Influence of CO_2 emission to the various travel speed; Joint research IRE Indonesia and NILIM Japan

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Abstract: In most of Asian countries, motorcycle is the most popular vehicles. In Japan, Europe, and the US, motorcycles are rarely seen. It can easily be expected that a main transport in Asia will soon be changed from motorcycle to four-wheel vehicle. Four-wheel vehicle is safer than motorcycle, however, it has a higher ratio of CO_2 emission.

Institute of Road Engineering in Indonesia (IRE) and National Institute of Land and Infrastructure Management in Japan (NILIM) have jointly studied on "Environmentally Friendly Transport System, Using Motorcycle". This paper shows the results of field tests on CO_2 emissions of motorcycles in Indonesia and Japan. Incidentally, this paper shows the result of adding new insights to the result of CO_2 emission of motorcycle and four-wheel vehicle in Japan which was published in the interim paper.
Keywords: Motorcycles, CO_2 emission, Travel speed, Joint research, Indonesia, Japan

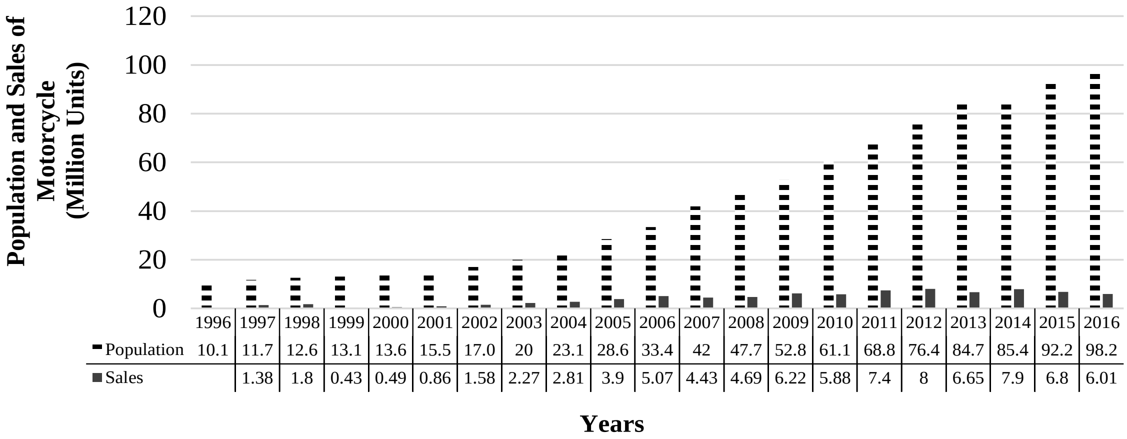
1. BACKGROUND

In most Asian countries, motorcycle is the most popular vehicles. In Japan, Europe, and the US, motorcycles are rarely seen. Motorcycle has some advantages which are: less CO_2 emissions, faster travel speed, and less impact on traffic capacity as motorcycles are smaller than other vehicles. It can easily be expected that a main transport in Asia will soon be changed from motorcycle to four-wheel vehicles, because these countries experience further economic growth. Consequently, it is considered that CO_2 emissions in road traffic may increase.

IRE and NILIM have jointly researched "Environmentally Friendly Transport System, Using Motorcycle". The objective of this research is to reconsider that the motorcycle is a road traffic mode superior in its ability to lower global environmental loads.

This paper shows the result of field tests on CO_2 emissions of motorcycles in Indonesia and Japan. Incidentally, this paper shows the result of adding new insights to the result of CO_2 emission of motorcycle and four-wheel vehicle in Japan which was published in the interim paper (DOHI and Agah M. MULYADI 2013).

Motorcycle is a most popular transportation mode in Indonesia and most rapid increase in population. The average increase of motorcycle population is by 12% annually during the period 2000 through 2016 (AISI, 2016). The population of motorcycles reached 98.4 million units or 81.4 percent of the overall composition of vehicles operating in Indonesia (BPS-AISI, 2016).



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Population	10.1	11.7	12.6	13.1	13.6	15.5	17.0	20	23.1	28.6	33.4	42	47.7	52.8	61.1	68.8	76.4	84.7	85.4	92.2	98.2
Sales		1.38	1.8	0.43	0.49	0.86	1.58	2.27	2.81	3.9	5.07	4.43	4.69	6.22	5.88	7.4	8	6.65	7.9	6.8	6.01

Figure 1. The Population and Sales of Motorcycle in Indonesia

The type of polluting fuel released by the engine with gasoline and diesel fuels is actually similar, but just different in proportion because of different ways of operating the machine. The type of emission observed in this study is CO_2 gas (which is included as a greenhouse gas) resulted directly or indirectly from human activity and is generally expressed in units as equivalent as tons of carbon dioxide (CO_2). Carbon emissions, particularly CO_2 emission, is a greenhouse gas (GHG) that can enlarge the Greenhouse Effect (ERK), which ultimately will increase the average temperature of the earth's flat surface also known as global warming. (SME-ROI, 1996).

The Government of the Republic of Indonesia issued Law No. 32 of 2009 on the Protection and Management of the Environment and the President Regulation of the Republic of Indonesia No. 61 Year 2011 on the National Action Plan for Greenhouse Gas Emission Reduction. In the Act stated that the preservation of the environment is done through the conservation of natural resources, reserves of natural resources and preservation of the function of the atmosphere.

