Assessing the Potential of Emission Inventory as Tools to Bridge the Sustainable Sea Port Concept and Business Process Improvements in Operation Terminal 3 Port of Tanjung Priok

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Abstract: In 2014, The United Nations Environment Programme (UNEP) in a joint research program with PUSTRAL-UGM first introduced the Emission Inventory (EI) activity as part of the larger sustainable port concept to the stakeholders of port operation in Indonesia. The initial research was able to show the link between business process and the emission level in the sea port area. The research also shows the feasibility of implementing the emission inventory activities in Indonesia. This paper assesses potential of EI as key tools to bridge the interest on business and economic development with the sustainable port concept. By comparing the initial EI research results and the new EI simulation using new dataset the research able to shows that EI has potential to be used by Indonesian regulator and port operator to assess their current and planned effort in environmental program in relation with their current regulation and business process

Keywords: Emission Inventory, Sustainable Infrastructure, Port of Tanjung Priok, Environmental Protection, Business Process

1. INTRODUCTION

In 2014 the United Nations Environment Programme (UNEP) proposed the concept of a sustainably developed and managed sea port in Indonesia. One of the key components for this concept is the monitoring of pollutant emission within the sea port area. The emission inventory activity was introduced as the method to determine the baseline emission by taking into account the actual activity within the sea port area. The initial research program was carried out in collaboration between UNEP and The Centre of Logistics Studied –Universitas Gadjah Mada (PUSTRAL-UGM).

The development of sustainable and clean port proposed by UNEP for Indonesia faced relatively similar issues currently with other environmental protection program. The most prevalent usually the usually conflicting needs between environmental protections against economic development. This conflicting condition is uncommon even in developed countries. Indeed in the 2004 European Union Economic review it is pointed out that the main cause of potential conflict between environmental protection and economic development can range from the concern over diversion of resources to the competing and difference of basic requirements. In order to address this problem, the initial research must utilized creative approach especially to receive the endorsement and participation of the stakeholders. Therefore fro the initial phase, the research utilizes the business improvement issues as the commercial aspect that potentially receives benefit from the reduction of pollutant reduction.

The proposed concept and study received positive response from the port operation stakeholder, which in the case of the research is the Indonesia Port Company (*PT. Pelabuhan Indonesia II*) as port operator and Directorate General of Sea Transportation, Ministry of Transportation. This support was shown by their support and cooperation during the data collection process. Despite of the relatively success initial EI activity, there is the needs for further research especially to assess the effect of changes in the port condition and business process with the environmental condition. The initial study does not yet possess the historical data nor cover the complete business process in the OT3 Tanjung Priok in detail. Difficulties in getting detail and reliable data remain the key challenges until the second research was carried out.

This paper try to further assess the potential of EI activity as tools to bridge the demand of business and economic development with the development and implementation of sustainable port concept. The challenges in data collection mitigated by the utilization The of data and findings of the 2014 Initial EI research which will be compared with the calculation and simulation result using the updated 2015 data supported by predetermined hypothetical assumption. One EI calculation utilizing 2015 data with Initial EI result precondition which will serve as comparative point of reference (Business As Usual). By ccomparing several different calculations and simulation results the effect of actual business process on emission level this paper aims to : (1) understand of effects caused by changes in business process and performance to the emission level; (2) assess the potentials of EI activity as key tools to bridge the economic and environmental protection demand;

2. LITERATURE STUDY

The US-EPA (2009) explains the description of emission inventory as a method of quantification for all emission criteria and other pollutants (which may include toxic pollutant and greenhouse gases) which may be emitted within certain area in certain period of time. The emission source itself maybe mobile based, point based or area based.

The emission inventory may provide benefits to: (1) analyze the emission level during the assessment period; (2) assess the trend of emission in the future since emission inventory shall be updated periodically; (3) evaluate the effectiveness of emission reduction efforts which has been implemented; (4) support the achievement of emission reduction efforts of certain pollutant with the largest source contribution or for certain geographic areas; (5) evaluate the cost-effectiveness for various emission reduction efforts; (6) record the progress of emission reduction over time as a result of the implementation of technology and efficiency improvements (UNEP & PUSTRAL-UGM, 2015)

Emission inventory can be carried out by either using “top-down” or “bottom-up” method. “Top-down” approach is based on the option of large-scale variables (for example, the amount of fuel sales or fuel consumption in national scale) which are then broken down into smaller scale by using a proxy variable or representing variable (for example population or data of registered vehicle). “Bottom-up” approach generally adopts energy consumption and activity based method. In the emission inventory for transportation sector, for example, the exhausted pollutants is projected from specific data such as number of vehicle, category and technical specification of vehicles, and vehicle activities (travel distance and time) (UNEP & PUSTRAL-UGM, 2015)

The commonly used emission inventory for port operation is the one developed by US-EPA in 2009 (USEPA, 2009).The basic concept of the EI methodology itself actually utilizes the bottom-up approach by investigating energy consumption together with activities of emission source related to port activity. The EI's depth activity and analysis also determined by the availability and reliability of the data. In case of data being insufficient ly available and reliable, it is advised that streamlined EI method should be used (US-EPA, 2009).The steps to determine the most appropriate type of emission inventory in port area can be described as presented in the following figure

