Strategy for Reducing Pollutant Emissions from Ship Activities at the Port of Tanjung Perak, Surabaya

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Abstract: **-** Since te national policy to promote sea transportation as the main transportation, pollution from ship activities in the port is a national issue that needs to be addressed; because it is expected of marine pollution will increase in the future. The result of calculations of the emissions from ships in the Port of Tanjung Perak Surabaya shows that from year to year, either to ship overseas and domestically increased total exhaust emissions from ships. In this paper is addressed a stragey to reduce the emissions from ships activities in the port by use the port electricity for ship at the port and efficiency of ship turn round time in the port.

Key-Words: - Air Pollution, Emissions, Vessel Activities, Reducing Emissions, Tanjung Perak Port

1 Introduction

International and domestic shipping industries in the transportation sector includes the ocean going in port and inland waterway vessel activities. These activities produce air pollutant emissions, including CO_2, CO, VOC, SO_x and NO_x from the combustion of fuel. Waterway transportation is in fact the most environmentally friendly compared to other transportation modes, however, some ship activities that can be environmentally harmful to surface water and air include ship waste disposal, bilge pumping, tank cleaning and marine port activities.
Port of Tanjung Perak is one of the local movements of goods in Indonesia. Existing facilities at the port of Tanjung Perak, includes shipping lanes, pilot age, bunkers, passenger terminal facilities, container, scouting, and loading and unloading equipment.
With so many ships as well as domestic and foreign-flagged vessels that traverse these waters will have an impact on the increase in emissions that are released by the ship. Improved exhaust emissions are accompanied by a decrease in air quality is believed to have an impact on the quality of human health. Marine vessel traffic is expected to have a role in the deaths of about 60,000 premature infants worldwide [1].
Emission such as CO_2 contributed by the transportation sector reaches 23% of the national total emission. The emission of land transportation comprises 89% of the transportation sector's emission. In fact, the transportation sector in Indonesia uses the biggest share of the oil consumption at 51%. It is triggered by the increasing number of fleets and the low price of petroleum directed for transportation use due to subsidies by the government [9]. Since the national policy to promote sea transportation as the main of transportation in Indonesia, in the future emissions from sea transportation will be increased rapidly. In this case some strategy should be applied to reduce the pollution from the sea activities in the port.
One of the strategy to reduce the effect emissions is from economic and social point of view. This relations should be taking into account at environmental restrictions effects in order to provide maximum benefits for quality of life in general and human in particular [7]. Another strategy is to increase quality of fuel with use the additive Envirox^{TM}, by using it can reduce value of emission factor of CxHy by approximately 12%, NOX by about 8.50% and PM by 17% [6]
In this paper is addressed a strategy to reduce the emission from ship activities in the port by use the port electricity for ships at the port and efficiency of ship turn round time in the port.

2 Problem Formulation

Ship Traffic at the Port of Tanjung Perak, Surabaya

Port of Tanjung Perak located at Surabaya City, East Java is one of the local movements of goods in Indonesia. This port is the center of the collector and distributor of goods to Eastern Indonesia Existing facilities at the port of Tanjung Perak, includes shipping lanes, pilot age, bunkers, passenger, container, gas and oil terminal facilities and loading and unloading equipment facilities. Figure 1 shows the location of Tanjung Perak Port, Surabaya.

Figure 1. Location of Tanjung Perak Port, Surabaya

With so many ships as well as domestic and foreign-flagged vessels that traverse these waters will have an impact on the increase in emissions that are released by the ship. Figure 2 shows the layout of Tanjung Perak Port, Surabaya.

Figure 2. Layout of Tanjung Perak Port, Surabaya

Table 1 shows the ship call in unit ship at the port of Tanjung Perak, Surabaya. Data from 2009 to 2013 shows the number of ship visits increased from year to year, both for foreign and domestic vessels.

Table 1. Ship Call at Tanjung Perak Port (unit Ship)

	2009	2010	2011	2012	2013
Foreign Ship	2.435	2.114	2.220	2.194	2.063
Domestic Ship	12.629	12.084	11.908	12.579	12.135
Total	**15.064**	**14.198**	**14.128**	**14.773**	**14.198**

Meanwhile Table 2 shows the ship call in GT ship at the port of Tanjung Perak, Surabaya. Data from year 2009 to year 2013 shows the number of ship visits in gross tonnage (GT) increased from year to year, both for foreign and domestic vessels.