One of the substances released from the combustion of transportation fuels is carbon dioxide (CO_2). Carbon dioxide or acid substance is a kind of chemical compound composed of two oxygen atoms covalently bonded to a carbon atom. Carbon dioxide is a greenhouse gas which, if neglected, the concentration will accumulates in the atmosphere and potentially causes a global warming and in long term it results in a dangerous climate change for human life.

The equivalent CO_2 emissions in the transportation sector in the world in the estimate amounted to 13% of total equivalent CO_2 emissions in the world. Meanwhile, when calculated on the total CO_2 emissions come from energy use alone, the contribution of transportation is 23%. It is predicted that emissions of the transportation sector will increase by 120% from levels in 2000 until 2050. Another prediction states that emissions of the transport sector in 2030 will increase by 57% from the level in 2005, where 80% of the increase occurred in the developing countries. (Wendy Aritenang, 2011). Comparison of CO_2 emissions of Indonesia and Japan in the transportation sector has a different trend, during the last period of 5 years (2011-2015) Indonesia has a trend of increasing the percentage at the amount of 31.85% in 2015, while Japan has a decrease trend at the amount of 17.28% (World Bank, 2016), as shown in the Figure 2.

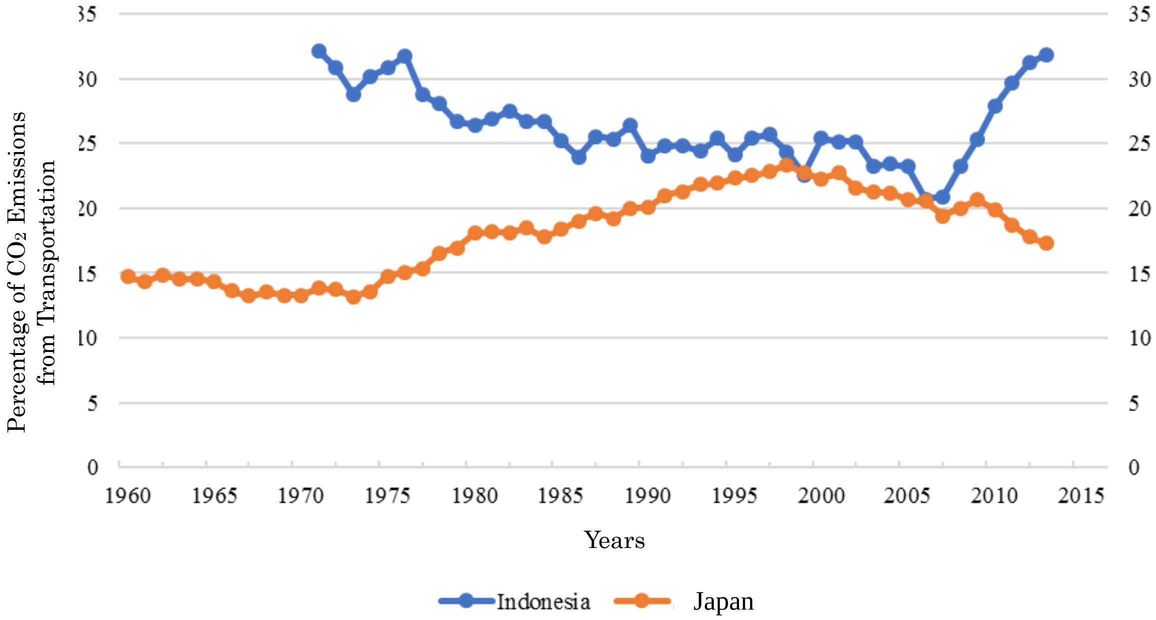


Figure 2. Percentage of CO_2 Emissions from Transportation Sector By Year

The Joint Research between Indonesian IRE and Japan NILIM concerns with the motorcycle exhaust emissions that is focused on the extent to which the motorcycle exhaust emissions accounted for the impact on the environment, with the parameters of various motorcycle speeds. This study is very important because the largest emitters in big cities come from the transportation sector.

2. ROAD MAP OF THE JOINT RESEARCH

The joint research between Indonesian IRE and Japan NILIM started in 2011 and was completed in 2017. The theme of the joint research is “Environmentally Friendly Transport System, Using Motorcycle”. At the beginning of the joint research in 2011, a comparison of factual data was conducted regarding traffic conditions in each state. Japan NILIM began to test CO_2 emissions of various types of vehicles in Japan (Motorcycles, Passenger Cars and electric motorcycles). Indonesian IRE has conducted a study in the year 2011 on the criteria design of exclusive motorcycle lanes and then Indonesian IRE started tests on the CO_2 emissions of the various types of motorcycles in Indonesia.

Reports were prepared during the research, which were published in 2013 and 2014 at the international conference, while the next paper on “The Influence of CO_2 emission on the various travel speeds” is going to be published in 2017. Table 1 shown summary of the roadmap of collaborative research conducted by Indonesian IRE and Japan NILIM.

