Carbon dioxide estimation at Lampung University based on vehicle volume

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Abstract. Of all activities related to carbon dioxide generation in Lampung University, vehicle exhaust is a main source of anthropogenic carbon dioxide (CO₂). Carbon dioxide (CO₂) may trap the earth’s heat which worsens the climate change. As for the physical condition of humans, high concentration of CO₂ exposure may cause death, unconsciousness, convulsions and fetus damage. Even in lower concentration, CO₂ exposure can cause hyperventilation, vision damage, lung congestion, central nervous system injury, and other health problems. A case survey was conducted to measure CO₂ emission based on two type of vehicles; private car and motorcycle to obtain the number of vehicle entry per gate. A mathematical model was also used to estimate CO₂ production. Several factors such as fuel consumption, emission factor, and number of running per day (distance) were used as inputs. CO₂ emission in the next five years was also estimated using the same method by previously extrapolated the earliest 5 years population data of Lampung University. The result shows that motorcycles are responsible for 1.636 ton of CO₂ emission or approximately 55% of the total CO₂ emission in Lampung University. Meanwhile, cars contribute to 1.34 ton of CO₂ emission or approximately 45% of the total CO₂ emission. It was also estimated that Lampung University would have an increase in vehicle number by 7.81%.

1. Introduction
It is an undeniable fact that transportation sector has become one of the biggest contributors of greenhouse gas (GHG) emissions around the world [1]. Report from IPCC in 2007 stated that more than a quarter of carbon dioxide (CO₂), shares of methane (CH₄), and nitrous oxide (N₂O) around the world was caused by transportation [2].

Based on the stated above fact, countries around the world has started to formulate strategies to tackle the challenge of GHG. Bali Climate Declaration in 2007 is one of the committed ways that emphasized joint efforts of developed and developing countries on climate change [3]. Green Campus concept is one of committed actions taken by Indonesian government to tackle the climate change issue in a small platform, in this case, university level.

Lampung University, is one of several campuses in Indonesia that has committed to provide a long term environmental improvement within the campus community, proved by its participation in UI GreenMetric along with other universities around the world. The aim of this program is to trigger participating universities to: a) provide more green space as well as the development of sustainable energy by 15%, b) increase the effort for energy efficiency in their buildings by 21%, c) establish programs related to waste treatments by 18%, d) decrease water usage by 10%, while at the same time, increase conservation program, e) limit the number of motor vehicles in campus by 18%, and f) raise
awareness that university plays a vital role in creating a new generation that is sustainability-conscious.

By early 2018, Lampung University has a 70 Ha of area with 29,462 number of people including students, lecturers, and academic staffs. This number triggers high and active movement from one building to another with 82.5% of it includes vehicles. Therefore, a high consumption of fossil fuel is to be expected along with the CO$_2$ emission as the result of vehicle exhaust. Estimation of current CO$_2$ concentration from vehicle exhaust is essentially needed in order to build an efficient countermeasure.

Conducting this research, some objectives were set. Those are: (a) to estimate CO$_2$ concentration from vehicle exhaust in Lampung University, (b) setting future planning for countermeasures of CO$_2$ emission in Lampung University.

2. Research Methods
The estimation of CO$_2$ in the Lampung University was based on the vehicle volume. In which the estimation was focused by the consumption of fuel from vehicle movement. Some data collection were needed. The estimation of CO$_2$ was performed by the simple mathematical model based on the fuel consumption

2.1. Subject and study area
This research was performed on two types of vehicle: cars and motorcycles; within the area of Lampung University in 2018 with a case survey study using random sampling method. Eight (8) faculties were chosen to become control points, as they generate most vehicle movements, with three main entrances: Gate 1, Gate 2, and Gate 3; as starting points as seen in Figure 2.1.

![Figure 1. Layout of Lampung University.](image)

2.2. Data collection
There are two types of data used in this study: secondary and primary data. Secondary data such as volume of vehicle was obtained from previous inventory study owned by Lampung University. Meanwhile, primary data: distance between gates and faculties and the number of vehicle entry per gate were obtained from the survey using random sampling method.

A time series of population number in Lampung University was also needed. The population data was used to predict the number of population within the next five years, by extrapolation. The plotting of population number in the next five years, helped to predict the vehicle population that may exist in Lampung University and its CO$_2$ emission.