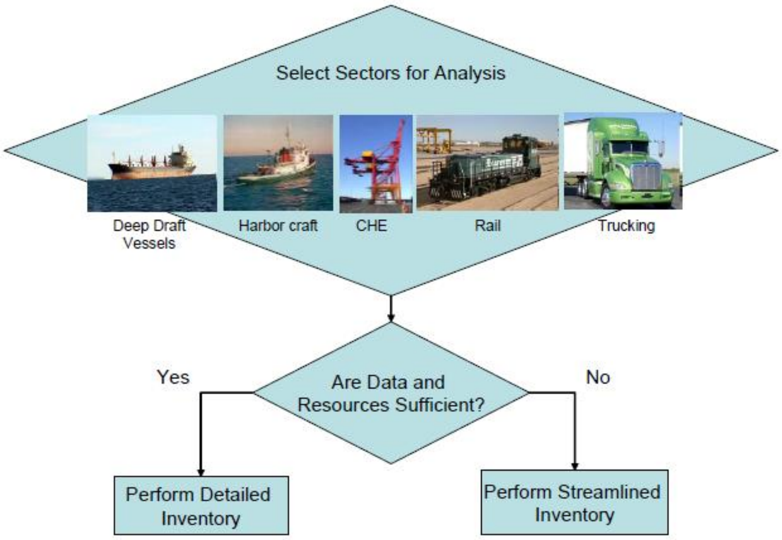


Figure 1. Steps for Emission Inventory in Port Area

Source: USEPA, 2009

The USEPA identify the five main categories for the emission source in port area (US-EPA, 2009)

Table 1. Sources of emission in port area

No	Category	Types
1	Ocean Going Vessels	Container ships, Tanker ships, Bulk carrier ship, Cruise ships, Reefer ships, Roll-on/Roll-off ships, Vehicle carrier ships
2	Harbor Craft/vessels	Tugboats and push boats, Ferries, Excursion vessels, Fishing vessels, Dredging equipment
3	Cargo Handling Equipment	Terminal tractors, Top and side loaders, Forklifts, Wharf cranes, Rubber tire gantry cranes, Skid loaders
4	Locomotives	Line haul locomotives & Switch yard locomotives
5	Vehicles	Other port vehicles

Source: USEPA ,2009

3. METHODOLOGY AND DATA COLLECTION

3.1 Scope of Study

The paper's location of study focused on the area of Operation Terminal 3 (OT 3) Port of Tanjung Priok. Port of Tanjung Priok itself actually consists of several terminals, which either directly operated by PT. Pelabuhan Indonesia II of Tanjung Priok Branch (now refer to as PT. Port of Tanjung Priok) or those operated in cooperation with private sectors. The Operation Terminal 3 alongside OT 1 and OT 2 are directly operated by PT Pelabuhan Indonesia II. The previous phase of research conduct the baseline emission inventory based on the agreement of UNEP, PUSTRAL-UGM and PT. Pelabuhan Indonesia II of Tanjung Priok Branch agreed to in the area by considering the business operation, service, accessibility, health and safety aspects as well as environment aspect. This paper asses the similar location analyzed by previous phase of research to simplify the analysis and comparative process.

Data availability and level of accuracy of the required data remains the greatest challenge in the study. With the condition of data management and processing system in Port of Tanjung Priok still focused more on the needs of the business administration aspects of the port some assumptions must be made to fill the gap required for the analysis. The first phase of research covers the period of January to March 2014 while the second study rely on the data from 2014 up to 2015 supported by predetermined hypothetical assumption for the comparative analysis.

Similar with the previous phase of the study, the mitigated sources of emission considered in this study include mobile emission sources from port-related activities in OT 3 area, both sea or land-based activities. The type of pollutant that were measured are Nitrogen Oxide (NOx), Carbon Monoxide (CO), Particulate Matter < 10 microns (PM10) and 2.5 microns (PM2.5), Black Carbon (CB), Sulfur Dioxide (SO2) and Carbon Dioxide (CO2).

3.2 Emission Inventory Approach

In line with the initial EI phase this paper carried out the EI activity for TO 3 Port of Tanjung Priok using the “bottom-up” methodology in which the calculation and simulation of pollutant is carried out based on the actual energy consumption and activity in the researched area. This decision is taken by taking into account the capacity and time constraint of the study, the research also conducted in simplified manner or streamlined inventory method.

The main considerations of this decision are : (1) The mobile sources of emission come particularly from sea-based and land-based activities and limited in specific area, i.e. Operation Terminal 3;(2)Tanjung Priok Port has not specially documented the accurate data for the purpose of periodic emission inventory .

