Impact of Axle Load Overloading on Freight Vehicles Towards the Increasing of Greenhouse Gas Emissions by Oxides of Carbon (Case Study : East Java, Indonesia)

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Abstract : Utilization of heavy freight vehicles as a transportation tool, both among the city, province, or island in Indonesia show a significant growth recently. Operational cost of heavy freight vehicles consist of fuel cost, depreciation and interest payments. The Asia Foundation survey in 2008 mention that the biggest payment for transport by using freight vehicle were fuel cost and worker fee (driver and mechanic). Hence, one atempt to decrease the operational cost of freight transport were by minimize the amount of vehicles that used in freight transportation. So on the other hand, as a concequency, there are many of freight vehicle that operate with overloading condition. Overload is condition where the axle load of vehicles have exceed the maximum allowable load limit (Iskandar, 2008). Overloading on vehicles would increase the effort of engine performance, so that will cause the increase of fuel consumption. That increasing also would affect the concentration of gas emission from vehicles. This research will discuss about the impact of overloading towards concentration of gas emission from heavy freight vehicle, especially oxydes of carbon which cause green house effect, specifically CO and CO_2.

Keywords : vehicles, freight, load, green house effect, CO, CO_2

1. INTRODUCTION

The movement of freigt transportation have a strategic role to support economic growth on some region. Compared to passenger transportation, freight transportation have a special characteristic. Character of freight transportation road modes have the high flexibility and capable to externalize door to door service and also have a role as a feeder as well as successor for the other modes of transportation. It's give concequences where the cost for road modes transportation is lower than the other modes. Road modes transportation tend to have independent characteristics and not so dependent to the other modes, both in operational aspect or regulatory aspect. So that give more attraction to many parties to have a role in road modes transportation activities. Moreover with affordable facilities making road modes transportation have the faster improvement than the other modes.

However, along with it, the operational cost of road modes transportation will be influenced by the operational cost of vehicle and will affect the price of the in some region. Operational cost of heavy freight vehicles consist of fuel cost, depreciation and interest payments. The Asia Foundation survey in 2008 mention that the biggest payment for transport by using freight vehicle were fuel cost and worker fee (driver and mechanic). Hence, one atempt to decrease the operational cost of freight transport were by minimize the amount of vehicles that used in freight transportation. So on the other hand, as a concequency, there are many of freight vehicle that operate with overloading condition. Overload is condition where the axle load of vehicles have exceed the maximum allowable load limit (Iskandar, 2008).

Based on Republic of Indonesian Regulation No. 22 Year 2009 about Traffic and Road Transportation, government have the right to supervise and enforce freight transportation. It's realized by weighbridge facilities which built for monitoring and enforcement function towards freigh transportation in roadway. In this case, the monitoring function of weighbridge intended to monitoring the load weight of vehicles whether already meet the Number of Alowable Load (NAL) on regulatory and suitable with the road class traversed. While the enforcement function was done if there were a NAL violation found on the monitoring function. Thus, weighbrige have a crucial part to increase the roadway transportation service in general and the continuity of transport in particular.

In the recent condition, the handling of overloading on transport not yet materialized well. There are many things that indicate it, such as many vehicle that still exceed the Number of Allowable Load when operate, weak law enforcement, and weak reporting sistem towards the data of freight vehicle which violate the Number of Allowable Load.

The problem on this handling of overloading freight vehicle become such a complex thing, because of multiplier effects which affect directly to various life activities, where along with transportation development, the overload of freight vehicle also bring out new problems which also provide loss such as traffic jam because the overload freigh vehicle didn't capable to run with average velocity. It's certainly will produce the derivative impact which is the increasing of emission from vehicle since the engine forced to adapt with the vehicle loading. Based on research by Guensler et al. on 2005, the amount of emission that produced by vehicle highly dependent to engine work alteration as shown at **Figure 1**.

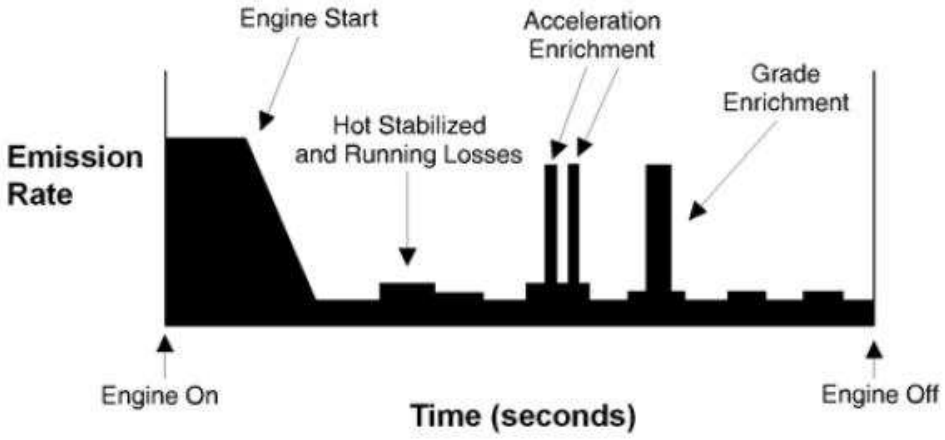


Figure 1. The dynamic alteration of emission concentration from vehicle (Guensler et ak., 2005)

According to engine temperature, flue gas from motor vehicles are divided into two types, the first one called cold emission which produced when engine turned on for the first time until reach a steady temperature. And the second one is hot emission which produced when engine operate on steady state temperature.

The lowest amount of emission are produced when the motor vehicle have reached steady state temperature, running on stable velocity, or in stationer condition but the engine are still hot and turn on. Condition of road and also stabilization of velocity control will affect the amount of emission that produced. The amount of emission will increase when there are a velocity enhancement and also gear changes because of road's climb or descendant. Velocity enhancement on vehicles will give more effort to vehicle engine so that the vehicle will produce the higher amount of emission. On heavy freight vehicle, the loading that given to the vehicle would also increase the effort that was conducted by vehicle engine so that wil produce high amount of emission.