Table 2. Ship Call at Tanjung Perak Port (GT Ship)

	2009	2010	2011	2012	2013
Foreign Ship	29.522.768	30.558.087	33.238.190	34.743.877	36.446.922
Domestic Ship	33.725.382	36.398.221	36.463.733	38.378.303	39.846.779
Total	**63.248.150**	**66.956.308**	**69.701.923**	**73.122.180**	**76.293.701**

Table 3 and tabel 4 shows domestic and foreign ship services or turn round time ship at the port of Tanjung Perak, Surabaya from year 2009 to year 2013 both for foreign and domestic vessels seems fluktuative.
In Domestic ship services or turn round time ship the longest waitingtime happen in 2009 but in Foreingn Ship happen in 2012.

Table 3. Domestic Ship Services at Tanjung Perak Port, Surabaya (Hour)

Domestic Ship	2009	2010	2011	2012	2013
Waiting time	1,23	1,40	1,33	1,38	2,09
Postpone time	8,60	6,16	9,32	11,02	10,62
Approach time	2,24	2,17	2,09	2,00	4,37
Berthing time	34,40	29,39	29,65	28,47	29,64
Turn Round Time	46,46	39,12	42,38	42,87	46,72

Table 4. Foreign Ship Services at Tanjung Perak Port, Surabaya (Hour)

Foreign Ship	2009	2010	2011	2012	2013
Waiting time	1,12	1,04	0,93	0,85	1,26
Postpone time	4,67	3,11	6,75	7,00	6,81
Approach time	2,55	2,54	2,53	2,40	4,57
Berthing time	50,33	41,76	49,51	50,39	51,42
Turn Round Time	58,67	48,45	59,71	60,63	64,05

3 Problem Solution

Estimation of Port Emissions

The model of estimation to calculate emissions from an airport area not only from activities an airport itself, but also included from the the contribution of various pollution sources located near to an airport. The estimation has been performed through atmospheric dispersion modelling [5]

In this study, in order to measure the exhaust emissions from ships in port activities carried out, both for the main engine and auxiliary engine taking into account since the arrival of the vessel (arrival time), loading and unloading activities including ship waiting time until the time of departure of the ship (departure time) or as known as the Time Round Time (TRT) ship in the port, as shown in Figure 3.

When the ship arrive at the port the ship will be assited by tugboat and pilot boat to approach the quay. The next activities on the quay is for loading and unloading and then ship will leave the port with the tugboat and pilot boat assist. As log as the ship arrive to the port until ship leave the port, the ship electricity will supply by auxilliary engine.

First necessary to determine the operational mode of the ship at the port. When estimating the fuel consumption and emissions, Trozzi *et al*. focuses on three operational modes, namely hotelling, maneuvering, and cruising [2] but in case of Tanjung Perak Port the operational modes only hotelling and maneuvering, due to the port regulations the main engine have to shutdown. In the cruising mode the main engine function to move the ship replacing by harbour tugboat.

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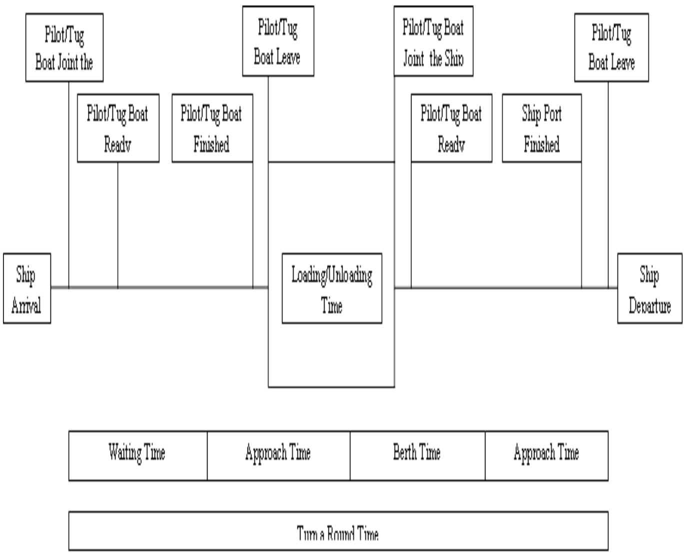

Figure 3. Ship Turn Round Time at the Port

After the operation mode is known, fuel consumption is calculated by considering the fraction of maximum fuel consumption of each mode of operation of the ship. It is necessary to consider the actual fuel consumption during different phases of ship operations carried out in the port area. In this study the exhaust gas emission from tugboat and pilot boat are not included, only considering from auxilliary engine for both domestic and foreign ship activities at the port.