3.3 Source of Emission

In the previous phase of EI activity it was identified that based on the business process of port services and referring to the emission inventory method developed by US-EPA, the emission sources in OT 3 could be identified as follows (UNEP&PUSTRAL, 2015): (1) international and inter-island vessels. Based on the transported cargo, vessels entered OT 3 could be categorized into container, bag cargo, dry bulk, liquid bulk, general cargo and unitized vessel; (2) harbor Craft is defined as vessels which operates inside or around the port such as tug boat, pilot boat, mooring boat, passenger boat (ferry), cruise, fishing vessel, dredging and dredging support vessels (USEPA-ICF, 2009). Harbor Craft in OT 3 consists of tug boats, pilot boats and mooring boats; (3) Cargo Handling Equipment (CHE) includes loading-unloading equipments; (4) Land transportation (truck) operates in the area of OT 3.

3.4 Data Collection

Data collected in this paper consist of two data sets. The first is data set collected from the initial study supported by the assumption taken from the international best practice and the second data sets consist of the updated data supported by predetermined hypothetical assumption which will be used for comparative analysis.

5.2.1 Initial study

The initial study cover the data from the data collected in the period January to March 2014 which consist of (1) detailed ship movement record; (2) detailed harbor vessel operation record; (3) detailed container handling equipment operation record; (4) detailed head truck movement record; (5) secondary supporting data which serve as the base of assumption in the case of actual data cannot be obtained or unavailable. The study use several assumptions based on the best practice reference.

5.2.2 Updated data and hypothetical scenario

Second data set for this paper consist of annual ship movement record and predetermined hypothetical assumption. The main assumption used in this paper for further analysis are as follows : (1) It is assumed that the domestic general cargo and tanker slot is replaced by domestic container due to changes in OT3 policy to become container terminal. The distribution of international ship assumed unaffected; (2) It is assumed that the improvements on the performance in OT 3 mostly on the head truck performance as the result of the previously presented EI activity result to the stakeholder in 2014; (3) HC operation does not change due to the regulation; (4) the number of ship call to OT 3 in 2013 utilize the calculation from initial study with the increase or decrease the next year utilize the actual growth or decrease of ship call in Port of Tanjung Priok.

4. EMISSION INVENTORY EQUATION AND ASSUMPTIONS

4.1 Vessel (Ocean Going Vessel & Domestics)

All the cargo ship emission in this paper would later be called as OGV emission both for ocean going vessel and domestics vessels. To calculate the emission per cargo ship arriving at the port, firstly we need to identify the type of ship entering the OT3. In this study, the ship call activity has been categorized by the transported cargo, i.e. (1) container, (2) general cargo (including bulk, bag cargo, unitized), (3) tanker (liquid bulk) and dry bulk (bulk carrier) similar to the previous study.

To determine the main engine power, the equation developed by Carlo Trozzi "Emission Estimate Methodology for Maritime Navigation-2010" has been used. The correlation between GRT and power output is explained in the equation. Considering that data of ship production year are not available, the formula for world vessel in 1997 has been used by taking into consideration that the emission inventory for ports in ASEAN region performed using the formula (ASEAN&GIZ, 2012)

Table 2 . Correlation between main engine power and gross tonnage – GT

Vessel Category	World Vessel 2010 (kW)	World Vessel 1997 (kW)
Liquid Bulk	$14.755 * GT^{0.6082}$	$29.821 * GT^{0.5552}$
Dry Bulk	$14.755 * GT^{0.6082}$	$89.571 * GT^{0.4446}$
Container	$2.9165 * GT^{0.8719}$	$1.3284 * GT^{0.9303}$
General Cargo	$5.56482 * GT^{0.7425}$	$10.539 * GT^{0.6760}$
RoRo	$164.578 * GT^{0.4350}$	$35.93 * GT^{0.5885}$
Passenger	$9.55078 * GT^{0.7570}$	$1.39129 * GT^{0.9222}$

Source: Trozzi, 2010

The next step is to calculate the load factor of the ship. Load factor of the propulsion engine varies by each vessel speed. During cruise speed, the LF of propulsion engine is assumed to be 83%. On other operational mode/condition, LF will be calculated using Propeller Law in which actual speed of vessel is compared with the maximum speed and then ranked by 3cubed. The equation is as follow:
with the following equation :

$$LF = (AS/MS)^3 \quad (1)$$

where,

LF : Load Factor (percent)
AS : Actual Speed (knots)
MS : Maximum Speed (knots)

Referring to USEPA (2009), LF fewer than 20% is still possible since the main engine is sometimes alternately turned off and on when maneuvering in order to reduce the speed. Considering that data of speed for ship-call in OT 3 are not available, typical speed information as adopting the information from US-EPA (2009) has been used. Other consideration taken into account is the “Maneuvering Standard in Tanjung Priok Port” document which has stipulated that: (1) maximum speed of vessel is the cruise speed divided by 0.94; (2) the speed during RSZ mode operation (within the breakwater area) and during maneuvering mode operation is stipulated in the “Maneuvering Standard in Tanjung Priok Port” in which speed for RSZ is 6 knot and 5 knot for maneuvering. Using the conversion of 1 knot = 1.852 km/hour, the speed for RSZ will be 11.11 km/hour and speed for maneuvering will be 9.26 km/hour. Load factor for auxiliary engine will vary by type and operation mode of vessels. Several previous studies have indicated that auxiliary engine will remain running in all operation modes.