Table 1. Summary of the roadmap

Year	NILIM JAPAN	IRE INDONESIA
2011	Comparison of the factual data on road traffic between Indonesia and Japan	
	Drafting of field test plans on CO_2 emissions of motorcycle and four-wheel vehicle in Japan	Study on design criteria of exclusive lane for motorcycle
	Field test on CO_2 emission of motorcycle, and four-wheel vehicle in Japan	
	Hearing from motorcycle factory	Hearing from motorcycle factory
2012	Estimation the effectiveness to reduce CO_2 emissions, using Japanese theory on traffic capacity	Model to predict CO and HC from motorcycle emissions
2013	Publish joint paper in 14th REAAA conference in March 2013 in Kuala Lumpur	
	Estimation of the CO_2 emissions effectiveness in the world, by switch motorcycle to four-wheel vehicle	Model to estimate CO_2 emission of motorcycle
		Evaluation of CO_2 on motorcycle lane
2014	Publish joint paper in the 1st IRF Asia Regional Congress & Exhibition in Bali	
2015	Providing a speed sensor, fuel consumption meter and GPS to be installed on motorcycle	IRE received the equipment and conduct collecting data of CO_2 emission for motorcycle on actual road with actual travel speed and actual geometric condition.
2016	Sharing data to be analyzed together, finding out the relationship between CO_2 emission and actual travel speed and actual geometric condition.	
2017	Making paper together and publish in workshop/international conference	

3. METHODS

3.1 Survey Methods in Indonesia

3.1.1 Methods of Survey

The fuel consumption surveys were conducted to obtain the value of the fuel consumption at a certain distance at a constant speed. The survey was conducted on the route of the access road stadium Gelora Bandung Lautan Api with a route length of 3.20 km. Selection of these surveys was conducted based on the need of each motorcycle speed data desired is constant. So the survey is done not on the highway with traffic mix, but a survey conducted on a relatively quiet street (Empty). Every decision of the data of motorcycle consumption made the trip as much as two times, so that each one has a testing trip along the 6.4 km long.

Tests performed on the fuel consumption of seven variations of speeds: 10 km/h, 20 km/h, 30 km/h, 40 km/h, 50 km/h, 60 km/h and 70 km/h. Motorcycles used to do the testing are as many as three motorcycles with various different engine displacement which represent the majority of motorcycles in Indonesia. The route of motorcycle fuel consumption testing is shown in the Figures and Tables of survey methods are shown in the Table 2.

Figure 3 Location of Fuel Consumption Survey Motorcycles

Tabel 2. Parameters of Motorcycle Fuel Consumption Surveys

Parameter	**Remarks**
Number of Motorcyles	3
Types of Engine Displacements	110cc, 125cc, 150 cc
Years of Productions	2013 and 2014
Number of Tested	7 times per motorcycle
Routes	Gelora Bandung Lautan Api Stadium
Average Travel Distances	6.2 km
Lane width	7 m
Driver Weight	60 kg
Types of Fuels	Pertamax with Octane Number (RON) 92
GPS Application	My Track (Android OS)

Survey of motorcycle fuel consumption before and after the motorcycle passed the predetermined route. Furthermore, fuel consumption value is obtained by calculating the amount of the used fuel consumption after a motorcycle run in liters (lt). The steps in making the fuel consumption data are as follows:

1) Before motorcycle drove passes through the predetermined route with a constant speed, the motorcycle tank must be filled fully.
2) The next the motorcycle passes through the route with a speed that has been determined.
3) Once the motorcycle finished through the route, the calculation of fuel consumption by filling fully the tank of motorcycle, so that the amount of fuel used (filling fully the

tank) is the motorcycle fuel consumption.

Figure 4. The Equipment of Motorcycle Fuel Consumption Survey

3.1.2 Methods of Analysis

The data processing method of fuel consumption is to convert from survey data of fuel consumption to CO_2 emissions calculated using the equation adopted by the Clean Development Mechanism (CDM) Methodology AMS-II1 as shown in the equation 1.

$$EF_{fl,km} = SFC \quad x \quad NVC \; x \quad EF_y \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Dengan:

$EF_{fl,km}$ = Emission factor for the vehicles with gasoline (gCO_2/km).
SFC = Value of vehicle fuel consumption (g/km).
NVC = Calorific value of fossil fuel consumed by vehicles (J/g).
EF_y = Emission factor of fossil fuel consumed by vehicles (gCO_2/J).

Integovermental Panel on Climate Change (IPCC) Indonesia has determined the amount of value for NVC amounted to in Indonesia amounted to 42.66 x 10^3 J/g and EFY of 69.3 x 10^6 gCO_2/J. As for the value obtained from the SFC consumption survey fuel is carried out in units of grams per km.

3.2 Survey Methods in Japan

3.2.1 Conditions

In order to confirm that motorcycles have an effect of reducing global environmental load compared to four-wheel vehicles, a driving survey was performed using the same vehicles on the same course under the same conditions.

Figure 5 shows the driving survey route was an ordinary congested road in Tokyo, Japan (9.2 km from Yoyogi Park to Hibiya Park). The driving survey period was three days on weekdays from 27th to 29th September 2011 (12 hours per day). All vehicles drove at the same time for one way for the same route every one hour.