On current condition, overloading in freight transport seemed to become a cultural that was considered as the best way and favorable for certain party. Meanwhile on the other side, the organizers of national road didn't have any authority to control the overloading in freight transport that was operating on primary artery road class-1. Law enforcement that supossed to work hard still not yet performing their function well. Essentially, the regulation of overloading in freight vehicle was already made accurately so that be expected capable to decrease the rate of violation on overloading in freight vehicle especially which operated at primary artery road class 1. But, based on facts in reality that was obtained from vehicle's violation data at weighbridge, the rate of violation on overloading in freight vehicle were increase every year. (JTC Center, 2011-2012)

Based on facts above, the derrivative of negative impacts were appear because of the repetition on overloaded freight vehicle, such as the degradation of ambient air quality which caused by emission from freight vehicle. All tis time, the overloading in freight vehicle just connected with it's impact towards damage on road structure and traffic jam, and didn't consider the impact on degradation of air quality. This is due to the assumption that the factors which affect the amount of exhaust emissions are engine maintenance and driver behaviour.

If condition like this just left the way it is, then the rate of emission pollution from freight vehicle flue gas, will increase significantly and escalate the potency of air pollution including Greenhouse Gas emission which affect directly towards climate change at East Java in particular and Indonesia in general. This climate change will produce a big challenge for sustainable development in Indonesia. Therefore, Indonesian government through the President Regulation No. 61 Year 2011, arrange a program called *Rencana Aksi Nasional Penurunan Emisi Gas Rumah Kaca (RAN-GRK)* or National Action Plan for Greenhouse Gas Emission Reduction, to reach national goals, sectoral target, bencmark, and also priority action by consider the mitigation problem of climate change for economic sectors which attached by the impact.

Transportation sector is one of the priority scope included on *RAN-GRK* program. The observation by Ministry of Environmental Life Indonesia show that the amount of CO_2 emission which produced by transportation sector in Indonesia was increase from 58 million ton at 2000 to 73 million ton at 2007. Compared to CO_2 emission from the other source, transportation were the second largest CO_2 producer was equal to ±25% below electric utilixation (KLH, 2009)

In an attempt to overcome and mimalize derivative impact from overloaded freight vehicle, the action plan which done gradually is really necessary. The mentioned action plan

was intend to identify the correlation between overloaded freight vehicle and greenhouse gas emission.

2. LITERATURE REVIEW

2.1 Configuration of Axle Load on Heavy Freight Vehicle

According on Technical Guidance from Public Works Ministry of Indonesia No. 19 Year 2004, freight vehicle are classified into some type based on the number of axis and vehicle's wheel as shown in **Figure 2.**

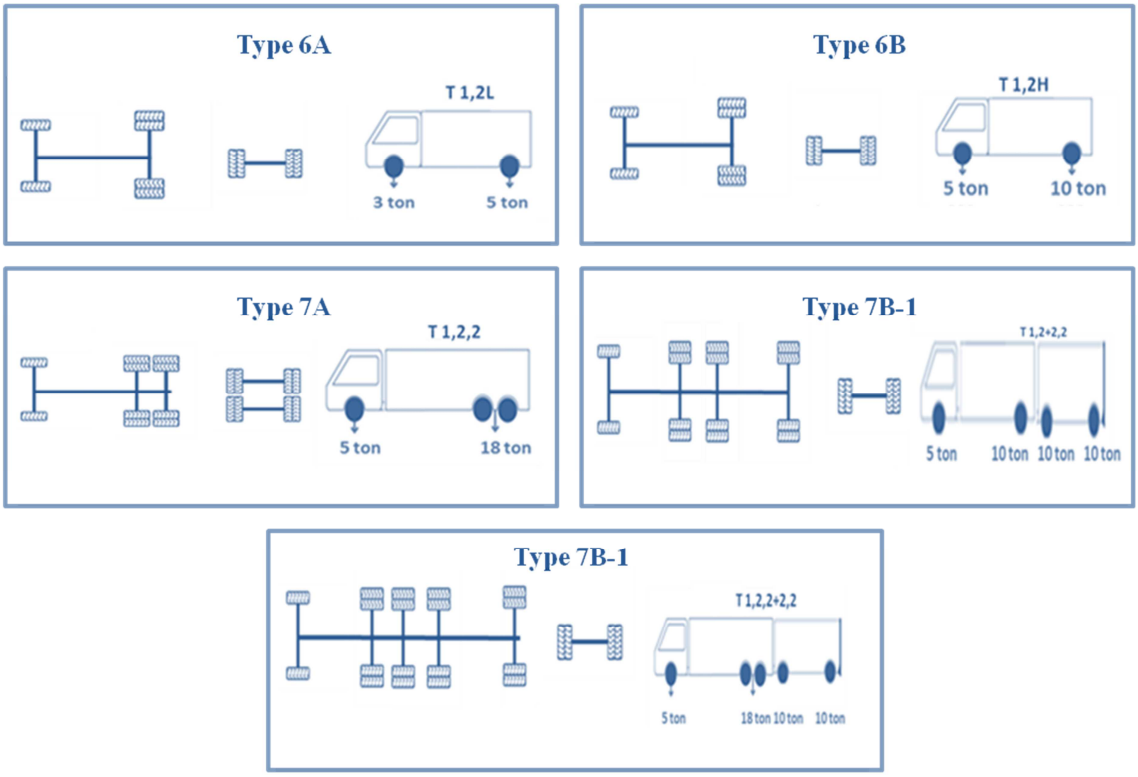


Figure 2. Clasification of freight vehicle based on the number of acis and vehicle's wheel

1. **Type 6A** (Truck 1,2 L)
   Single Axis Double Wheel; Load distribution: sb-1(3Ton), sb-2(5Ton)
2. **Type 6B** (Truck 1,2 H)
   Single Axis Double Wheel; Load distribustion: sb-1(3Ton), sb-2(5Ton)
3. **Type 7A** (Truck 1,2,2)
   Tandem Axis Double Wheel; Load distribution: sb-1(5Ton), sb-2(9Ton), sb-3(9Ton)
4. **Type 7B-1** (Truck 1,2+2,2)
   Tandem Axis Double Wheel; Load distribution: sb-1(5Ton), sb-2(10Ton), sb-3(10Ton), sb-4(10Ton)
5. **Type 7B-2** (Truck 1,2,2+2,2)
   Tandem Axis Double Wheel; Load distribution: sb-1(5Ton), sb-2(9Ton), sb-3(9Ton), sb-4(10Ton), sb-5(10Ton)

Whilst according to Regional Regulation of East Java Province No. 4 Year 2012, freight vehicle are classified to :

1. Type I : Number of Allowable Load 1.500 kg (1,5Ton) – 8000 kg (8,0Ton)
2. Type II : Number of Allowable Load 8.000 kg (8,0Ton) – 14.000 kg (14,0Ton)
3. Type III : Number of Allowable Load 14.000 kg (14,0Ton) – 21.000 kg (21,0Ton)
4. Type IV : Number of Allowable Load > 21.000kg (21,0Ton)

The implementation of Regional Regulation of East Java Province No. 4 Year 2012 couldn't be used for evaluation of pavement performance, but could be used to estimate it's impact towards the increasing of exhaust gas emission.