The next step is to determine the emission factor of the ship. The emission factor is a representative value which correlates the quantity of pollutant released to the atmosphere from an activity related to pollutant source. The emission factor of vessel engine varies depending on the speed (rotation) of engine and the consumed fuel. The general rule is that vessel usually uses residual oil (RO) or marine diesel oil (MDO) or marine gas oil (MGO) as its fuel. The emission factor for vessel in this study is adopted from “USEPA Current Methodologies Report (ICF, 2009).

Table 3 Emission factor of OGV

Type of Boat	Emission Factor (g/kWh)								
	Engine Type	Fuel	Sulphure (%)	NO_x	CO	PM_{10}	$PM_{2.5}$	SO_2	CO_2
Propulsion Engine	SSD	RO	2.70%	18.10	1.40	1.42	1.31	10.29	620.62
Auxiliary Engine	SSD	RO	2.70%	14.70	1.10	1.44	1.32	11.98	677.91
Boiler	SSD	RO	2.70%	2.1	0.2	0.80	0.60	16.50	970.71

Source: USEPA ,2009

By taking into account the result of Air Emission Inventory of South Caroline Ports (2013) it is assumed that vessels entering OT 3 uses engine with RO fuel, slow-speed diesel and a sulfur content of 2.7%.For load factor of propulsion engine under 20%, correction factor will be applied to calculate the increase of emission per kW due to decreased engine efficiency on low LF. The correction factor is for low LF is as follows:

Table 4 . Correction factor for propulsion engine with low LF

Load	NO_x	HC	CO	PM_{10}	$PM_{2.5}$	SO_2	CO_2
1%	11.47	59.28	19.32	19.17	19.17	5.99	5.82
2%	4.63	21.28	9.68	7.29	7.29	3.36	3.28
3%	2.92	11.68	6.46	4.33	4.33	2.49	2.44
4%	2.21	7.71	4.86	3.09	3.09	2.05	2.01
5%	1.83	5.61	3.89	2.44	2.44	1.79	1.76
6%	1.60	4.35	3.25	2.04	2.04	1.61	1.59
7%	1.45	3.52	2.79	1.79	1.79	1.49	1.47
8%	1.35	2.95	2.45	1.61	1.61	1.39	1.38
9%	1.27	2.52	2.18	1.48	1.48	1.32	1.31
10%	1.22	2.20	1.96	1.38	1.38	1.26	1.25
11%	1.17	1.96	1.79	1.30	1.30	1.21	1.21
12%	1.14	1.76	1.64	1.24	1.24	1.18	1.17
13%	1.11	1.60	1.52	1.19	1.19	1.14	1.14
14%	1.08	1.47	1.41	1.15	1.15	1.11	1.11
15%	1.06	1.36	1.32	1.11	1.11	1.09	1.08
16%	1.05	1.26	1.24	1.08	1.08	1.07	1.06
17%	1.03	1.18	1.17	1.06	1.06	1.05	1.04
18%	1.02	1.11	1.11	1.04	1.04	1.03	1.03
19%	1.01	1.05	1.05	1.02	1.02	1.01	1.01
20%	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Source: USEPA – ICF, 2009

In this paper the calculation of Black Carbon (BC) emission is estimated based on various researches such as the Emission Inventory Methods and Comparisons (EPA). BC for vessel is calculated at 28% from $PM_{2.5}$.

Based on the USEPA (2009), the emission per ship can then be calculated using the following equation:

$$E = P \times LF \times A \times EF \tag{3}$$

where,

- *E* : Emission (gram/year)
- *P* : Maximum Continuous Rated Power (kilowatts [kW]); size of the installed engine, propulsion engine and auxiliary engine.
- *LF* : Load Factor (percent of vessel's total power in use for each operation mode)
- *A* : Activity (hour/year); duration for each operation mode within one year period
- *EF* : Emissions Factor (gram per kilowatt-hour, g/kWh); level of emission for each pollutant parameter

4.2 Harbor Craft (HC)

The emission calculation process for HC is similar with OGV with the following aspect should be taken into account .

Table 5 . HC power rate & load factor

No	Pilotage Fleet	Average Power (hP)*		Load Factor**		Total Power
		Main Engine	Supporting Engine	Main Engine	Supporting Engine	
1	Tug Boat	1,227.94	216.68	0.79	0.56	1,091.41
2	Pilot Boat	281.82	17.70	0.45	0.56	136.73
3	Mooring Boat	112.14	6.70	0.45	0.56	54.22

Sources:
** Average number from Data of Pilotage Fleet*
*** USEPA - ICF International 2009*

Table 6 . HC emission factor

Type of Boat	Power Total (kW)	Emissions Factor (gr/kWh)					
		NOx	CO	PM10	PM2,5	SO2	CO2
Tug Boat	1,091.41	13.00	2.5	0.3	0.29	1.3	690
Pilot Boat	136.73	10.00	1.5	0.4	0.39	1.3	690
Mooring Boat	54.22	10.00	1.7	0.4	0.39	1.3	690