Calculation of exhaust gas emissions is calculated based on the standard European methodology (MEET), estimates of emissions into account the twelve classes that have a gross tonnage vessels over 100 GT Trozzi, *et al* [2], but in the case of the Turkish Straits, the calculation included main engine types, fuel types, operation types, navigation times and ship speed [8]. While the modelling for exhaust gas estimation pollutant emission from ship activities at the Tanjung Priok Port, Jakarta [4]. The calculation of gas exhaust emissions included ship operation mode such as approaching time, berthing time and leave time from the port, fuel type and engine type. In this study the calculation of gas exhaust emissions not included the ship services owned by the port, such as tugboat and pilot boat.

In order to calculate the exhaust gas emissions, data include emissions factors, and specification parameters such as ship fuel consumption, engine type and ship operation mode at the port using Trozzi, et al. This method calculation engine fuel consumption of each type of vessel is obtained from a linear regression analysis of fuel consumption in ton per daay to the gross tonnage for each type of ship as shown in Table 5.

Table 5. Ship Type and Fuel Consumption (ton/day)

Ship Type	Fuel Consumption (ton/day)
Solid Bulk	$C_{jk} = 20.1860 + 0.00049 \times GT$
Liquid Bulk /Tanker	$C_{jk} = 14.6850 + 0.00079 \times GT$
General Cargo	$C_{jk} = 9.8197 + 0.00143 \times GT$
Container	$C_{jk} = 8.0552 + 0.00235 \times GT$
Ro-Ro Cargo	$C_{jk} = 12.8340 + 0.00156 \times GT$
Passenger	$C_{jk} = 16.9040 + 0.00198 \times GT$
High Speed Ferry	$C_{jk} = 39.4830 + 0.00972 \times GT$
Inland Cargo	$C_{jk} = 9.8197 + 0.00143 \times GT$
Sail Ship	$C_{jk} = 0.4268 + 0.00100 \times GT$
Tugs	$C_{jk} = 5.6511 + 0.01048 \times GT$
Fishing	$C_{jk} = 1.9387 + 0.00448 \times GT$
Other Ships	$C_{jk} = 9.7126 + 0.00091 \times GT$

In addition, the gas exhaust emissions from ship activities are calculated by considering emission factor for NO_x, CO, CO_2, VOC, PM and SO_x. The emision also included the engine, fuel type and mode of operation of the vessel activities at port.

Based on Trozi on MEET research [2] data of emission factor for each fuel consumption type, engine type and operation mode type, such as hotelling, cruising and manouevering as shown in Table 6.

Table 6. Ship Emission Factor (Kg/Ton)

Mode	Engine / Fuel	NO_x	CO	CO_2	VOC	PM	SO_x
Cruising	SSD/BFO	87	7.4	3200	2.4	1.2	60
	MSD/BFO	57	7.4	3200	2.4	1.2	60
	HSD/MDO	70	9	3200	3	1.5	20
Manoeu vering	SSD/BFO	78	28	3200	3.6	1.2	60
	MSD/BFO	51	28	3200	3.6	1.2	60
	HSD/MDO	63	34	3200	4.5	1.5	20
Hotelling	SSD/BFO	35	99	3200	23.1	1.2	60
	MSD/BFO	23	99	3200	23.1	1.2	60
	HSD/MDO	28	120	3200	28.9	1.5	20
SSD = Slow Speed Diesel Engine				BFO = Bunker Fuel Oil			
PM = Particulate Matter				VOC = Volatile Organic Compound			
MSD = Medium Speed Diesel Engine				MDO = Marine Diesel Oil			
HSD = High Speed Diesel Engine							

