Study of carbon dioxide emission inventory from transportation sector at Kualanamu International Airport

I Suryati *1,3, I Indrawan2, K N Alihta1
1Environmental Engineering, Faculty of Engineering, University of Sumatera Utara, Medan 20155, Indonesia
2Civil Engineering, Faculty of Engineering, University of Sumatera Utara, Medan 20155, Indonesia
3Sustainable Energy and Biomaterial Center of Excellence, Universitas Sumatera Utara, Padang Bulan, Medan 20155, Indonesia
*Email: isratl@usu.ac.id

Abstract. Transportation includes sources of greenhouse gas emission contributor in the form of carbon dioxide (CO2). CO2 is one of the air pollutant gases that cause climate change. The source of CO2 emissions at airports comes from road and air transportation. Kualanamu International Airport is one of the public service airports in North Sumatera Province. The purpose of this study is to inventory the emission loads generated by motor vehicles and aircraft and to forecast contributions of CO2 emissions from motor vehicles and aircraft. The research method used is quantitative and qualitative methods. The quantitative method used is to estimate emission loads of motor vehicles based on vehicle volume and emission factors derived from the literature and using the Tier-2 method to calculate the aircraft emission loads. The results for the maximum CO2 concentration were 6,206,789.37 μg/m3 and the minimal CO2 concentration was 4,070,674.84 μg/Nm3. The highest aircraft CO2 emission load is 200,164,424.5 kg/hr (1.75 x 109 ton/year) and the lowest is 38,884,064.5 kg/hr (3.40 x 108 ton/year). Meanwhile, the highest CO2 emission load from motor vehicles was 51,299.25 gr/hr (449,38 ton/year) and the lowest was 38,990.42 gr/hr (341,55 ton/year). CO2 contribution from a motor vehicle is 65% and 5% from aircraft in Kualanamu International Airport.

1. Introduction
According to [1], the aviation service industry has contributed significantly to the growth of trade, communications, and tourism. In addition to the increasing specialization of air transport services also occurred the addition of the number of vehicles that are very significant. The increase in the number of vehicles will be directly proportional to the emission load, thus increasing air pollution and affecting ambient air quality.

Air pollution at the airport comes from exhaust fumes, aircraft refueling, motor vehicles within the airport area, ground service equipment, heating plants, fuel evaporation spilled on refueling, and emissions from combustion gases in incinerators. The environmental impacts of air traffic are often associated with noise, smoke and emissions of carbon monoxide (CO), unburned hydrocarbons (HC), including methane (CH4) and nitrogen oxides (NOx), carbon dioxide (CO2), sulfur dioxides (SO2) around the airport which can be detrimental [2; 3].

CO2 is one of the greenhouse gas pollutants. Increased greenhouse gas emissions will cause global warming. Global warming is an international issue that correlates with climate change. Climate change
is a phenomenon triggered by human activities related to the use of fossil fuels as well as land-use activities.

The Government of Indonesia in the Pittsburg G-20 meeting is committed to reducing greenhouse gas emissions by 26% by self-effort and reaching 41% if received international assistance by 2020.

Following the GHG emission reduction commitment, the government issued Presidential Regulation No. 61 of 2011 on the National Action Plan for Greenhouse Gas Emission Reduction (RAN-GRK) which mandates to provinces to be responsible for the preparation of the Local Green House Gas Emission Reduction Action Plan (RAD-GRK) no later than 12 months after the enactment of the presidential regulation.

The effects of the development of aircraft transport and air quality at airports today are so complex and controversial. This effect occurs not only in the area surrounding the airport but also at the regional and global levels. Emissions from aircraft not only affecting air quality in the airport area but are also driven by other emissions such as vehicles entering and exiting from the airport entrance, power usage, machine use, and other supportive things in the operation and activities of the airport itself [3].

Kualanamu International Airport is the main airport in North Sumatra Province. The airport is expected to become the main entrance, which is an international transit base for the region of Sumatra and its surroundings. Therefore the airport should be supported by the quality of infrastructure, services and in terms of good management and environmental management.

This study aims to calculate the concentration of CO\textsubscript{2} pollutants in the ambient air in Kualanamu International Airport, calculate CO\textsubscript{2} emissions load from aircraft and motor vehicles located in Kualanamu International Airport, and forecast contribution of CO\textsubscript{2} emissions from aircraft and motor vehicles versus ambient air quality in Kualanamu International Airport.

2. Methodology

The study was conducted at Kualanamu International Airport. Administratively, Kualanamu International Airport is in Beringin Village, Beringin District, Deli Serdang Regency. The research location located in Kualanamu International Airport area will be divided into 5 (five) sampling points, namely runway 05, runway 23, apron w, A7 parking lot and the gate of Kualanamu International Airport. Selection of this sampling point using purposive sampling method.