Source : USEPA - ICF International 2009

4.3 Container handling Equipment

The equation to calculate emission for each CHE is as follow:

$$E= P \times LF \times A \times EF \qquad (4)$$

where,

E : Emission, gram/year
P : Power, hp or kW
A : Activity, hours/year
LF : Load Factor (ratio of average usage during normal operation to maximum load)
EF :Emission Factor, gram pollutant per-working unit (g/hp-hour or g/kW-hour)

CHE emission calculation utilize the following assumption due to the limited available data

Table 7 . Assumptions to calculate emission of CHE source

Data	Assumption, Estimation, Conversion for Calculation
Unit of CHE Power in kVA (kilo volt ampere)	1 kVA = 1000 kW 1 kW = 1,340 hP
Some equipment are broken and not operate	Excluded from the calculation

Equipment power (reach stacker and some of HMC) is not available; however, there is equipment data from similar equipment of different brad	Using available data from other equipment brand
Forklift power and RTG Power are not available	Adopted from Los Angeles Port, Inventory of Air Emission, 2012
Activity of the equipment only available for the period of January and February 2014	The data for March 2014 is made equal to January 2014

In this study, load factor data for CHE is adopted from CARB (2011) as presented in the following table

Table 8 . Load Factor by Type of CHE

No	Type of CHE	LF
1	Quay Container Craine (QCC)	0.43
2	Harbour Mobile Crane (HMC)	0.43
3	Rail Mounted Gantry Crane (RMGC)	0.20
4	Rubber Tyred Gantry Crane (RTGC)	0.20
5	Reach Stacker	0.59
6	Forklift	0.51

Source: California Air Board Resources

The calculation of emission of CHE is performed using streamlined method in which emission factor of CHE is determined based on the engine power and production year of the engine. The challenges are that there is differences on the quality and condition of the engine with some differ by around 46 years. Other problem is the issue of Indonesia diesel fuel quality which according to the Ministry of Environment (2014), the sulfur content in diesel fuel could reach 3500 ppm. Considering this, therefore it is decided that the calculation will be carried out by using the characteristic of TIER 0 engine according to the USEPA (2009). The detail of emission factor is presented in the following table

Table 9. Emission Factor of CHE by Equipment Power

Power (hP) CHE	NOx	CO	PM_{10}	$PM_{2,5}$	SO_2	CO_2
>100 -175	14	6.1	1.6	1.55	0.16	526
>175 - 300	14	6.1	1.6	1.55	0.16	526
>300 - 600	14	6.1	1.6	1.55	0.16	526
>600 - 750	14	6.1	1.6	1.55	0.16	526
>750	14	6.1	1.6	1.55	0.16	526

Source: USEPA (2009)

4.4 Head Truck

The emission for head truck activity is calculated both during operating/running condition (vehicle km travelled, VKM) and during idling condition (hour).The calculation of emission for truck is based on USEPA (2009), using the following equation:

$$E = A \ x \ EF \quad (5)$$

where,

E	:	Emission (gram/year)
A	:	Activity (hour or travelled/year)
EF	:	Emission Factor (gram/hour or gram/km

Head truck emission factor is calculated either during truck's mobile or static phase (idling position). According to CARB (2011), emission factor can vary depending on the vehicle's speed. In this study, idling equal to truck operates in the speed of 0 km/hour. Within the OT3 area the truck commonly moves in the speed of 5 – 15 km/hour. Based on the data, the emission factor according to CARB (2011) can be seen in the following table

Table 10. Emission Factor of Head Truck by Travel Speed

Speed		Unit	NOx	CO	PM_{10}	$PM_{2,5}$	SO_2	CO_2
mph	km/hour							
0 (Idle)	0 (Idle)	gr/hour	28.2877	16.6140	0.0629	0.0579	0.0396	54,947.38
1 -5	1.6 - 8.0	gr/mile	18.5872	7.3365	0.1015	0.0934	0.0171	22,102.58
		gr/km	11.5520	4.5597	0.0631	0.0580	0.0106	13,736.85
6 - 10	9.7 - 16.1	gr/mile	13.9498	4.5914	0.0868	0.0799	0.0171	22,102.58
		gr/km	8.6699	2.8536	0.0539	0.0497	0.0106	13,736.85

Source: CARB (2011)

5. EMISSION INVENTORY SIMULATION

5.1 Initial Studies

In calculating the emission level several considerations should be taken into account. The first of which is related to the ships 'movements into and out from the OT 3 Tanjung Priok . The movement itself follows several modes which later determine the ship's speed. Those are: (1) cruise Mode (hour/call), usually performed in wide-open ocean in which the movement of vessel is not disturbed. In this mode, the typical speed is 94% of its maximum speed. During cruise mode, propulsion engine and auxiliary engine are operating together; (2) Reduce Speed Zone Mode (RSZ Mode), performed when the vessel operate below its cruise speed but above its maneuvering speed and in which its propulsion and auxiliary engines operate; (3) Maneuvering Mode (hour/call), performed when the vessel is to moor, usually assisted by pilot boat. All engines are still running. (4) Hoteling Mode (hour/call), performed when the vessel is tied up in the wharf, the propulsion engine is off and auxiliary engine and boiler remain running. The speed for each phase are as follows:

Table 11. Estimated Ship Movement Speed

Ship's Type	**Cruise Speed**		**Maximum Speed (km/hour)**	**Estimated Speed for Each Operation Mode (km/hour)**	
	knot	**km/hour**		**RSZ**	**Manuver**
Container	21.60	40.00	42.56	11.11	9.26
General Cargo	15.20	28.15	29.95	11.11	9.26
Tanker	14.80	27.41	29.16	11.11	9.26
Curah kering	14.50	26.85	28.57	11.11	9.26

Lain-lain	13.00	24.08	25.61	11.11	9.26

Source : USEPA, 2009
RSZ (6 knot) & Manuvering (5 knot) based on Potrt of Tanjung Priok Ship Movement and Maneuver Standard

By taking into account the distance for each mode, the required time for each mode can be seen in the following table

Table 12. Movement time per mode

Vessel Type	Distance (m) Per Operational Mode			Vessel Speed (km/hour)*			Duration Per Call (Hour)**		
	Cruise	**RSZ**	**Manuv**	**Cruise**	**RSZ**	**Manuv**	**Cruise**	**RSZ**	**Manuv**
Container	46,300.00	3,186.12	2,390.05	40.00	11.11	9.26	2.31	0.57	0.77
General Cargo	46,300.00	3,186.12	2,390.05	28.15	11.11	9.26	3.29	0.57	0.77
Tanker	46,300.00	3,186.12	2,390.05	27.41	11.11	9.26	3.38	0.57	0.77
Dry Bulk	46,300.00	3,186.12	2,390.05	26.85	11.11	9.26	3.45	0.57	0.77

Notes: Duration Per-Call = when the vessel in and out of the port
The "time" of maneuvering is added by 15 minutes for tie process

The average berthing period for OT 3 can be seen in the following table

Table 13 .Berthing period

Vessel Type	Average Berthing Time (hours)		
	Domestic	**International**	**Average**
Container	31.23	22.59	26.91
General Cargo	82.75	37.87	60.31
Tanker	65.92	0	65.92
Dry Bulk	0	90.33	90.33

Source: The berthing time was analyzed from data of Marketing Division of TO3, Jan-Mar 2014

In general, the emission inventory calculation in the initial studies shows the following results

Table 14 . Initial phase emission inventory calculation

	Emission Source	Emission(Ton)						
		NO_x	**CO**	**PM_{10}**	**$PM_{2.5}$**	**SO_2**	**BC**	**CO_2**
1	OGV	110.08	8.83	12.13	10.61	133.59	2.97	7,783.34
2	Harbor Craft	-	8.60	1.63	0.21	0.20	0.88	466.20
3	CHE	-	72.13	23.18	3.43	3.35	1.37	4,516.46
4	Head Truck	-	0.91	0.48	0.00	0.00	0.00	1,545.69
	Total (Jan - Mar 2014)	**110.08**	**90.46**	**37.42**	**14.26**	**137.15**	**5.22**	**14,311.69**
	2014 Estimation	**440.32**	**361.84**	**149.69**	**57.03**	**548.58**	**20.90**	**57,246.75**

5.2 Data Update and Hypothetical Scenario

5.2.1 Data update

The main difference between OT3 during initial research and 2015 is the startof new policy on the terminal activity. In the 2014 the OT3 still provide service for general cargo and bilk cargo for domestic route. It is planned that the OT3 will become full container terminal. The starting date of the policy still needs to be confirmed with the port operator until this paper was made therefore later in the hypothetical scenario it is assumed that during the entire 2015 the OT3 has already fully transformed into container terminal with limited international general or bulk cargo service capacity. Statistics also shows the constant reduction on the number of ships making call at Port of Tanjung Priok from 2013 until 2015. In 2013 there are 18,283 ships, the number reduced to 16,747 ships in 2014 and further reduced to 14,654 in 2015.

5.2.2 Assumptions and hypothetical scenario

The detail of the scenario used in this paper can be explained in the following table

Table 15. EI scenario comparison

Aspect	Initial EI (2014)	2015 No Changes in Operational	2015 Hypothethical Scenario
Ship Call Data	Based on January – March 2014 findings	Conversion from 2015 annual data	Conversion from 2015 annual data
Harbour Vessel	Based on January – March 2014 findings	Based on January – March 2014 findings	Based on January – March 2014 findings
CHE Data	Based on January – March 2014 findings	Based on January – March 2014 findings	Based on January – March 2014 findings
Head Truck	Based on January – March 2014 findings	Based on January – March 2014 findings	Improvements of idle time
Operational	Based on January – March 2014 findings	Based on January – March 2014 findings	Implementation of full terminal policy

In the initial phase the emission inventory results show the emission level for the period of January-March 2014 and a forecasted value for 2014. By assuming the emission level the January-March emission level represents the pollutant emission to serve the activity of 336 Ocean Going Vessel. Then the 2014 forecasted value equal to the pollutant emission to due to the activity of 1344 ships within the OT 3 Port of Tanjung Priok.