The vehicles used for the survey were a four-wheel vehicle, motorcycles (250cc, 125cc, and 50cc). Table 3 shows the specification of each vehicle used for the survey. Air conditioning of four-wheel vehicle was turned off.

The driving method was basically the same in each vehicle. Only motorcycles, even if there were parking vehicles on the first lane on the sidewalk side, it is possible to drive if there was sufficient width of the vehicle for traffic safety. Survey items were fuel consumption per a round trip of the vehicle, average travel speed and travel time.

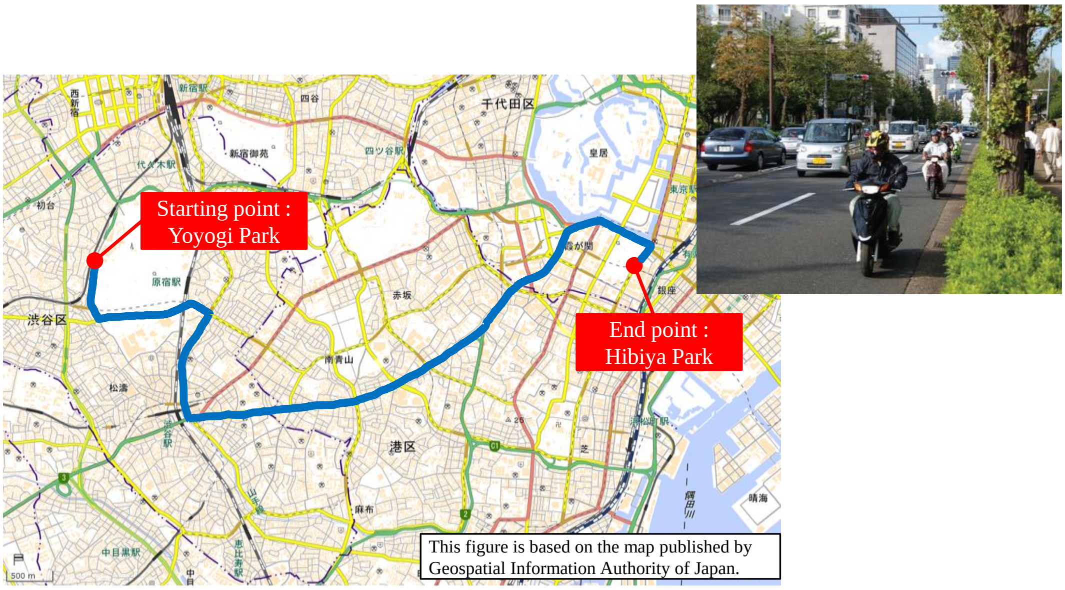


Figure 5. Route using survey test and its situation

Table 3. Vehicles used for the survey

Test Vehicle	Displacement (cc)	Weight (kg)
Four-wheel vehicle	1,490	1,405
Motorcycle 250 cc	248	204
Motorcycle 125 cc	124	110
Motorcycle 50 cc	49	68

3.2.2 Method of converting fuel consumption to CO_2 emissions

CO_2 emissions were converted from fuel consumption. Fuel consumption was surveyed using an actual fuel consumed after one round trip. Equation of converting fuel consumption to CO_2 emissions is the below (UNFCCC, 2011).

$$CO_2 emissions (gCO_2/km) = 67.1\times10^{-6} \times 46.1\times10^{3} \times 0.75\times10^{3} \times Fuel\ consumption\ (L/km) \quad (2)$$

where,

$67.1\times10^{-6}\ (gCO_2/J)$: Emission factor of fossil fuel consumed by a vehicle

$46.1\times10^{3}\ (J/g)$: Net calorific value of fossil fuel consumed by a vehicle

$0.75\times10^{3}\ (g/L)$: Specific gravity of gasoline

4. DATA AND ANALYSIS

4.1 Data and Analysis in Indonesia

4.1.1 Data of Survey

The fuel consumption survey was conducted on Wednesday, November 30, 2016, in these route conditions it can be said to be quiet, because there is no activity around the stadium GBLA. Survey activities were carried out begin at 07.00 am and finished at 13:00 pm. The mileages of motorcycles against each survey route varied depending on the characteristics of the driver, so even with the average speed and maximum speed obtained. The activities of fuel consumption surveys are shown in the figure and the raw data obtained are shown in the Table 4.

Figure 6. The Activities of Motorcycle Fuel Consumption Survey

Table 4. Data of Survey Results on The Motorcycle Consumption

No	Motorcycles	Travel Distance (km)	Travel Time (Minutes)	Projection Speed (km/h)	Average Speed (Km/h)	Maximum Speed (km/h)	Fuel Consumption (lt)
1	110 cc	6.7	35	10	11	12	0.06
2	110 cc	6.4	20	20	19.4	20.5	0.033
3	110 cc	6.6	20	30	31.5	32.3	0.04
4	110 cc	6.4	20	40	41.1	44.3	0.04
5	110 cc	6.2	21	50	49.6	51.6	0.047
6	110 cc	6.2	10	60	62,3	62.4	0.03
7	110 cc	6.2	11	70	71.2	71.4	0.04
8	125cc	6.42	38	10	9.9	11.9	0.035
9	125cc	6.2	20	20	18.2	21	0.015
10	125cc	6.4	16	30	33.6	31.7	0.04
11	125cc	6.4	12	40	39.5	43.3	0.02
12	125cc	5.9	12	50	51	54	0.04
13	125cc	6.38	8	60	63.2	64	0.02
14	125cc	6.4	8	70	69.2	75	0.04
15	150cc	6.6	42	10	9.1	10.6	0.09
16	150cc	6.4	22	20	17.3	19.7	0.12
17	150cc	6.4	14	30	24.8	28.6	0.02