2.1. Data Collection

The data collected in this study consist of primary and secondary data. Primary data is a measurement of CO\textsubscript{2} concentration using monitoring tool CO\textsubscript{2} with analysis method that is NDIR Analyzer, the volume of aircraft traffic and motor vehicle and meteorology condition at the time of research. The duration of the primary data is 1 (one) hour with the measurement frequency 2 (two) times.

Secondary data collected are wind direction and wind speed data to obtain wind rose for consideration in determining sampling location, airplane fuel usage data, plane type data, and landing and take-off (LTO) data.

2.2. Data Analysis

Data analysis used is quantitative analysis. For quantitative analysis used with 4 (four) methods of data processing, namely:

1. Data on CO\textsubscript{2} concentrations measured at 5 (five) sampling points together with Balai Teknik Kesehatan Lingkungan and Pengendalian Penyakit (BTKLPP) Medan City.

2. The calculation of the emission load will use the Tier 2 method. This method is chosen because the Tier in the emission calculation shows the accuracy of the calculation [4]. The Tier-2 methodology is used for estimation of GHGs from aviation-fueled aircraft. In this methodology aircraft operations are divided into landing and take-off (LTO) and flying (cruise). To be able to use Tier-2 data landing and take-off (LTO) must be known. Steps for calculating GHG emissions by the Tier-2 method are as follows:

   a. Estimate aircraft fuel consumption for domestic and international
b. Estimate LTO fuel consumption for domestic and international

c. Calculate current LTO emissions for domestic and international

LTO Consumption = Number of LTO × Consumption per LTO

\[ (1) \]

LTO Emission = LTO Consumption × Emission Factor of LTC

\[ (2) \]

3. Calculation of vehicle emission load at Kualanamu International Airport. The data of the calculation of the number of vehicles that have been done will be converted into Passenger Car Unit (SMP). The conversion can be done by multiplying the number of vehicles calculated in the study sites with the factor value of SMP in accordance with the Indonesian Road Capacity Standards Manual [5]. After conversion to passenger car units, vehicle activity data is multiplied by the emission factor. The emission factor used refers to Minister of Environment Regulation No.12 Year 2010. The calculation of emission load for a pollutant from a motor vehicle on a road segment using Equation 3:

\[
E_j = \sum_{i=1}^{n} E_{ij} = \sum_{i=1}^{n} l P_i V_i C_{ij} = l V \sum_{i=1}^{n} P_i C_{ij}
\]

\[ (3) \]

Where: \(E_j\) = emission load (g / hour); \(l\) = the length of the observed road (km); \(V\) = total volume of vehicles passing a road (vehicle / hour); \(P_i\) = the probability distribution fraction of the type vehicle. (If the number of vehicles per category has been obtained, this probability value is not required); \(C_{ij}\) = vehicle emission factor (g / km)

4. Regression test and correlation of emission load on ambient air quality by using SPSS

3. Result and Discussions

3.1. Volume of Aircraft Traffic and Vehicles

Observation of aircraft traffic volume conducted on Wednesday and Thursday with 2 times the measurement frequency that is morning and afternoon. Segments observed on Wednesday are in Apron W and on Thursday are on runway 05 and runway 23. For more details, traffic volume based on observation time of morning and afternoon can be seen in Figure 1.
Based on Figure 1, it is can be seen that the average volume of aircraft is more on daytime measurement than in the morning measurement. This is due to the number of flight planes departing at around 10:00 to 15:00 pm.

Observation of motor vehicle traffic volume was done on Thursday with the frequency of sample measurement 2 times that is morning and afternoon. A segment of roads observed along ± 200 m. The traffic volume during observation can be seen in Figures 2. The location for observing the number of vehicles is at the entrance and exit Kualanamu International Airport.

**Figure 1. Aircraft Traffic Volume in Apron W and Runway**

**Figure 2. Number of Motor Vehicle Traffic at Entrance and Exit of Kualanamu International Airport**

Figure 2 shows the most dominant types of vehicles at the entrance of Kualanamu International Airport in the morning are passenger cars (gasoline) by 45.84%, motorcycles by 28.85%, 22.49% for
passenger cars (solar), buses by 2.44% and trucks by 0.37%. Meanwhile, during the day, the number of passenger cars (gasoline) by 62.46%, passenger cars (solar) and motorcycles are less than the morning of 17.80% and 14.84%, the number of buses also increased to 4.45%, and the number of trucks by 0.45%.