Assuming the initial phase EI forecast on the number of ship visiting OT3 is true for then the it means that OT3 accounted for 8% of total ship movements in Port of Tanjung Priok. By taking into account the number ship in 2015 then assuming the percentage of ships going into and out from OT3 remains then the number of ships serviced by OT3 in 2015 equal to 1176 ships. The detail of assumption can be explained by table below

Table 16 Ships Number at OT 3

Year	Port of Tanjung Priok (ships)	Assumed percentage	Assumed number at OT 3 (ships)
2014	16,747	8%	1,344
2015	14,654	8%	1,176

The berth time for each scenario utilize the 2014 data while the detail ship type for each scenario can be seen in the following table

Table 17. Ship call at OT3

Cathegory	2014 Projection		2015 No Changes in Operational		2015 Hypothethical Scenario	
	Domestic	International	Domestic	International	Domestic	International
Container	692	196	605	172	651	172
General Cargo	48	364	42	318	0	318
Tanker	4	0	4	0	0	0
Dry Bulk Cargo	0	40	0	35	0	35
Total	744	600	651	525	651	525

The initial EI activity points out the urgency of head truck and CHE efficiency to reduce the ships hoteling time due to loading and unloading activity. In this scenario it is assumed that in 2015 the OT 3 manage to reduce the head truck idling time down to 15 minus from the previously 20 minutes and the CHE. Ship berth time is per category is assumed .

Using the available data and assumption, the emission inventory for 2015 can then be calculated with the result as follows

Table 18. 2015 hypothetical scenario emission inventory calculation

Emission Source	Emission(Ton)						
	NO_x	CO	PM_{10}	$PM_{2.5}$	SO_2	BC	CO_2
OGV	365.47	29.38	39.89	34.92	435.18	9.78	25,365.25
Harbor Craft	-	34.40	6.51	0.84	0.81	3.51	1,864.81
CHE	-	288.50	92.73	13.74	13.39	5.50	18,065.85
Head Truck	-	3.02	1.55	0.01	0.01	0.00	4,983.24
2015 Estimation	365.47	355.29	140.69	49.50	449.39	18.79	50,279.15

As a comparison the following are the possible 2015 emission inventory result without any improvement in performance or changes in port operation. The ship's hoteling time assumed to be stable in with the initial EI activity hoteling time serve as reference value.

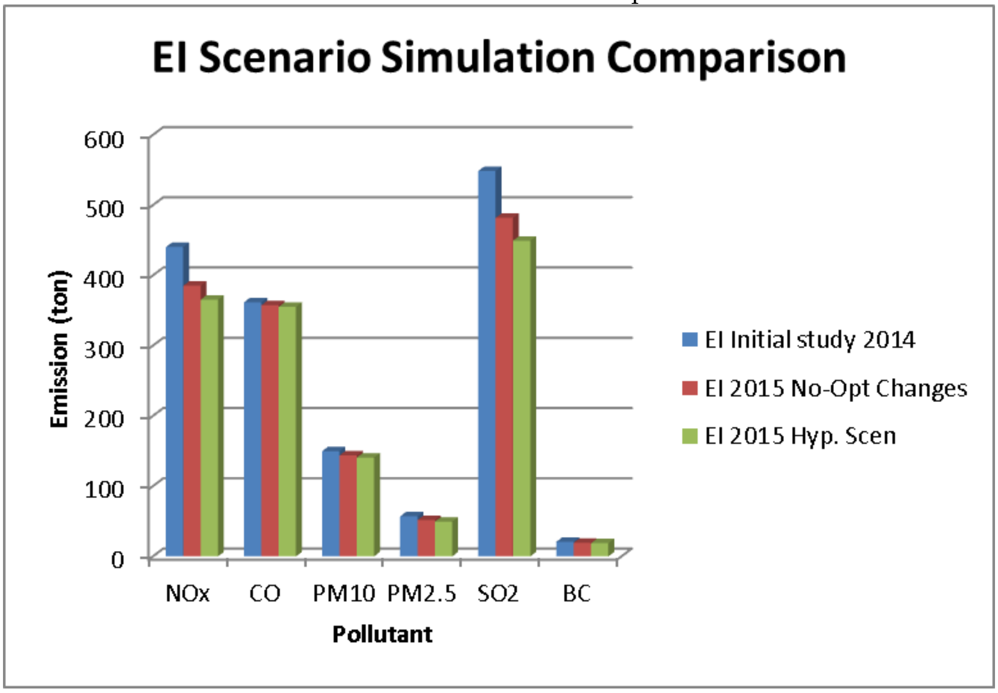
Table 19 . 2015 no changes in operational emission inventory calculation