Table 4. Data of Survey Results on The Motorcycle Consumption

No	Motorcycles	Travel Distance (km)	Travel Time (Minutes)	Projection Speed (km/h)	Average Speed (Km/h)	Maximum Speed (km/h)	Fuel Consumption (lt)
18	150cc	6.4	12	40	40.6	39.7	0.02
19	150cc	6.8	10	50	55.8	47.4	0.02
20	150cc	6.4	10	60	62.8	58.8	0.1
21	150cc	6.4	8	70	67.3	70.4	0.13

From the results of data collection we obtained a number of 21 data on the fuel consumption in liters based on the types of motorcycles and speeds as well as other supporting data. The other supporting data are data of motorized-vehicle mileage (km), travel time to the motorcycle (minutes), the average speed at the time of the survey (km/h) and a maximum speed of travel at the time of the survey (km/h). To do the conversion and fuel consumption (It) to the equation of the Clean Development Mechanism (CDM) Methodology AMS-III, it is necessary to do a unit conversion from liter to liter/km and further to grams/km to be introduced into the equation.

4.1.2 Analysis

The value of motorcycles fuel consumption is directly correlated with the value of motorcycle CO_2 emissions. In the 110cc-motorcycle obtained the highest value of motorcycle CO_2 emissions which is equal to 21 gCO_2/km and the lowest value is 11 gCO_2/km. Meanwhile, types of 125cc-motorcycle obtained the highest value for CO_2 emissions is 16 gCO_2/km and the lowest is6 gCO_2/km. Engine displacement of 150cc-motorcycles, the highest value 48 gCO_2/km and the lowest is 7 gCO_2/km.

Tabel 5. Data of Analysis Results of Motorcycle CO_2 emissions

No	Motorcycles	Travel Speed (km/h)	Fuel Consum-ption (lt)	Fuel Consum-ption (lt/km)	Fuel Consumption (gr/km)	NVC (J/g)	EFy ($grCO_2$/km)	(gCO_2/ km)
1	110 cc	10	0.06	0.00896	7.16	42660	0.000069	21
2	110 cc	20	0.033	0.00516	4.13	42660	0.000069	12
3	110 cc	30	0.04	0.00606	4.85	42660	0.000069	14
4	110 cc	40	0.04	0.00625	5.00	42660	0.000069	15
5	110 cc	50	0.047	0.00758	6.06	42660	0.000069	18
6	110 cc	60	0.03	0.00484	3.87	42660	0.000069	11
7	110 cc	70	0.04	0.00645	5.16	42660	0.000069	15
8	125cc	10	0.035	0.00545	4.36	42660	0.000069	13
9	125cc	20	0.015	0.00242	1.94	42660	0.000069	6
10	125cc	30	0.04	0.00625	5.00	42660	0.000069	15
11	125cc	40	0.02	0.00313	2.50	42660	0.000069	7
12	125cc	50	0.04	0.00678	5.42	42660	0.000069	16
13	125cc	60	0.02	0.00313	2.51	42660	0.000069	7
14	125cc	70	0.04	0.00625	5.00	42660	0.000069	15
15	150cc	10	0.09	0.01364	10.91	42660	0.000069	32

Tabel 5. Data of Analysis Results of Motorcycle CO_2 emissions

No	Motorcycles	Travel Speed (km/h)	Fuel Consum-ption (lt)	Fuel Consum-ption (lt/km)	Fuel Consumption (gr/km)	NVC (J/g)	EFy (grCO_2/km)	(gCO_2/ km)
16	150cc	20	0.12	0.01875	15.00	42660	0.000069	44
17	150cc	30	0.02	0.00313	2.50	42660	0.000069	7
18	150cc	40	0.02	0.00313	2.50	42660	0.000069	7
19	150cc	50	0.02	0.00294	2.35	42660	0.000069	7
20	150cc	60	0.1	0.01563	12.50	42660	0.000069	37
21	150cc	70	0.13	0.02031	16.25	42660	0.000069	48

4.2 Data and Analysis in Japan

CO_2 emissions of four-wheel vehicles and motorcycles were compared and the effect of reducing environmental impact of motorcycles for four-wheel vehicles was analyzed. Figure 7 shows the driving survey data of CO_2 emissions per a km in each round trip from four-wheel vehicles and motorcycles. Figure 8 shows simple average, the maximum and minimum values (described as "I") of CO_2 emissions (per km). It is evident from these figures that the greater level of CO_2 emission occurs with four-wheel vehicles than motorcycles.