2.2 Air Pollution

According to Government Regulation of Indonesia No. 41 Year 1999 about Air Pollution Control the basic meaning of ambient air is the free air in earth surface on the troposfer layer which stand on Indonesian jurisdiction area and affect human health, organism and the other environment life element. At normal condition, ambient air consist of 78%n of N_2, 20% of O_2, 0,93% of Ar and 0,03% of CO_2. While emission is a substance, energy, or other component wgich produce by certain activities and enter or included to ambient air, which have/haven't a potency to be a pollutant.

Air pollution which is a proccess of inclusion some substance, energy, or other component to ambient air by human activities can cause decreasing of ambient air quality until certain degree which cause the ambient air can't fullfill it's function. Therefore, the ambient air quality standards was compiled to anticipate that. Ambient air quality standards is a limit concentration of some substance, energy, or other component which have a potency to be a pollutant in ambient air. The polutants, derrived from motor vehicle emission and have potency to cause air polution can be seen on **Table 1**.

Table 1. Polutants from motor vehicle emission which can cause air pollution

Emission	Impact	Impact Scale
Carbon Dioxide (CO_2)	Climate change	Global
Carbon Monoxide (CO)	Human health, climate change	Local
Fine Particles (PM_{10}; $PM_{2,5}$)	Climate change, esthetics	Local
Road Dust	Human health, esthetics	Local
Lead (Pb)	Human health, ecological hazards	Local
Methane (CH_4)	Climate change	Global
Oxides of Nitrogen (NO_x)	Human health, ozone precursor, ecological	Local dan Regional
Ozone (O_3)	Human health, plants, esthetics	Regional
Oxides of Sulphur (SO_x)	Human health, ecological hazards	Local and Regional
Volatile Organic Compounds	Human health, ozone precursor	Local and Regional

(Source : USEPA, 2002)

Regional ambient air quality standards was established according to the consideration of ambient air quality status in relevant region, which have purpose to protect environment on the adequate margin safety of human health and generally established to protect some people (15-20%) who vulnerable to air pollution. And also to protect society welfare (material, plants, and animals) from every negative effects of air pollution which had known or could be anticipated.

Ambient air quality standards for East Java are based on Regulation of East Java Governor No. 10 Year 2009, given in **Table 2**.

Table 2. Ambient air quality standards for East Java, Indonesia

Parameter	Exposure Time	Quality Standards	Metode Pengujian
Sulfur Dioxide (SO_2)	24 hour	262μg/Nm^3	Pararosaniline
Carbon Monoxide(CO)	8 hour	22600μg/Nm^3	NDIR
Oxides of Nitrogen (NO_x)	24 hour	92,5μg/Nm^3	Saltzman, NDIR
Oxidant (O_x)	1 hour	200 μg/Nm^3	Neutral Buffer Potasium Yodida
Dust	24 hour	0,26 mg/Nm^3	Gravimetric
Black Lead (Pb)	24 hour	0,06 mg/Nm^3	Gravimetriv
Hydrogen Sulphide (H_2S)	30 minutes	42μg/Nm^3	Methylen Blue
Ammonia (NH_3)	24 hour	1360μg/Nm^3	Indophenol
Hydrocarbon (HC)	3 hour	160μg/Nm^3	Flame Ionization

Exhaust gas emission from heavy freight vehicles caused by incomplete combustion because of lack oxygen during energy production on vehicle engine. The air pollution substances according to Indonesian Ministry of Health in 2002 have specific characteristics, such as CO and CO_2. CO or karbon monoxide are the subtances that odorless, colorless, and tasteless on the normal air temperature. CO have a toxic potency which dangerous because capable to create a strong bond with hemoglobin. Exposure of CO from ambient air are reflected as carboxyhemoglobin (HbCO) concentration on human blood. Formation process of HbCo in human blood occur very slowly, it takes 4-12 hour to equalize the CO concentration on ambient air and HbCO on human blood. Aside from impact to human health, CO is secondary gas that can cause greenhouse effect. In the air, some amount of CO will be oxidized become CO_2 as primary greenhouse gas. CO have a limited scale of impact deployment, because dispersion of CO in air not as large as CO_2 (USEPA,2002).

3. METHODOLOGY

The overloaded heavy freight vehicle have high fuel consumption characteristic. This is due to the carrying capacity which exceed vehicle proporsion so that the work load of vehicle engine are higher than usual. It cause the increasing of exhaust gas emission which decrease ambient air quality and have potency to cause some interference in human healths (direct impact) and greenhouse effects (indirect impact).

Generally, this research are intend to discover the influence of overloaded freight vehicles towards ambient air quality degradation at East Java, Indonesia. The primary hypotesis that be used in this research are the availability of emission concentration difference between overloaded freight vehicles and normal load freight vehicles.

Some important point that would be able to be identified by this reseach are the correlation function between overloaded freight vehicles and the increasing of exhaust gas emission especially CO and CO_2. Furthermore, this correlation function are expected to produce a costs formulation of ambient air quality degradation which caused by overloaded freight vehicles and in the end would capable to give a recommendation in the form of technical guidance for decision maker to control the overloaded freight vehicles especially at East Java, Indonesia. So that be able to minimize the costs level from the impact posed.

The approach that was used in this research is evaluative-descriptive methods. With the first step that was taken is describing the existing data as a results from primary and secondary survey, such as comparing the total load of vehicle with the Number of Allowable Load, the emission concentration from heavy freight vehicles, the condition and volume of traffic, and also the ambient air quality.