Calculation of total emissions of a pollutant from the main engine is shown in the following equation Trozzi, [2]:

$$E_i = \Sigma_{jklm} E_{ijklm} \qquad (1)$$

$$E_{ijklm} = S_{jkm}(GT)\, t_{jklm}\, F_{ijklm} \qquad (2)$$

where i = pollutant; j = type of fuel; k =ship type; l = engine type; m = vessel operating mode; Ei = total emissions pollutans i; E_{ijklm} = Total emissions of pollutant i, type of fuel is j, type of ship is k and l is type of engine and m is vessel operating mode. F_{ijklm} = average emission factor of fuel pollutant i, and type of fuel is j, types of vessel is k and engine type is m. S_{jkm} (GT) = Daily fuel consumption by type of fuel j, type of ship is k, with the vessel operating mode m by using the function GT. t_{jklm} = navigation of the ship type k with the type of engine is l, the type of fuel is j and ship operation mode is m.
While to estimate the fuel consumption of auxiliary engines obtained from the following equation Ishida [3].

$$f = 0{,}2 \; x \; O \; x \; L \qquad (3)$$

where: f = fuel consumption (kg/ship/h), O = rated output (PS/engine), L = load factor (cruising: 30%, hoteling (tanker): 60%, hoteling (other ship): 40% and 50% maneuvering.

4 Strategy to reduce the Emissions

As an island nation, Indonesia is heavily dependent upon shipping for its internal and external transportation. Since the national policy to promote sea transportation as the main of transportation in Indonesia, and the port of Tanjung Perak is the center of the collector and distributor of goods to Eastern Indonesia. The efficiency of the domestic and foreign ship activities at the port is therefore a vital matter in order to reduce the pollutsnt emissions from ships activities in the port.
The International Maritime Organization, a specialized U.N. organization, is the highest supervisory body in international shipping. The most important convention regulating and preventing marine pollution by ships is the International Convention for the Prevention of Pollution from Ships created in 1973 and modified by the Protocol of 1978 (MARPOL 73/78). In addition the IMO has adopted a resolution on the dumping at sea, tributyl tin (TBT) in antifouling coatings, double hulls for oil carrier and preventions of accidental pollution (SOLAS).
Recently, new limits for NOx and SO_X emissions for new marine diesel engines based on the rated engine per minute or RPM were adopted in MARPOL Annex VI. Reduction of NOx emissions from marine diesel engines can be achieved through primary and secondary treatment method, such as Selective Catalytic Reduction equipment. Special fuel quality provisions exist for SOx emission, where the sulphur content of fuel oil used on board ships must not exceed 1.5%. Alternatively, ships must install an exhaust gas cleaning system or use any other technological method to limit SOx emissions to ≤ 6 g/kWh [10].

In order to reduce CO_2 emissions from shipping activities, some researches have been done by the IMO. For instance, a speed reduction of 10% may result to a 23.3% reduction of emissions by 2010 and when it is integrated with other operational measurers such as utilizing higher quality fuels, incorporating weather routing and voyage planning procedures, it predicted that about 40% reduction in CO_2 emissions by 2010 and more than 50% reduction by 2020 can be achieved [10]. The researchers also identifies that the technical improvements such as advances in hull shape, modernizing machinery and propulsion system can significantly result to greenhouse gas reduction for both existing and new ships.
Meanwhile design and implementation of methodologies for transport SUCCESS (Smaller Urban Communities in Civitas for Environmentally Sustainable Solutions) was a 4-year project, within

the CIVITAS II Program. The SUCCESS proposal was submitted by the "Urban Community" in response to the European Commission's call for proposals for indirect RTD (Research and Technological Development) Programme actions under the specific program for research, technological development and demonstration. New technologies and concepts for all surface transport modes (road, rail and waterborne) testing implementation and transition strategies for clean urban transport. The general objectives of SUCCESS were to demonstrate that alternative fuels could be an efficient choice for urban transport matters; the target for all vehicle fleets was a decrease of 20% in the use of fossil fuels and a decrease of 10% in energy consumption, CO2 emissions, particulates, NOx and NO2 emissions [11]

The calculation of pollutant emissions from ship activities at the Tanjung Perak Port, Surabaya are evaluated by assessing the impact of measures in the framework as well as some alternative development for emission reduction. Furthermore, three scenarios have been developed: scenario one or Business As Usual (BAU) scenario; scenario two or port electricty scenario; and scenario three or effeciecy Turn Round Time (TRT) scenario.

