results show that the substitution of fuel from gasoline to gas fuels results in a reduction in CO\textsubscript{2} emissions ranging from 5.78% - 9.16%.

3.4. Selected alternatives scenario for reduction of GHG emissions on the transportation sector in Medan City

In Section 3.3, the scenario for the reduction of CO\textsubscript{2} emissions from the transportation sector has been discussed. If illustrated the percentage of GHG emission reduction for each scenario can be seen in Figure 7.
Based on Figure 7, it can be seen that the reduction in CO\textsubscript{2} emissions from the three scenarios varies. The highest reduction in CO\textsubscript{2} emissions from the first scenario is the application of BRT. Medan City as an ideal metropolitan city already has sustainable mass transportation. The implementation of BRT (Bus Rapid Transit) has been planned in Medan City since 2015 but has not been realized. The main obstacle in implementing BRT is high investment, operational and maintenance costs. Another obstacle is the lack of socialization and communication between the government and the city transportation companies, resulting in rejection in the implementation of BRT. Despite all these obstacles, the implementation of BRT is expected to be able to reduce the number of private vehicles in the form of motorbikes and cars so that it is the chosen scenario to reduce the specific and significant burden of greenhouse gas emissions.

Research [16] concluded that the use of the BRT system resulted in significant CO\textsubscript{2} emissions reductions with BRT emissions ranging from 11\% to 85\% of passenger car emissions. Bus Rapid Transit System (BRT) has significant advantages in reducing congestion and reducing carbon emissions [17].

The results of the study [18] in the city of Bandung showed that the implementation of the BRT named Trans Metro Bandung (TMB) was one solution to reduce private vehicles but the presence of TMB affected the air quality in the city of Bandung. Therefore the BRT concept that is applied should be with environmentally friendly fuels.

Parking management is a scenario that is ranked second in this study in percent reduction in CO\textsubscript{2} emissions. The principle of the parking management system is to regulate vehicles that stop in areas close to the road segment with a solid v / c ratio so as not to cause congestion which results in congestion. The parking management system is implemented on roads that represent government areas, shopping centers, and city centers, which are areas that often use road bodies as parking areas (on-street).

The fuel to gas fuel substitution for the type of truck and bus vehicle is the lowest in reducing CO\textsubscript{2} emissions. This is because these types of vehicles are not the most numerous in the study location so the reduction in CO\textsubscript{2} emissions is not too significant. If the substitution of private vehicles is made, the reduction in CO\textsubscript{2} emissions can reach 17\%. Meanwhile, research conducted in Malaysia by [5] states that efforts to reduce CO\textsubscript{2} emissions in Malaysia from the transportation sector can be done by...
diversifying fuels and developing public transportation systems and increasing public awareness about eco-driving.

The application of fuel oil substitution to natural gas requires consideration of technical aspects and cost aspects. The technical aspect is the addition of a converter kit in each type of vehicle to deliver fuel to the engine combustion chamber. Besides, the need for the construction of gas refueling stations. The addition of converter kits and the construction of gas refueling stations require quite a lot of cost

4. Conclusion
CO₂ emissions generated from the transportation sector in Medan using the TIER II method amounted to 4.29 million - 7.01 million tons of CO₂ / year. If mitigation measures are not taken, there will be an increase in CO₂ emissions. Therefore, it is necessary to do a scenario of reducing CO₂ emissions. Implementation of BRT can reduce CO₂ emissions by 18.23% - 24.28% Parking management scenario can reduce CO₂ emissions by 8.47% - 12.08%, and the fuel substitution scenario reduces the burden of CO₂ emissions by 5.78% - 9.16%. Based on the advantages and disadvantages of each scenario, the chosen scenario is the application of BRT. The implementation of BRT is a mitigation measure in reducing GHG emissions and climate change which is most suitable to be applied in Medan City as a metropolitan city to create sustainable transportation.

Acknowledgments
The authors gratefully acknowledge that the present research is supported by University of Sumatera Utara. This research was funded by the University of Sumatera Utara in accordance with the contract of implementation of the TALENTA USU 2019 No: 4167/UN5.1.R/PPM/2019 date April 1st, 2019.

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