2.3. Formula and equation
CO$_2$ emission concentration was estimated by calculating the number of vehicle movements in several faculty buildings with road segments connected to the entrance gates of Lampung University.
Approach was done [4] by classifying vehicles into motorcycles and cars with the fuel being used is petrol. Estimation of CO2 emission shall be calculated with Eq.1.

\[
EM(\text{CO}_2) = FC \times EF_F
\]  

(1)

Where,

\(FC\) = Fuel consumption

\(EF_F\) = Emission factor (kgCO2/L)

Value of emission factors were obtained by referring to emission conversion factors provided by DEFRA (2017) as shown in Table 1.

| Fuel     | Emission Factor (kgCO2/L) |
|----------|---------------------------|
| Petrol   | 2.1876                    |
| Diesel   | 2.57843                   |

*Source: [5]*

As for Fuel Consumption (FC), it can be calculated using Eq.2. as stated below.

\[
FC = AC \times V \times RD
\]  

(2)

Where,

\(AC\) = average consumption of fuel by each type of vehicle (L/km)

\(V\) = number of each type of vehicle

\(RD\) = amount of running per day/distance (km)

Oetomo, et al. (2006) used a table provided by IRMS (International Road Management System) to determine the average value of fuel consumption by each type of vehicle as seen in Table 2.

| Vehicle ID | Type of vehicle       | Fuel consumption (L/km) |
|------------|-----------------------|-------------------------|
| Veh 1      | Motorcycle            | 0.02                    |
| Veh 2      | Sedan/Jeep            | 0.09                    |
| Veh 3      | Passenger vehicle     | 0.1                     |
| Veh 4      | Goods distribution vehicle | 0.1                |
| Veh 5A     | Small Bus             | 0.12                    |
| Veh 5B     | Bus                   | 0.2                     |
| Veh 6A     | 2 axis-light truck    | 0.15                    |
| Veh 6B     | 2 axis-mid truck      | 0.2                     |
| Veh 7A     | 3 axis-truck          | 0.3                     |
| Veh 7B     | Trailer               | 0.3                     |
| Veh 7C     | Semi-trailer          | 0.3                     |

*Source: [6]*

3. Result and Discussion

3.1. Trip distance

This research taken into account just eight faculties as primary work units in Lampung University as trip destinations. Those faculties were: (1) Mathematics and Science Faculty (FMIPA), (2) Education
Faculty (FKIP), (3) Medical Faculty (FK), (4) Agriculture Faculty (FP), (5) Engineering Faculty (FT), (6) Economics and Bussinees Faculty (FE), (7) Law Faculty (FH). Trip distance was calculated with origin of trip were the three gates in Lampung University. The trip distance will influence how much the fuel was consume for the purpose of movement within Lampung University.

The longest distances from trips into those eight faculties were the trips from Gate 1. And the lowest distance were from Gate 3. The trip distance from Gate 1 were around 1 km until 1.3 km. While from Gate 3, the trips were around 0.4 km to 0.9 km.

3.2. Number of Vehicles in Lampung University

The number of vehicles in Lampung University is shown in Table 3 below. Based on the table, the vehicles in Lampung University was dominated by motorcyles with number of 20964 (86%) while private car was 3334 (14%).

| No | Destination | Number of Motorcycle | Number of Private Car | TOTAL |
|----|-------------|----------------------|-----------------------|-------|
|    |             | Student | Lecturer | Staff |          | Student | Lecturer | Staff |          |
| 1  | FMIPA       | 3543    | 15       | 87    | 3645     | 48       | 124      | 26    | 198      |
| 2  | FKIP        | 6100    | 39       | 104   | 6243     | 560      | 195      | 26    | 781      |
| 3  | FK          | 557     | 5        | 32    | 594      | 324      | 60       | 40    | 424      |
| 4  | FP          | 2236    | 101      | 104   | 2441     | 63       | 154      | 26    | 243      |
| 5  | FT          | 2303    | 34       | 88    | 2425     | 178      | 130      | 20    | 328      |
| 6  | FE          | 432     | 0        | 55    | 487      | 4        | 109      | 17    | 130      |
| 7  | FH          | 1453    | 10       | 74    | 1537     | 795      | 95       | 14    | 904      |
| 8  | FISIP       | 3402    | 61       | 129   | 3592     | 168      | 73       | 85    | 326      |
|    | Total       | 20964   |          |       |          | 3334     |          |       |          |

(Source: Lampung University inventory, 2017)

3.3. CO₂ Emission Estimation

Calculation of CO₂ Emission was performed based on Eq.1 and Eq.2 was shown in Table 4 and Table 5. It is estimated that motorcyles contribute to at least 1.636 ton/day of CO₂ emission or approximately 55% of the total CO₂ emission in Lampung University. Meanwhile, cars contribute to at least 1.344 ton/day of CO₂ emission or approximately 45% of the total CO₂ emission as shown in Figure 2.