Based on Figure 2, the most dominant vehicle types at the exit of Kualanamu International Airport in the morning are passenger cars (gasoline) by 61.20%, motorcycle (26.11%), and diesel cars (9.58%), bus (2.40%) and trucks i.e. 0.72%. While at noon, the number of gasoline cars is less than the morning of 49.21%. In addition, diesel and motorcycle cars more than the morning of 14.48% and 31.94%. While the number of buses by 2.28% and trucks by 2.08%.

3.2. CO$_2$ Emissions Load From Aircraft and Motor Vehicles

The estimated total CO$_2$ emission load generated by each measuring time can be seen in Figure 3.

![Figure 3. Total CO$_2$ Emissions Load from Aircraft at Kualanamu International Airport](image)

Figure 3 shows that the highest estimated CO$_2$ emission load on Thursday at noon is 200,164.424.5 kg/hour, followed by the morning time of 123, 954,502.8 kg / hour. This is also due to the high flow of traffic at the time of measurement on Thursday when compared on Wednesday. The lowest CO$_2$ emissions burden on Wednesday morning is 38,884,064.5 kg/hour.

Results of research [6] at Soekarno Hatta International Airport show total CO$_2$ emissions per year is 588.747,3 tons (67,208,6 kg/hour). When compared to the CO$_2$ emission load results obtained from this research, the CO$_2$ emissions load at Kualanamu International Airport is higher than the previous study. This difference is caused by meteorological conditions, data retrieval times, and is influenced by machine type and aircraft type [7].

The estimated total CO$_2$ emission load generated at the entrance and exit of the airport at each measurement time can be seen in Figure 4.
Figure 4. Total Motor Vehicle CO$_2$ Emissions Load at Kualanamu International Airport

Figure 4 shows that the highest estimated CO$_2$ emission load from a motor vehicle at the exit of Kualanamu International Airport is 51.299.25 g/hr, followed by the morning time of 41.054.64 g/hr. This is due to the high flow of traffic on both sides of the road. Road segment that produces the lowest CO$_2$ emission load is at the entrance of Kualanamu International Airport in the morning at 38,990.42 g/hour.

3.3. CO$_2$ Concentration at Kualanamu International Airport

The result of measurement of CO$_2$ concentration in ambient air at each measurement location can be seen in Figure 5.

Figure 5. CO$_2$ Concentration at Kualanamu International Airport
Figure 5 shows the measured CO\textsubscript{2} concentration. The highest CO\textsubscript{2} concentration is at KNO Gate at daytime measurements of 6,206,789.37 μg/m\textsuperscript{3} or 3.449 ppm. The lowest concentration of CO\textsubscript{2} is Runway 05 in the morning measurement of 4,070,674.85 μg/m\textsuperscript{3} or 2.462 ppm. The CO\textsubscript{2} concentration of the measurement results is still below 5,000 ppm or still within reasonable limits. According to [8], concentrations greater than 5,000 ppm are not good for health while concentrations greater than 50,000 ppm can endanger animal life.

3.4. Effect of CO\textsubscript{2} Emission Load from Aircraft on CO\textsubscript{2} Observation

The result of analysis of CO\textsubscript{2} emission load data from aircraft to measured CO\textsubscript{2} concentration by using statistical analysis got regression equation as follows:

\[ y = 4.2 + 0.001x \]  \hspace{1cm} (4)

Where: \( y \) = CO\textsubscript{2} concentration; \( x \) = CO\textsubscript{2} Emission Load from Aircraft

Based on equation (4), it can be explained that each addition of 1 (one) CO\textsubscript{2} emission load value from the plane there is an increase in the CO\textsubscript{2} concentration of 0.001 μg/m\textsuperscript{3}. Correlation value (R) and the value of the coefficient of determination (R\textsuperscript{2}) obtained for 0.224 and 0.050. The R\textsuperscript{2} value states that the CO\textsubscript{2} emission load of the aircraft influences the CO\textsubscript{2} concentration of R\textsuperscript{2} = 0.05 or 5%, while 95% is influenced by other factors such as meteorological conditions i.e. wind direction and speed, increase of airplane flight frequency, movement of the opposite plane. The amount of power and fuel used will also impact on the emissions load [7; 9; 10].