In scenario one or BAU scenario, it is assumed that ship activities at the port without improvement or no counter measure scenario. In the fig. 4 shows the exhaust emissions in foreign ships service at the Port of Tanjung Perak. Exhaust emissions produced between 2009 to 2013

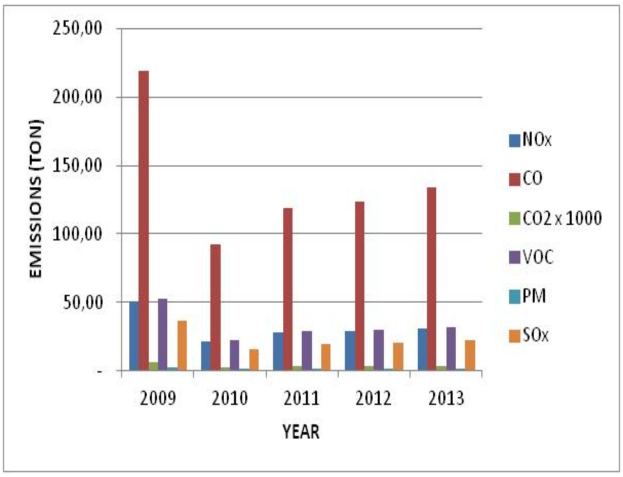

Figure 4. Foreign Ship Emissions BAU Scenario

Fig. 5 shows that the exhaust emissions produced by domestic ships at the Port of Tanjung Perak, Surabaya. Exhaust emissions that are generated NOx, CO, CO2, VOCs, PM and SOx. In 2013 domestic ship exhaust emissions.

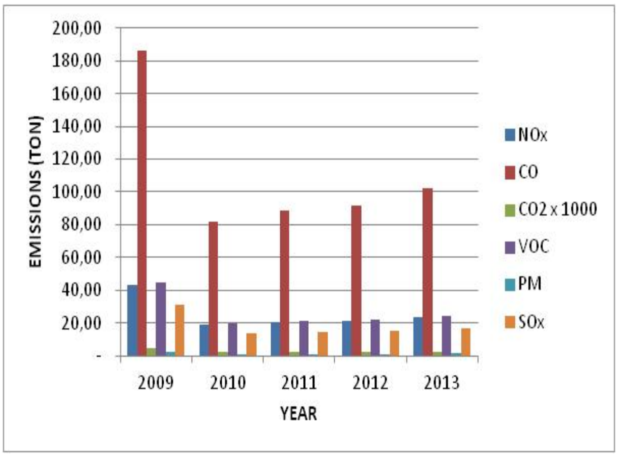

Figure 5. Domestic Ship Emissions BAU Scenario

Total pollutant emissions from foreign and domestic shipping at the Port of Tanjung Perak, Surabaya during 2009 to 2013 shown in Fig. 6. Total pollutant emissions in 2013 from domestic and foreign exhaust emissions were estimated 55,080 ton for NOx, 236,060 ton for CO, 6.294,830 ton for CO_2, 56,850 ton for VOC, 2,950 ton for PM and 39,340 ton for SOx.

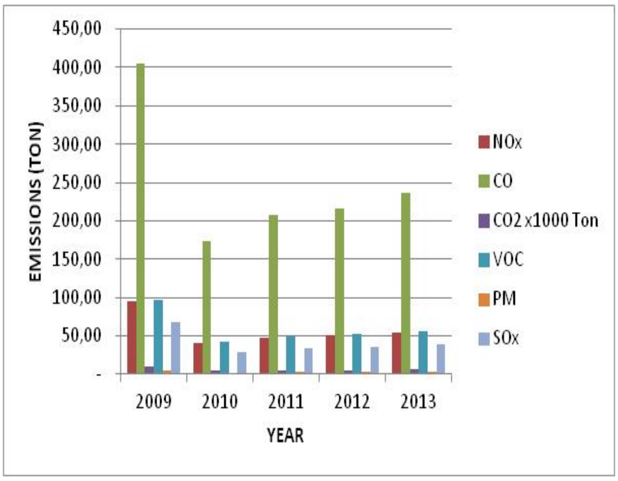

Figure 6. Total Foreign and Domestic Ship Emissions BAU Scenario

In scenario two or electricity scenario, it is assumed that the port electricty will be used for ships activities at the port, such as lighting, air conditioned or all ships ellectricty requirement will be supported by port electricity. In this scenario, all ships engine for both main and auxilliary engine will not use at the port when ships have loading/ unloading activities at the port.