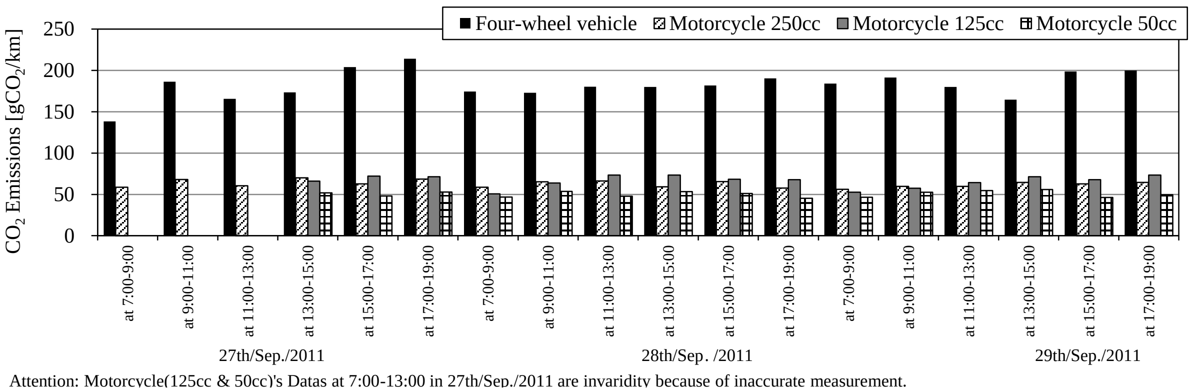


Figure 7. Driving survey data of CO_2 emissions from four-wheel vehicles and motorcycles

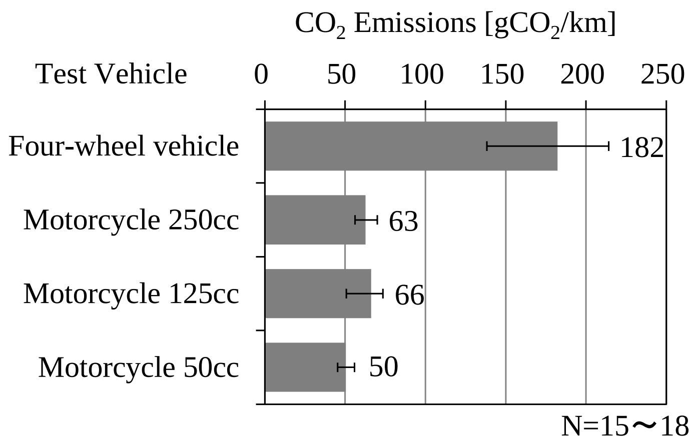


Figure 8. Simple average values of CO_2 emissions

5. RESULT

5.1 Result in Indonesia

Based on the results of the analysis of the value of the lowest CO_2 emissions to 110cc-motorcycles are at a speed of 40 km/h and 50 km/h. For 125cc-motorcycle lowest CO_2 emission the motorcycle speed is obtained on a 30 km/h and 40 km/h, then to 150cc-motorcycles are at a speed of 40 km/h.

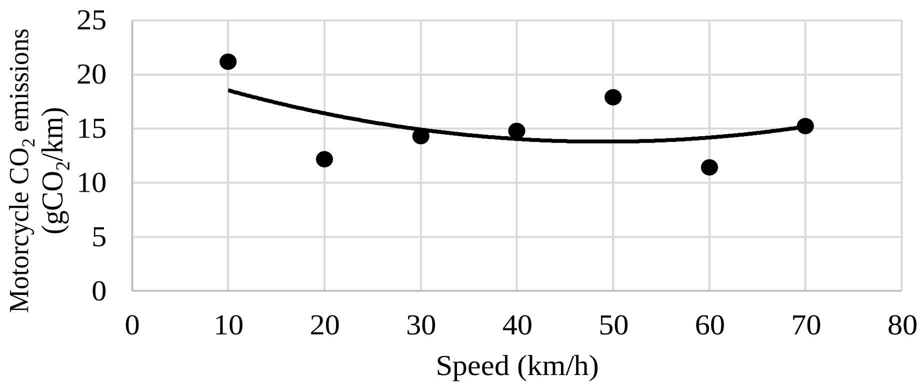


Figure 9. The relationship between travel speed and 110cc motorcycle CO_2 emissions

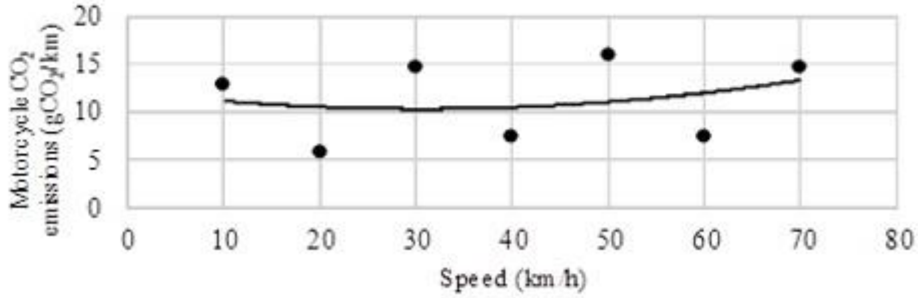


Figure 10. The relationship between travel speed and 125cc motorcycle CO_2 emissions