The next step are evaluation method. This method was intend to identify the correlation between overloaded freight vehicle and ambient air quality or greenhouse gas emission. On this method of approach, the analysis tools that can be used are modelling analysis towards dispersion of exhaust gas emission which be correlated with ambient air quality standards. The framework of this research can be seen on **Figure 3**.

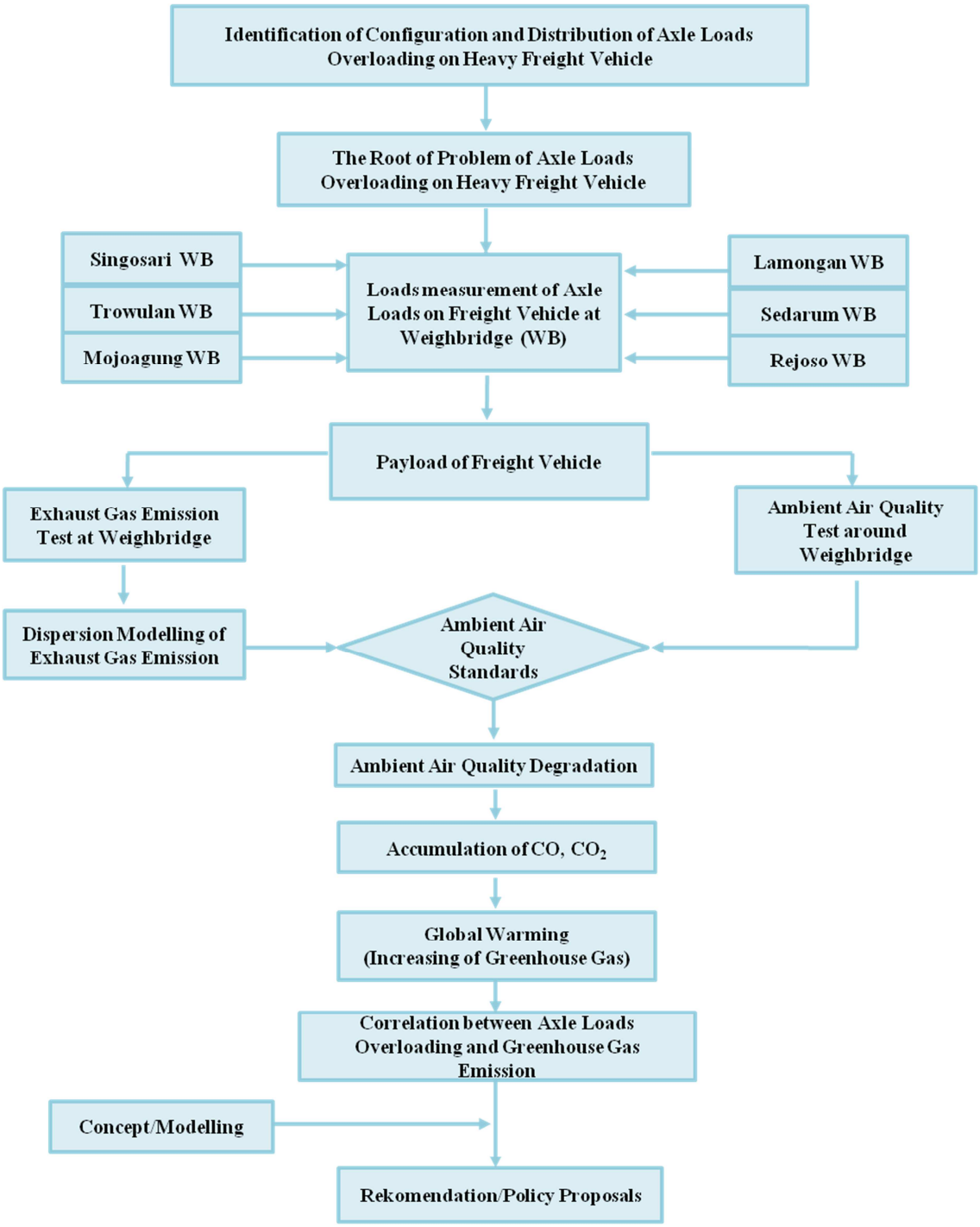


Figure 3. Framework of Research

3.1 Location of Field Survey

Determination or selection of location of field survey based on 8 (eight) Investment Interest Areas (KPI) in MP3EI in East Java Province, namely Lamongan Regency, Gresik, Surabaya, Sidoarjo, Pasuruan, Malang, Kediri, and Mojokerto. From those areas, 4 (four) location selected based on the traffic congestion, which are North Cross (Lamogan and Pasuruan), Middle Cross (Mojokerto), and Connecting Cross (Malang). Sampling locations are in 6 (six) weighbridges and 4 (four) national roads as shown in **Figure 4**.