In the fig. 7 shows the exhaust emissions from foreign ships service at the Port of Tanjung Perak, Surabaya.

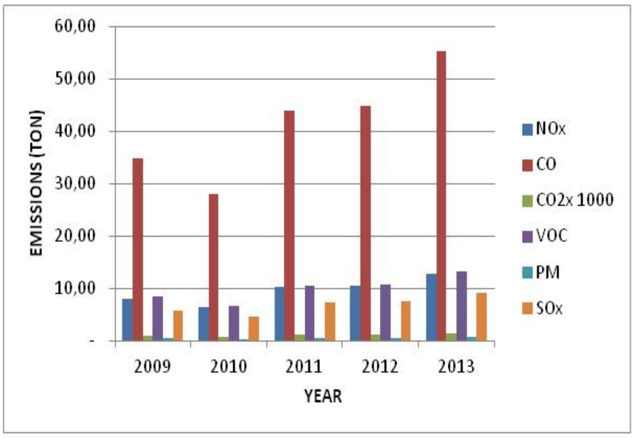

Figure 7. Foreign Ship Emissions Electricity Scenario

Fig. 8 shows that the exhaust emissions produced by domestic ships at the Port of Tanjung Perak, Surabaya. Exhaust emissions that are generated NOx, CO, CO2, VOCs, PM and SOx.

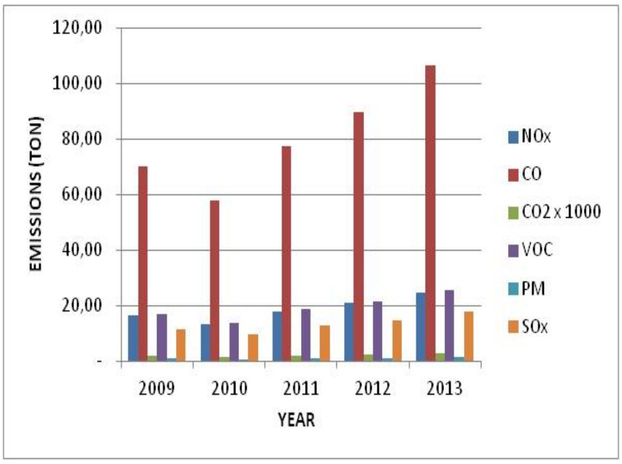

Figure 8. Domestic Ship Emissions Electricity Scenario

Total pollutant emissions from foreign and domestic shipping at the Port of Tanjung Perak, Surabaya during 2009 to 2013 shown in Figure 9. Total pollutant emissions in 2013 In 2013 foreign and domestic ship exhaust emissions were estimated 37,710 ton for NOx, 161,610 ton for CO, 4.309 ton for CO_2, 38,920 ton for VOC, 2,020 ton for PM and 26,940 ton for SOx.

In scenario three or efficiency of ship TRT scenario, the improvement of ship time service in the port will be improved about 10% from total TRT ship in the port, such as waiting time, delay time, postpone time and berthing time.In the fig. 10 shows the exhaust emissions in foreign ships service at the Port of Tanjung Perak, Surabaya.

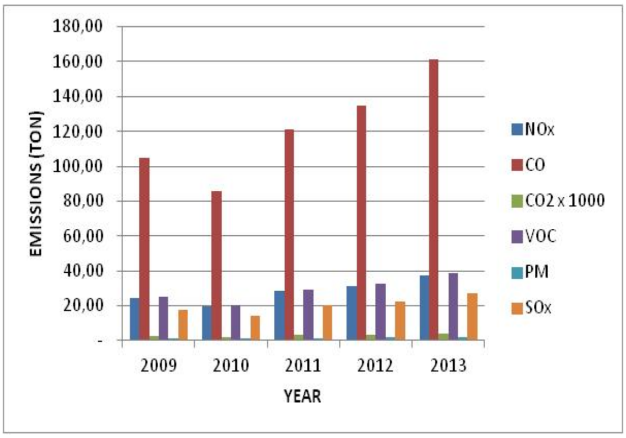

Figure 9. Total Foreign and Domestic Ship Emissions Electricity Scenario

The calculation of exhaust gas emissions from ship activities at the port, shows that CO_2 emissions are the largest contributor to gas exhaust emissions followed by CO and NO_x emissions. While the polluting from gas exhaust emissions from ships activities at the port was highest in year 2009 throughout the last five years, this is due to the foreign ships visits at the port of Tanjung Perak, Surabaya with the ships visits reached about 12.629 units.