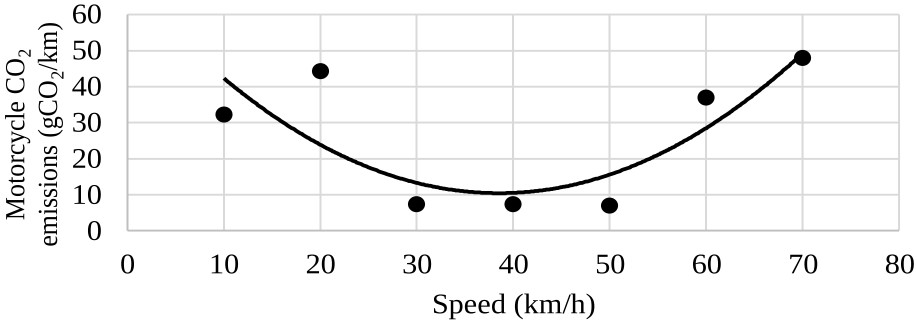


Figure 11. The relationship between travel speed and 150cc motorcycle CO2 emissions

In the motorcycle type with the lowest combined CO_2 emission value is contained in the motorcycle speed of 40 km/h. From the values of motorcycle CO_2 emissions produced by the motorcycle speed, it can be concluded at a low speed of 10 km/h and 20 km/h value of CO_2 emissions tends to be high so even when the motorcycle at a high speed of 60 km/h and 70 km/h CO_2 emission values tend to re-grow. Constant speed on a motorcycle affects the value of CO_2 emissions, resulting in traffic jams can be said vehicle CO_2 emissions released even greater. Graph of the relationship between the motorcycle and the overall speed of the motorcycle type as shown in the Figure 12.

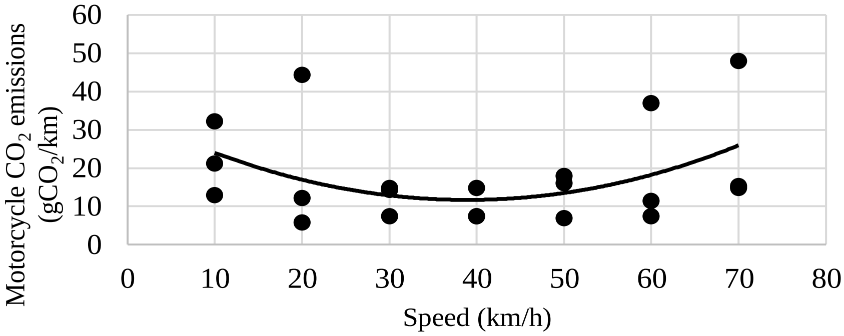


Figure 12. The relationship between travel speed and combined motorcycle CO_2 emissions

5.2 Result in Japan

Different levels of CO_2 emission with various travel speed was analyzed using the driving survey data. Figure 13 shows comparison data between the average travel speed and the CO_2 level released by each vehicle. The result show clear evidences shown below:

1) The level of CO_2 emissions becomes lower as an increase was seen in the average travel speed of all four-wheel vehicles and motorcycles on congested road.
2) Average travel speed on the congested road is higher for the motorcycles with 250cc and 125cc than four-wheel vehicles.