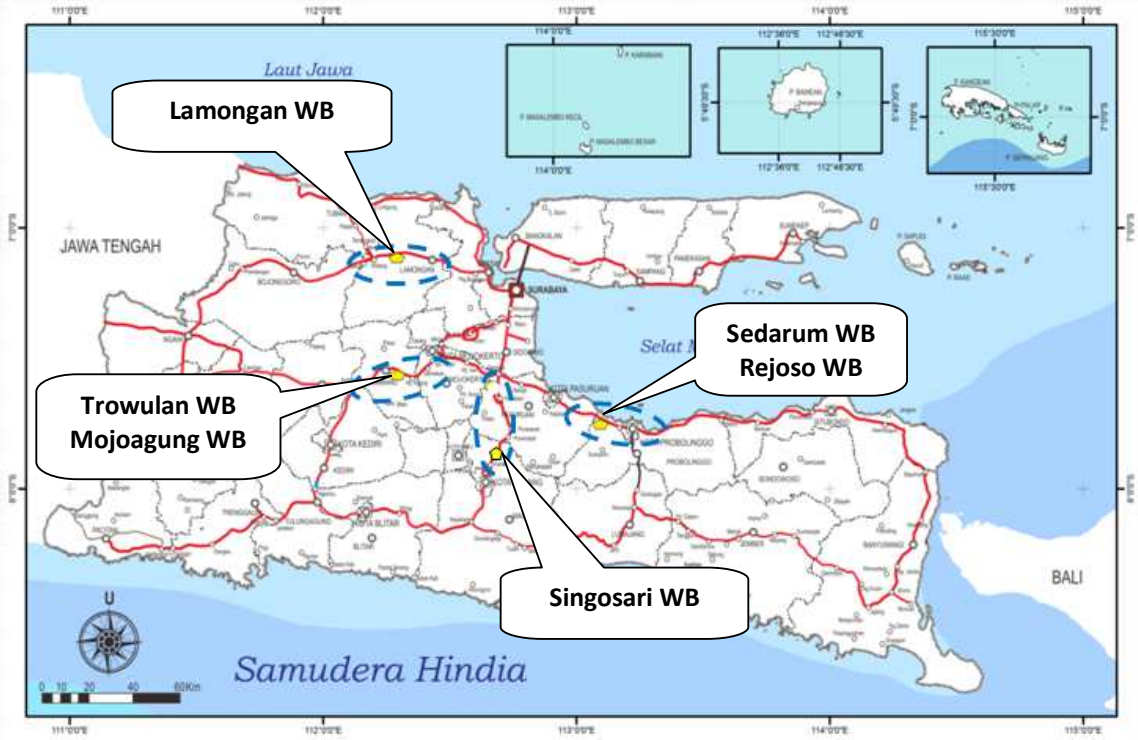


Figure 4. Location of the Research

Determination in Malang is represented by Singosari weighbridge, Lamongan by Lamongan weighbridge, and for Pasuruan and Mojokerto represented by two weighbridges for each regency. Pasuruan by Rejoso and Sedarum weighbridges, and Mojokerto by Trowulan and Mojoagung weighbridges.

3.2 Survey Implementation

Early stage in the implementation of the survey was to determine the population and sample of the study, where the population is region generalization that consists of the object / subject that has certain of qualities and characteristics, defined by the researchers (Sugiyono, 2007:90). Population not only people but also objects and other natural objects. Population is also not just the number of objects / subjects under study, but includes all the characteristics / properties owned by the subject or the object.

The population in this study is the number of heavy vehicle freight cargo overload and reported at weighbridges (JT) Sedarum (Pasuruan), JT Rejoso (Pasuruan), Lamongan JT, JT Trowulan (Mojokerto), JT Mojoagung (Mojokerto) and JT Singosari (Malang).

Sampling technique in this study preferred method of proportional stratified random sampling which is done randomly but the numbers are adjusted for the proportion of the number of each class of heavy freight vehicles. As for the determination of the number of field samples using an accuracy rate of 95% or 5% error, obtained from the secondary data volume of heavy vehicle traffic is more laden freight recorded at weighbridges. The reason of using 95% accuracy rate is due to the limited time of observation and testing provided by the truck driver. Estimation of calculation sample is using **Equation (1)**.

$$\mathbf{n = \frac{N}{(1+N\alpha^2)}} \quad \textbf{(1)}$$

where :

n = number of sample
N = number of population
α = terror

Based on the estimation above, this study used 1,393 heavy freight vehicles which overloaded in 6 (six) weighbridges. Types of activities during the implementation of field study as shown on the **Table 3**.

Table 3. Survey implementation schedule

Survey Type	Survey Location	Survey Duration	Data	Unit Mesaurement
Traffic Counting	Singosari Lamongan Mojokerto Pasuruan	2 days per Location	Traffic counting, Vehicle flow, Type of vehicle proportion	Vehicles, Vehicles/hour, %
Axle Load Survey	Singosari WB Lamongan WB Rejoso WB Sedarum WB	7 days per Location	Loads distribution on each of vehicle's axle loads	Ton.Vehicle
Exhaust Gas Emission Survey	Trowulan WB Mojoagung WB	30 days per Location	Exhaust gas emission (CO_2, CO)	μ g/m^3
Ambient Air Quality Survey	Singosari WB Lamongan WB Sedarum WB Trowulan WB	7 day per Location	NO_x, CO, NO_2, H_2S, HC, SO_2, NH_3, O_x, Particles, Pb	%; ppm

The heavy freight vehicles used in this study need to be classified according to the class of the vehicle so it will be easier to identify the emissions test and axle load in every weighbridges. The classification is calculated based on the data in weighbridges with error 5% and it can be seen in **Table 4**.

So that, we can get the number of emission test sample and axle loads at each weighbridges with error level of 5% as we can seen on **Table 5**.

After the number of sample were determined, the technical implementation of survey at the weighbridges could be divided into two types of survey, which is the measurements of axle payload and exhaust gas emission

Table 4. Percentages of research samples

Weighbridge	Population of Overloaded Freight Vehicles (vehicle/day)	Number of Samples (vehicle)	Percentage of Vehicle Types				
			6A	6B	7A	7B	7C
Singosari	362	189	53,50%	23,80%	18,42%	2,10%	2,00%
Trowulan	820	268	49,50%	22,00%	20,43%	6,07%	2,00%
Mojoagung	367	191	48,70%	24,08%	22,87%	3,40%	2,00%
Lamongan	832	271	58,60%	21,06%	15,66%	3,60%	2,00%
Sedarum	703	255	51,70%	26,80%	15,63%	5,40%	2,00%
Rejoso	488	219	53,50%	23,80%	18,42%	2,10%	2,00%
Total/Average	**3572**	**1393**	**52,58%**	**23,59%**	**18,57%**	**3,78%**	**2,00%**

(Source: Statistics data of heavy freight vehicles in each weighbridge , 2013)

Table 5. Number of research samples with error 5%

Weighbrige	Number of Samples (Vehicle)	6A (Vehicle)	6B (Vehicle)	7A (Vehicle)	7B (Vehicle)	7C (Vehicle)
Singosari	189	101	45	35	4	4
Trowulan	268	133	59	55	16	5
Mojoagung	191	112	40	30	7	4
Lamongan	271	131	65	62	9	5
Sedarum	255	132	68	40	14	5
Rejoso	219	117	52	40	5	4
Total	**1393**	**726**	**329**	**262**	**55**	**27**

(Source: Calculation of data, 2013)

4. RESULTS AND DISCUSSION

4.1 Results of Ambient Air Quality Test

Ambient air quality testing done around the weighbridges samples in this study, namely Weighbridges (JT) Singosari, JT Trowulan, Lamongan JT, and JT Sedarum. Intake of ambient air quality test data using noise parameter, CO, HC, NOx, particulates, NH3, and SOx. The results show that the air particles are used as the majority of the testing parameters are still below or meet the ambient air quality standard. However, there are two parameters particle in every weighbridges that higher than the ambient air quality standard, namely nitrogen oxides (NO_2) and particulate matter such as dust. More detail can be seen in the **Table 6**.