The factors causing the high gas exhaust emissions at the port is due to the ship takes time for loading and unloading activities at the port. The foreign vessels berthing time has fluctuative, whereas in the year 2009 for 50,33 hours and in 2012 amounted to 50,39 hours, while in the year 2013 is 51,42 hours. The longest total time at the port occured at the year 2013 by 64,05 hours and followed in 2012 by 60,63 hours and in 2011 amounted to 59,71 hours.

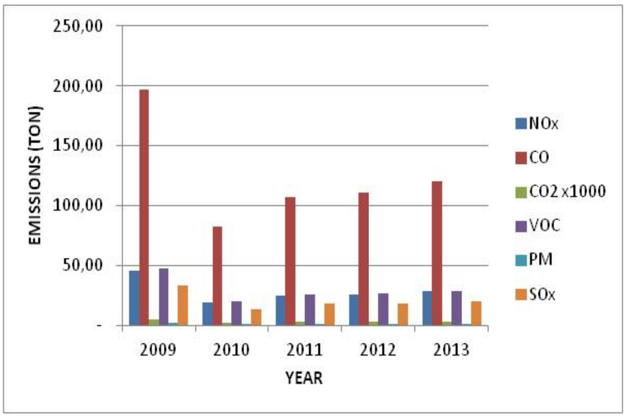

Figure 10. Foreign Ship Emissions TRT Scenario

Fig. 11 shows that the exhaust emissions produced by domestic ships at the Port of Tanjung Perak, Surabaya. Exhaust emissions that are generated NOx, CO, CO2, VOCs, PM and SOx.
Polluting exhaust gas emissions from ships activities in port was highest in 2009 throughout the last five years, this is due to the increasing of domestic ship visits by 2,435 units in the port of Tanjung Perak, Surabaya.
The process of loading and unloading of ships at the Port of Tanjung Perak, Surabaya for domestic vessels occurred in year 2009 at 34,40 hours followed in year 2011 at 29,64 hours and subsequently in year 2013 amounted to 29,64 hours while the longest total time ship at the port occurred in 2013 amounted to 46,72 hours followed in year 2009 amounted to 46,46 hours and subsequently in year 2012 amounted to 42,87 hours.

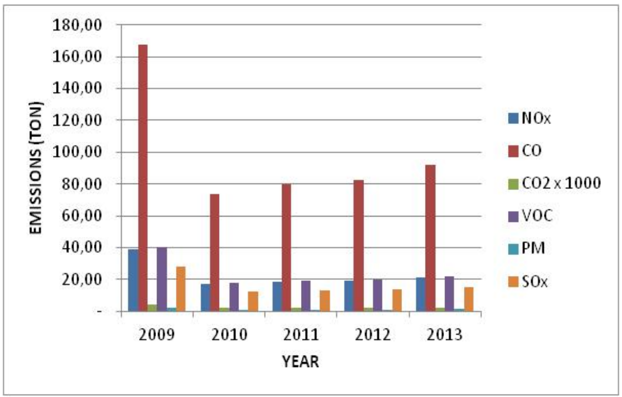

Figure 11. Domestic Ship Emissions TRT Scenario

Total pollutant emissions from foreign and domestic shipping at the Port of Tanjung Perak, Surabaya during 2009 to 2013 shown in Fig. 12.
The polluting gas exhaust emissions from ships activities at the port was highest in year 2009 throughout the last five years, this is due to the ship visits , both foreign vessels and domestic vessels with a total ship visits was 15,064 units.
Other factors that increase exhaust emissions from ships is the length of the ship activities at the port area. Longest total time the ship was at the port, both for foreign and domestic vessels occur in year 2013 amounted to 110,77 hours while the lowest was in year 2010 at 87,57 hours.
Total pollutant emissions in 2013 total foreign and domestic ship exhaust emissions were estimated 49,570 ton for NOx, 212,450 ton for CO, 5.665 ton for CO_2, 51,165 ton for VOC, 2,650 ton for PM and 35,400 ton for SOx.