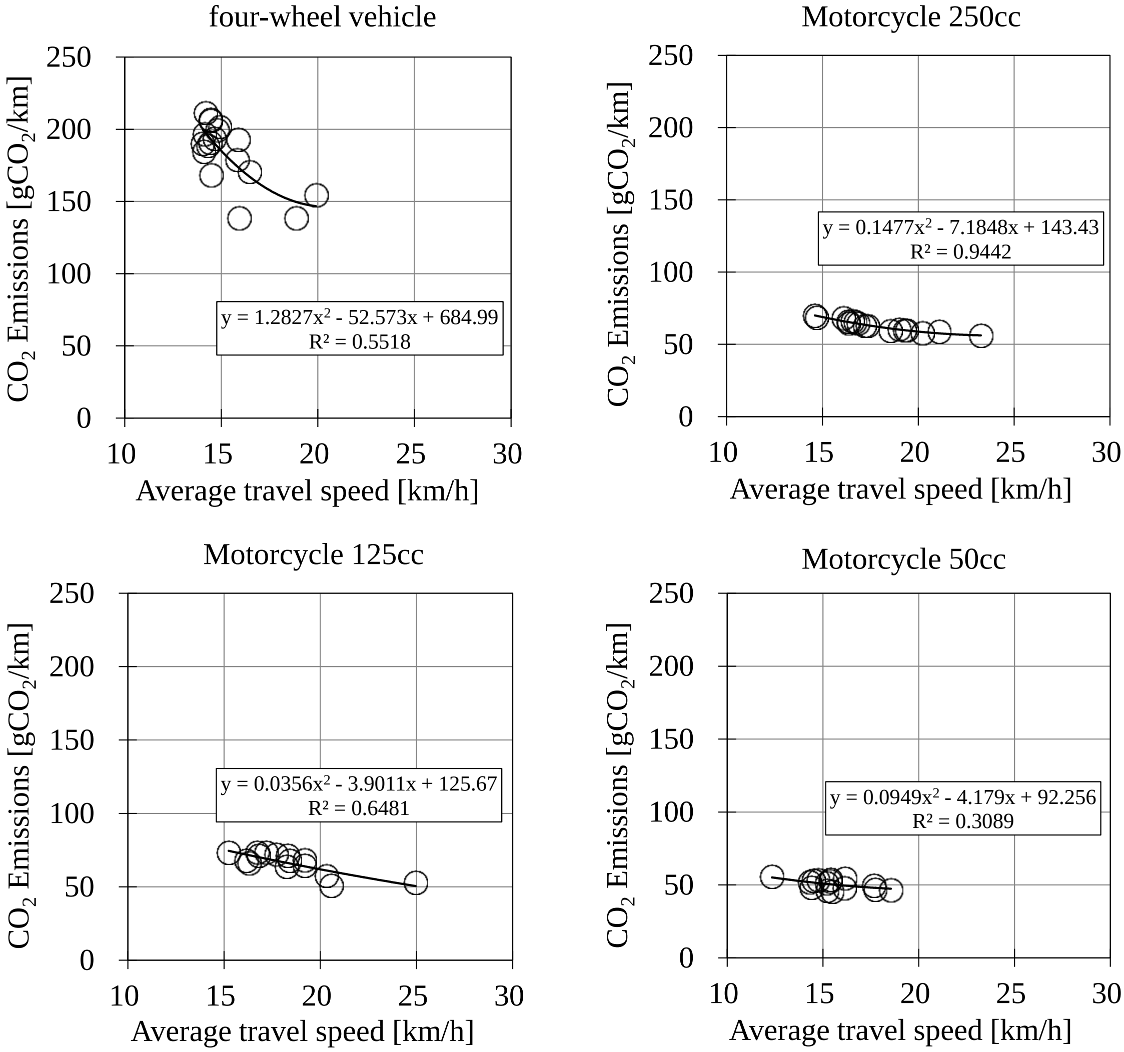


Figure 13. The relationship between average travel speed and CO_2 for each vehicle

5.3 Comparison Result between Indonesia and Japan

The results of the survey conducted in the two countries shows the following results:

1. The motorcycle CO_2 emission from the results of research in the two countries, Indonesia and Japan at low speeds tend to be high value of CO_2 emissions.
2. In the Indonesia studies, types of 125cc-motorcycles have average of the lowest CO_2 emissions while 150cc motorcyles is the largest CO_2 emissions.
3. In Japan, CO_2 emissions increase in the order: motorcycles, four-wheel vehicle. It has been shown by measurement data that motorcycles are superior in terms of impact on global environment compared to four-wheel vehicles.
4. In Japan, average travel speed on the congested road is higher for the motorcycles 250cc and 125cc than four-wheel vehicles.

6. CONCLUSIONS

Through this joint research, the effectiveness of motorcycles as environmentally friendly road transport mode was verified.

Motorcycle is suited for relatively short trips such as commuting within a city, but it is not ideal to drive inter-city such as a purpose of logistics. Therefore, it is critical that the trip which should control the conversion to four-wheel vehicles of road traffic mode is considered.

Motorcycle is the most preferred means of transportation in Indonesia, the number of motorcycles that reached 98.4 million units, is expected to reduce traffic performance and cause congestion. Congested traffic conditions causes large fuel consumptions and lead to the increase of CO_2 emissions. Establishment of restrictions on motorcycles or motorcycle traffic arrangements are needed so that traffic conditions improve and traffic flow becomes smoother (reduce frequent stops). Some solutions that can be submitted are to improve public transport in order to the motorcyclists will switch to use the public transport, and then it is conducted the homogenization of motorcycles with other vehicles for improving the traffic flow by implementation exclusive motorcycles lane.

REFERENCES

Aritenang, Wendy. (2011) Potential for Reducing Emissions Transport Sector, Ministry of Transportation, Jakarta. Indonesia.

Association of Indonesia Motorcyles Industry (AISI)., Central Bureau of Statistics (BPS), (2016) Vehicle Development Based on Types of Vehicle. Jakarta.

Manabu, D., Mulyadi, A. (2013) Bilateral Joint Research on Environmentally Friendly Transport System, focusing Motorcycle (Interim Report), 14th REAAA Conference 2013.

UNFCCC (2011) CDM Methodology: AMS-III.C. Emission reductions by electric and hybrid vehicles.

Mulyadi, A. (2012), Final Report, CO_2 Emission for Motorcycles, Institute of Road Engineering, Ministry of Public Works and Housing, Bandung, Indonesia.

NILIM, (2011), Environmentally Friendly Road, Using Motorcycle, Japan.

SME-ROI (State Ministry for Environment, Republic of Indonesia). (1996) Indonesia: First National Communication under the United Nations Framework Convention on Climate Change. Jakarta.

Tri-Tugaswati A, Suzuki S, Kiryu Y, Kawada T, (1995) Automotive Air Pollution in Jakarta with Special emphasis on lead, Particulate, and nitrogen dioxide. Jpn J of Health and human Ecology 61:261-75

United Nations Framework Convention on Climate Change, (2011) CDM Methodology Booklet, Germany.

World Bank. (2016) CO_2 Emissions from Transportation Sector.