Ambient air quality measurement results on average in the four study sites showed that the overall concentration of the pollutants causing air pollution is still under the standards that have been determined in accordance with the Regulation of the Governor of East Java Province No. 10 Year 2009. However, for parameters NOx in Malang and Mojokerto locations showed concentrations above the specified quality standards.

Carbon oxides are the focus of this study as measured in the measurement of ambient air concentrations of carbon monoxide only, where the results shown are still below the standards that have been determined. However, high concentrations tend indicated.

Table 6. Ambient air quality in each location research

Parameter	Unit	Average of Ambient Air Concentration*				Ambient Air Quality Standards**
		Malang	Mojokerto	Lamongan	Pasuruan	
Carbon Monoxide (CO)	µg/Nm^3	9966,67	4753,33	2031,67	1648,33	22600
Oxides of Nitrogen (NO_x)	µg/Nm^3	115,20	126,07	41,57	74,23	92,5
Nitrogen Dioxide (NO_2)	µg/Nm^3	54,77	53,70	24,77	41,17	-
Sulfur Dioxide (SO_2)	µg/Nm^3	26,10	17,20	0,70	9,70	262
Hydrogen Sulphide (H_2S)	µg/Nm^3	<0,4	0,90	1,20	0,73	42
Ammonia (NH_3)	µg/Nm^3	12,23	25,33	16,70	13,67	1360
Oxidant (O_x)	µg/Nm^3	<5,8	5,93	11,60	5,43	200
Dust	mg/Nm^3	0,35	0,32	0,05	0,17	0,26
Black (Pb)	mg/Nm^3	0,000070	0,00	0,00	0,00	0,06
Hydrocarbon (HC)	µg/Nm^3	-	-	-	-	160

*measurements was held 3 times in each location
** based on Regulation of the Governor of East Java Province No. 10 Year 2009
(Source: Data calculation, 2013)

4.2 Traffic Condition at Location of Study

The observation towards traffic condition at location of study were implemanted to identify the vehicle flow that was passing at the segment of road that was being studied. Furthermore, this observation was also to identify the proportion of vehicles type and time where the maximum number of vehicles are reached. On the **Table 7** can be seen the procedure of traffic condition observation.

Table 7. Implementation procedure of traffic condition

Location	Segment of Roads	Duration	Observation Time	Type of Vehicles
Malang	Malang-Surabaya Surabaya-Malang	2 days	Morning (7am-9am) Day (11am-13pm) Night (7pm-9pm)	LV = Light Vehicles HV = Heavy Vehicles MC = Motorcycles
Mojokerto	Mojokerto-Jombang Jombang-Mojokerto			
Lamongan	Lamongan-Gresik Gresik-Lamongan			
Pasuruan	Pasuruan-Probolinggo Probolinggo-Pasuruan			

Results of the traffic observation show that flow of heavy freight vehicles (HV) that was passing the location of study about 416-678 vehicle/hour as we can see on **Figure 5**.

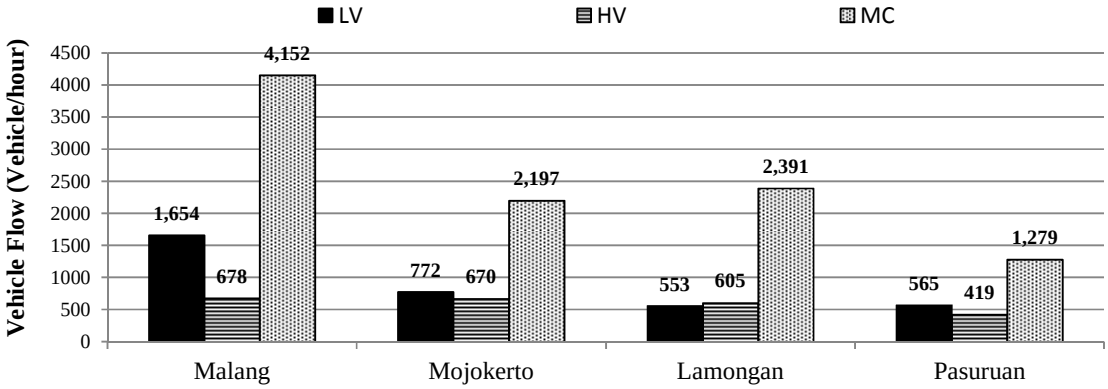


Figure 5. Vehicle flow at location of study

When observed by the types proportion, the types of vehicle that were most passing at the location of study are motorcycles (MC) with percentages about 56,52%-67,14%. While, the heavy freight vehicles were about 10,45%-18,50%. The proportion of vehicle types that was passing at each location of study can be seen on **Figure 6**.

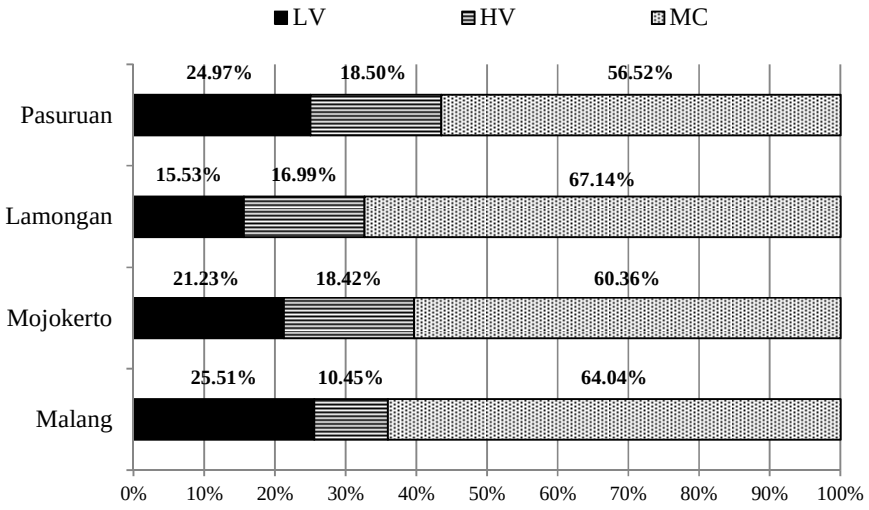


Figure 6. Proportion of vehicle types that was passing at each location of study

The vehicles flow that was passing at location of study show that the peak time of traffic counting was occur at the morrning (7am-9am) like we can seen on **Figure 7**.