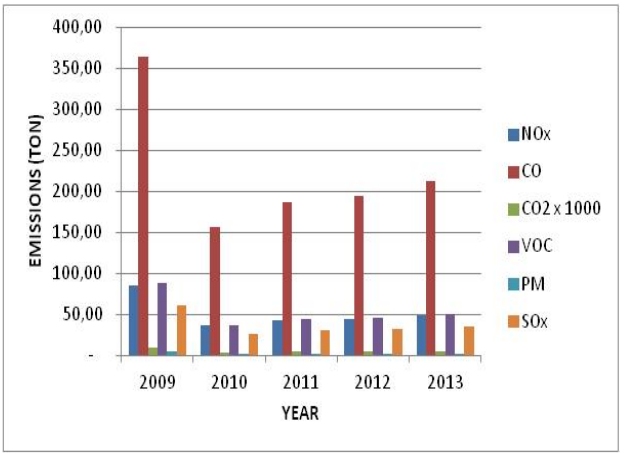

Figure 12. Total Foreign and Domestic Ship Emissions TRT Scenario

Tabel 11 shows the comparison between total gas exhaust emissions in 2013 among BAU Scenario, Electricity Scenario and TRT Scenario. From the results shows the higest reduction of pollutant emissions are from Electricty Scenarios compare to the BAU Scenarios.
Based on the statistics data for ships visits and ship waiting time at the port, both for foreign and domestic vessels as the significant factors in increase the exhaust gas emissions at port. The results for the implementation of the port electricity as a power source for vessel electricity or Eletricity Scenario can reduce exhaust gas emissions reached more than 31 % compared to business as usual (BAU) Scenario. While the TRT scenario can reduce exhaust emissions up to 10 % compared to business as usual (BAU) Scenario.

Table 7. Pollutant Emissions Comparison Among Scenarios (Ton)

Scenarios	NOx	CO	CO2	VOC	PM	SOx
BAU	55,080	236,06	6.294.830	56,850	2,95	39,343
Electricity	37,709	161,612	4.310,000	38,922	2,020	26,935
TRT	49,572	212,451	5.665,000	51,165	2,656	35,408

The implementation of Eletricity Scenario and TRT scenario can be the priority for development port in Indonesia, with this scenarios the implementation of eco port in Indonesia can be achieved and can reduce of exhaust gas emissions from the sea transport sector in Indonesia and finally can support government programs in order to reduce exhaust gas emissions.
Since Indonesia policy to reduce exhaust gas emissions from all sectors, it is necessary to

calculate the exhaust gas emissions. In the transport sector, particularly sea transport required database of exhaust gas emissions from ships activities in the port and when the ship sailing. Calculation of exhaust gas emissions from ships activities at the port of Tanjung Priok, Jakarta has done [4]. This study conducted exhaust gas emissions of vessels activities at the port of Tanjung Perak, Surabaya. Further study is calculating exhaust gas emissions from ships activities at the port of Belawan, North Sumatera Province, Sukarno-Hatta Port, Makasar Province and finally Port of Tanjung Emas, Central Java Province. Since the fifth port is a main port in Indonesia which can be assumed as a representative of the port in Indonesia. The main goal of this study is to show the total exhaust emissions from marine transport sector in Indonesia by calculate the total exhaust as emissions from ships when sailing in Indonesia and ship activities at the port for both foreign and domestic ships .

5 Conclusion

Based on data collection, discussion and analysis of data, the strategy for reducing pollutant emissions from ships activities at the Port of Tanjung Perak, Surabaya obtained the following conclusions:

1. The rapid growth in international and domestic shipping activities at the port of Tanjung Perak, Surabaya led to the increase in greenhouse gas emissions such as $NO_{X,}$ CO, CO_2 VOC, PM and SOx into the atmosphere. Some scenarios have identified a potential system for emissions reduction.
2. The number of ship visits at the port of Tanjung Perak in unit and gross tonnage (GT) increased from year to year, both for foreign and domestic vessels.
3. The average of Turn Round Time (TRT) ship for domestic shipping is about 44 hours, meanwhile for foreign shipping is about 58 hours. In this point of view the port should have development to decrease the waiting time at the port.
4. The higest reduction of pollutant emissions are from Electricty Scenarios compare to the BAU Scenarios.

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