| No | Destination | Rd (km) | Ac (l/km) | V | Total Vehicle | EM (CO₂) Kg | TOTAL EMISION (ton) |
|----|-------------|---------|-----------|---|---------------|-------------|---------------------|
| 1  | FMIPA       | 0.8     | 0.4       | 0.02 | 1761, 737, 1147 | 3645 | 81.189, 27.189, 21.147 |
| 2  | FKIP        | 0.8     | 0.4       | 0.02 | 2497, 1665, 2081 | 6243 | 115.126, 61.400, 38.375 |
| 3  | FK          | 1.3     | 1         | 0.6  | 208, 79, 307  | 594 | 12.460, 3.651, 8.489 |
| 4  | FP          | 1.1     | 0.5       | 0.7  | 1261, 529, 651 | 2441 | 63.957, 12.191, 21.007 |
| 5  | FT          | 1.1     | 0.4       | 0.7  | 808, 916, 701  | 2425 | 40.992, 16.894, 22.608 |
| 6  | FE          | 1.4     | 0.8       | 1    | 244, 73, 170  | 487 | 15.716, 2.694, 7.858 |
| 7  | FH          | 1.2     | 0.6       | 0.8  | 622, 293, 622  | 1537 | 34.417, 8.998, 22.945 |
| 8  | FISIP       | 1.3     | 0.7       | 0.9  | 1967, 599, 1026 | 3592 | 117.890, 19.320, 42.582 |

Estimation of CO₂ motorcyle comes into Lampung University (a) 0,818
Total CO₂ motorcyle come and out from Lampung University (a*2) 1,636
Table 5. Estimation of CO₂ emission from private car

| No | Destination | Rd (km) | Ac (l/km) | V | Total Vehicle | EM (CO₂) Kg | TOTAL EMISSION (ton) |
|----|-------------|---------|-----------|---|---------------|-------------|---------------------|
|    |             | G1  | G2   | G3 | G1  | G2   | G3   | G1  | G2   | G3 | G1  | G2   | G3 | G1  | G2   | G3 | G1  | G2   | G3 | G1  | G2   | G3 |
| 1  | FMIPA       | 1   | 0.8  | 0.4 | 0.1 | 96  | 40  | 62  | 198 | 22,051 | 7,384 | 5,744 | 0.0352 |
| 2  | FKIP        | 1   | 0.8  | 0.4 | 0.1 | 312 | 208 | 260 | 781 | 72,011 | 38,406 | 24,04 | 0.1342 |
| 3  | FK          | 1.3 | 1    | 0.6 | 0.1 | 148 | 57  | 219 | 424 | 44,469 | 13,031 | 30,298 | 0.088 |
| 4  | FP          | 1.1 | 0.5  | 0.7 | 0.1 | 126 | 53  | 65  | 243 | 31,834 | 6,068  | 10,456 | 0.0484 |
| 5  | FT          | 1.1 | 0.4  | 0.7 | 0.1 | 109 | 124 | 95  | 328 | 27,722 | 11,425 | 15,289 | 0.0544 |
| 6  | FE          | 1.4 | 0.8  | 1   | 0.1 | 65  | 20  | 46  | 130 | 20,976 | 3,595  | 10,488 | 0.035 |
| 7  | FH          | 1.2 | 0.6  | 0.8 | 0.1 | 366 | 172 | 366 | 904 | 101,23 | 23,815 | 67,47 | 0.193 |
| 8  | FISIP       | 1.3 | 0.7  | 0.9 | 0.1 | 179 | 54  | 93  | 326 | 53,496 | 8,767  | 19,322 | 0.0812 |

Estimation of CO₂; motorcyle comes into Lampung University (a) 0.669
Total CO₂; motorcyle come and out from Lampung University (a*2) 1.338
(Source: Analysis)

Figure 2. Percentage of CO₂ emission each type of vehicles in Lampung University.

It also estimated that by 2023, Lampung University would sustain an increase in number of students. Thus, an increase of vehicle number shall be expected. Using linear extrapolation and the same calculation method that is based on the earliest 5 years data, it was estimated that Lampung University would an increase in vehicle number by 7.81%. Early countermeasure shall be efficiently planned and practiced in order to achieve a greener campus. Figure 3. shows the result of CO₂ emission estimation in present time and the next 5 years.

Figure 3. Estimation of CO₂ emission in UNILA (present time and the next 5 years)
Based on this result, an immediate future planning is needed to reduce the concentration of CO$_2$ emission. Centralized parking system for student’s motorcycle can be a technical solution for this problem as it might reduce the running distance of vehicle. Hence, a decrease in CO$_2$ emission by is also to be expected. Figure 4. shows where the centralized parking system shall be located.

![Location of Centralized Parking System](image)

**Figure 4.** Expected location of centralized parking system

4. **Conclusion**

The vehicle movement in Lampung University was dominated by motorcycle with its number was around 20964. For private car, it was around 3334. By considering petrol as vehicle’s fuel, CO$_2$ estimation finding showed that motorcycles contributed about 55% or 1,636 ton/day while cars created about 45% or 1,34 ton/day. The projection for the next five years shown that there will be 7.81% of vehicle increment with CO$_2$ emission were 1,764 ton/day for motorcyles and 1,443 ton/day for cars. Centralized parking system for student’s motorcycle can be a technical solution for this problem as it might reduce the running distance of vehicle. Hence, a decrease in CO$_2$ emission by is also to be expected.

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