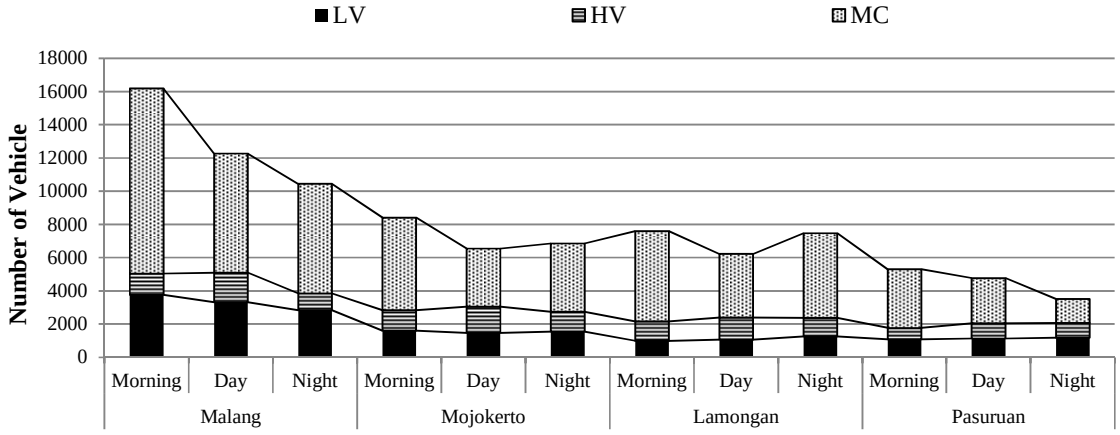


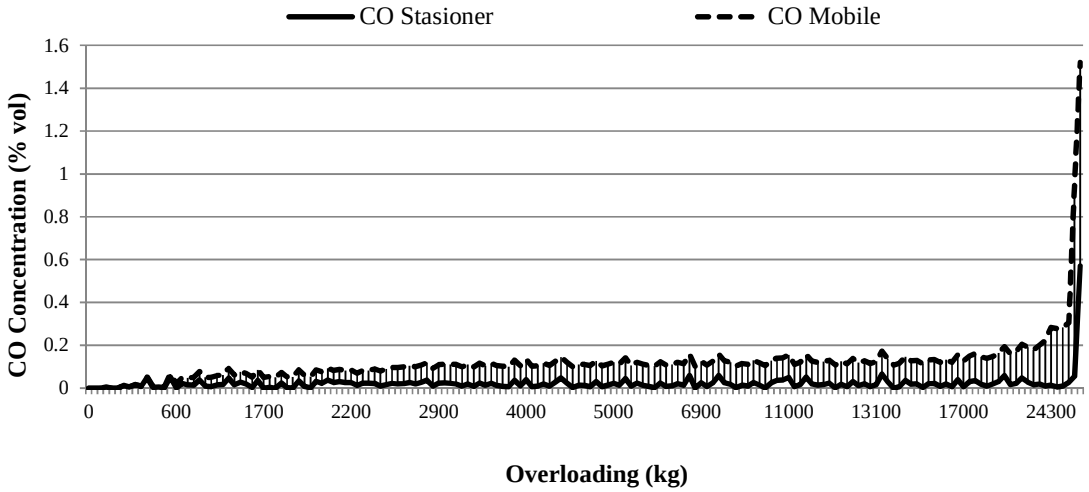
Figure 7. Traffic counting at different time

From the observation, could be identified that the highest vehicle flow are in Malang compared to the other location. The amount of vehicle that was passing at the road will give the influence to the amount of greenhouse gas emission. The peak time of vehicles flow also will gave influence to dispersion pattern of greenhouse gas emission at the ambient air. Because the meteorological condition at morning, day, and night are different.

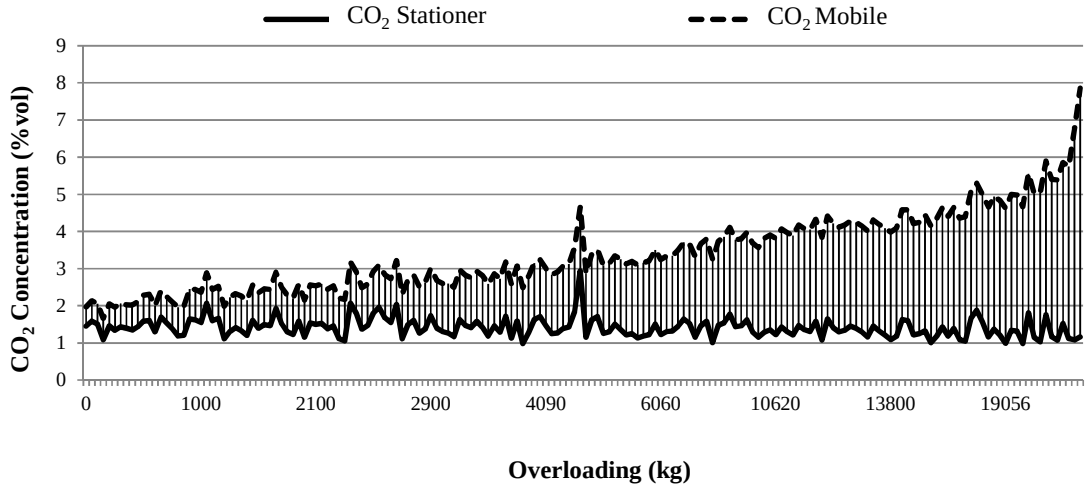
4.3 Correlation Analysis of Overloading on Heavy Freight Vehicles with the Increasing of Greenhouse Gas Emission Concentration

Exhaust gas emission test was held towards the freight vehicles on stationer condition and also mobile condition. The processed data was taken from the combined data of all measurement locations, which is Malang, Mojokerto, Lamongan, and Pasuruan.