3.5. Effect of CO\textsubscript{2} Emission Load from Motor Vehicles on CO\textsubscript{2} Observation

The result of data analysis of CO\textsubscript{2} emission load from motor vehicle to measured CO\textsubscript{2} concentration by using statistical analysis got regression equation as follows:

\[ y = -2,100 + 942.285x \]  \hspace{1cm} (5)

Where: \( y \) = CO\textsubscript{2} concentration; \( x \) = CO\textsubscript{2} Emission Load from Motor Vehicles

Based on equation (5), it can be explained that each addition of 1 (one) CO\textsubscript{2} emission load value from aircraft then there is an increase of CO\textsubscript{2} concentration as much 942.285,69 μg/m\textsuperscript{3}. Correlation value (R) and determination coefficient value (R\textsuperscript{2}) obtained for 0.806 and 0.65. The R\textsuperscript{2} value states that the CO\textsubscript{2} emission load of the motor vehicle affects the CO\textsubscript{2} concentration of R\textsuperscript{2} = 0.65 or 65%, while 35% is influenced by other factors such as meteorological conditions, CO\textsubscript{2} exchange with both main carbon sources i.e. biosphere, catalytic converter, fuel used and other activities at airports such as electricity usage and waste incineration [7; 11; 12; 13].

CO\textsubscript{2} emissions from motor vehicles and aircraft contribute 65% and 5% to measured CO\textsubscript{2} concentrations. This is due to the technology of motor vehicles that are currently using a catalytic converter. Catalytic converter is a tool that will react the harmful exhaust gases through chemical reactions so that later these gases will turn into a gas that is not harmful to the environment. However, the use of catalytic converter does not guarantee that all exhaust gases issued are not 100% clean of harmful flue gases such as CO that will become CO\textsubscript{2}, where the use of catalytic converter reduces CO emissions by up to 94% and HC to 86% but increases CO\textsubscript{2} emissions [14; 15]. This, therefore, causes a greater CO\textsubscript{2} emission load on motor vehicles compared to aircraft emission loads.

4. Conclusion

The results for the maximum CO\textsubscript{2} concentration were 6,206,789.37 μg/m\textsuperscript{3} and the minimal CO\textsubscript{2} concentration was 4,070,674.84 μg/m\textsuperscript{3}. The highest aircraft CO\textsubscript{2} emission load is 200,164,424.5 kg/hour and the lowest is 38,884,064.5 kg/ hour. The highest CO\textsubscript{2} emissions load from motor vehicles amounted to 51,299.25 g/hr and the lowest was 38,990.42 g/hr. The aircraft emission load contributes
5% to the measured CO$_2$ concentration. Meanwhile, motor vehicle emissions contribute 65% to the measured CO$_2$ concentration.

5. References

[1] Singh V, Sharma S K 2015 *Journal. Eur. Transp. Res. Rev.* 7: 12
[2] Olivier J G, Janssens-Maenhout G, Peters J A H W, Wilson J 2011 *Long-Term Trend in Global CO$_2$ Emission* (European Union: PBL Netherlands Environmental Assessment Agency)
[3] Ashford N J, Mumayiz S A, Wright P 2011 *Aiport Engineering* (USA: John Wiley & Sons Inc)
[4] KLH 2012 Pedoman Penyelenggaraan Inventarisasi Gas Rumah Kaca Nasional. Buku II-Volume 1 Metodologi Perhitungan Tingkat Emisi Gas Rumah Kaca (Indonesia: KLH)
[5] Direktorat Bina Marga dan Jalan Kota 1997 Baku Manual Kapasitas Jalan Indonesia (Jakarta: Kementerian Perhubungan)
[6] Adiati R R, Rahardyan B 2011 *Estimasi Kondisi Eksisting sebagai Dasar Rancangan Eco Airport Bandar Udara Soekarno Hatta* (Bandung: FSTL ITB)
[7] Ombasta, Osha 2012 *Pengaruh Siklus Landing Take Off (LTO) Pesawat di Bandar Udara Terhadap Fluktuasi Kadar NOx Pada Udara Ambien Studi Kasus Bandar Udara Internasional Soekarno Hatta di Jakarta* (Depok: Universitas Indonesia)
[8] Sehabudin S 2011 *Penambatan Karbon Dioksida dan Pengaruh Densitas Alga Air Tawar (chlorella sp)* (Jakarta: UIN)
[9] Slamet LS 2012 Potensi dan Dampak Polusi Udara dari Sektor Penerbangan. *Jurnal LAPAN*, 31 -36
[10] Kaleka Y U, Suyasa I W B, Mahendra M S 2014 *Jurnal Ecotrophic* 9 (1), 72-79
[11] Samiaji T 2012 *Berita Dirgantara* 12 (2), 68 -75
[12] Sanata A 2012 *Jurnal Rotor* 5 (2), 1-7
[13] Winarno J 2014 *Jurnal Fakultas Teknik Universitas Janabadra*, 1 -7
[14] Ellyanie 2011 *Prosidig Seminar Nasional AVoER UNSRI* 3, 1 – 9
[15] Sudjada C M, Warju 2014 *Jurnal Teknik Mesin Universitas Negeri Surabaya* 3 (2), 104 - 113