Emission test data that was taken from freight vehicles are using CO and CO_2 parameter which is a type of oxides of carbon that can be caused a greenhouse effect and produced by motor vehicle. On the **Figure 8** below we can see graphics ofa correlation between overloading and oxides of carbon (CO and CO_2) emission measurements results on stationer and mobile condition.



(a)



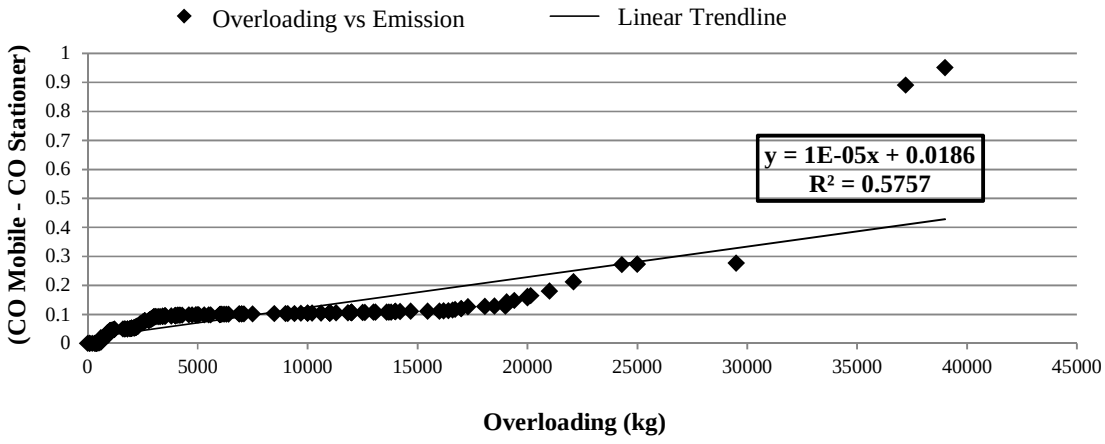
(b)

Figure 8. Graphic of correlation between overloading on freight vehicles and exhaust gas emission in stationer and mobile condition:
(a) Carbon monoxide (CO); (b) Carbon dioxide ($CO_{2)}$

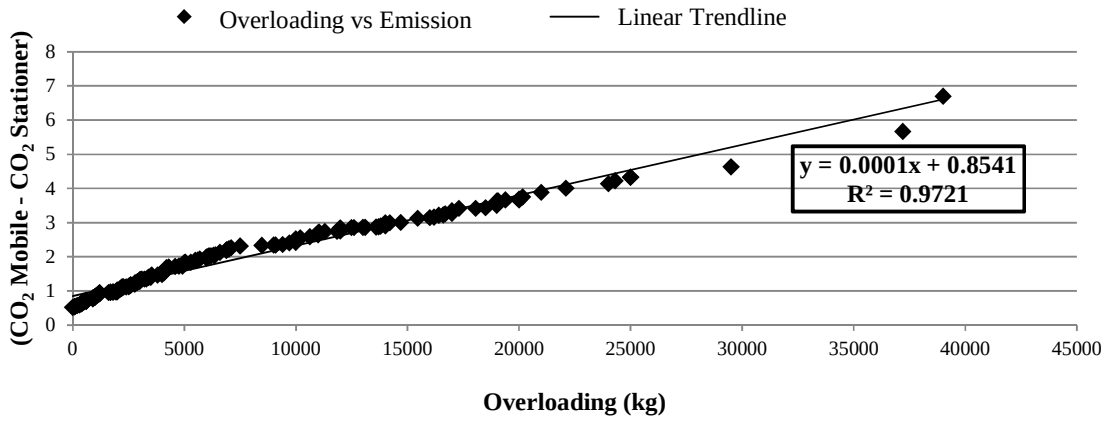
From **Figure 8** above could be identified that the higher overload on heavy freight vehicles give the higher amount of greenhouse gas emission both stationer and mobile condition. From the figure, also could be identified that the difference between CO_2 emission at the stationer and mobile condition are higher than the difference between CO emission at the stationer and mobile condition. This is because of CO_2 was the main product of complete combustion of fuel that was held on vehicle engine. While CO are the side product of the incomplete combustion. Moreover, the mobility on vehicle causing the higher combustion temperature on the engine so that the combustion can be happen more completely.

The higher difference concentration of CO_2 both at stationer and mobile condition indicate that overloading on vehicles give the big influence towards increasing of greenhouse gas, in this case the gas was CO_2.

To identify the deeper correlation between overloading on heavy freight vehicles and the amount of oxides of carbon emission, on the **Figure 9** below we can see the regression graphic with linear trendline between overloading and the concentration differences between oxides of carbon emission on mobile and stationer condition.



(a)



(b)

Figure 9. Correlation regression between overloading on freight vehicles and concentration differences of oxides of carbon emission at mobile and stationer condition:
(a) Carbon monoxide (CO); (b) Carbon dioxide (CO_2)

Results of correlation regression between overloading on freight vehicles and concentration differences of oxides of carbon emission at mobile and stationer condition with linear trendline give the number of determination coeficient > 0,5. This suggests that there is a linear correlation between them. From both oxides of carbon which was the focus of this research obtained the results of regression function as follow :

1. Carbon monoxide → $y = 10^{-5}x + 0{,}0186$ dengan $R^2 = 0{,}5757$
2. Carbon dioxide → $y = 0{,}0001x + 0{,}8541$ dengan $R^2 = 0{,}9721$

Where : y = concentration differences of oxides of carbon emission at mobile and stationer condition (ppm)
x = overloading (kg)

5. CONCLUSION

Based on the analysis in this study, it can be concluded that the charge over the axle load freight vehicles have comparable correlation with exhaust emissions.

Based on the analysis in this study, it can be concluded that the charge over the axle load freight vehicles have comparable correlation with exhaust emissions generated. The heavier cargo freight vehicles, the greater exhaust emissions generated. This condition leads to the increasing of accumulated levels of CO and CO_2 in the ambient air and also the increasing potential for the formation of the greenhouse gas emissions.

In other words, the charge over the axle load freight vehicles affect the increase in greenhouse gas emissions in the province of East Java. Therefore expected to be drafted ahead formulations air quality impairment caused by overloaded freight vehicles and technical guidance for decision makers to control the overload of freight vehicles especially in East Java.

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