Emission Source	Emission(Ton)						
	NO_x	CO	PM_{10}	$PM_{2.5}$	SO_2	BC	CO_2
OGV	385.29	30.90	42.47	37.14	467.58	10.40	27,242.37
Harbor Craft	-	34.40	6.51	0.84	0.81	3.51	1,864.81
CHE	-	288.50	92.73	13.74	13.39	5.50	18,065.85
Head Truck	-	3.63	1.91	0.01	0.01	0.00	6,182.75
2015 Estimation	385.29	357.43	143.63	51.72	481.80	19.41	53,355.78

6. ASSESSMENT OF EMISSION INVENTORY ACTIVITY

By comparing the data from initial EI study in 2014 with updated data simulation it is clear that emission inventory activity can be used to help regulator and port operator in designing the most applicable but effective method to apply the sustainable port concept. The graph below shows that possible emission outcome of several different operational scenario can be compared directly. The drastic reduction of SO_2 and NO_x in from 440.32 ton and 548.58 ton in 2014 down to 365.47 ton and 449.39 ton in 2015 scenario mostly attributed by the reduction of ship volume itself. One interesting point from the diagram below is that the change of OT3 into fully container terminal drastically reduce the emission of SO_2 and NO_x as compared to the 2015 No-Opt change scenario without any changes in terminal operation

Table 20 . EI calculation comparison



The emission inventory analysis also shows that the most dominant source of pollution in all three scenarios is the OGV and CHE (for CO and PM_{10}). This result correlates especially with the amount of fuel consumption required by the ship's main engine especially during port maneuver and hoteling for the ships and the fuel and engine condition for the CHE which still operate almost exclusively on diesel fuel.

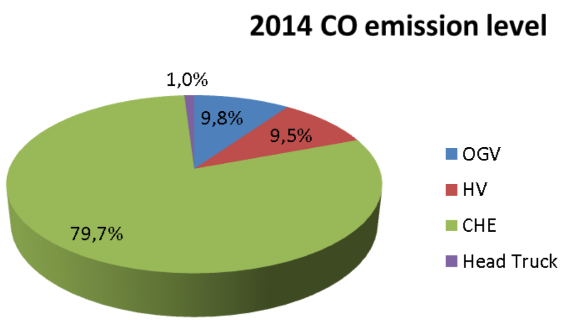


Figure 2. 2014 Simulated CO emission distribution

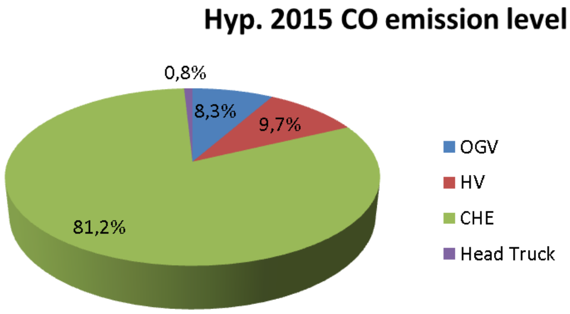
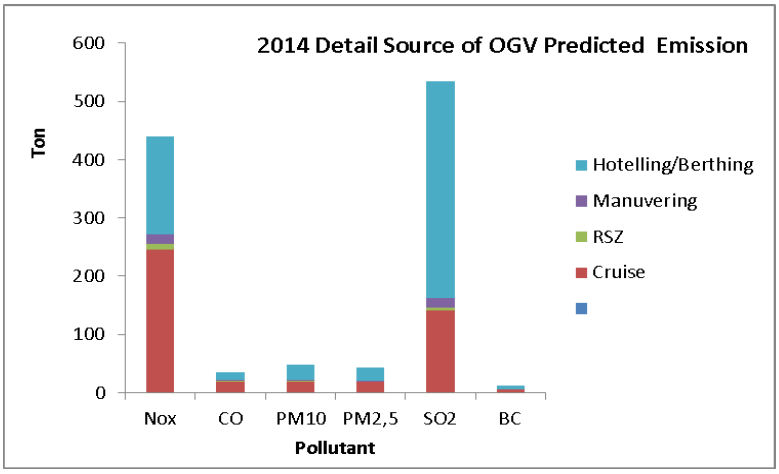


Figure 3. Hyp.2015 Simulated CO emission distribution

Table 21 2014 EI Detail OGV based emission



The simulation confirm the potential capability of emission inventory activity to provide detail emission monitoring both for past, present and future forecasted/ predicted condition. Indeed the EI has already been applied elsewhere to monitor the actual pollutant emission condition. The method heavily rely on the availability, accuracy and reliability of the data and should take into account as many actual field condition as close as possible to prevent bias of the result. The EI still need to be supported by actual field monitoring of the air pollution condition especially to provide cross checking over the actual condition of the monitored area.

The EI capability enables it to be used not only to support the implementation of sustainable sea port concept but also to be used for other economic activity especially to support the Indonesian government goal on the reduction of GHG emission by 2050. The critical key for the implementation of EI as a standard air pollution monitoring and forecasting is the acceptance of the Central Government especially the Minister of Forestry and Environmental Protection. Reliance on business sector alone will not provide sufficient push and prone to cause "patchy:" and sporadical implementation of the method.

7. CONCLUSION AND WAY FORWARD

The following are conclusions that can be taken from the study. Firstly from the EI technical aspects of the OT 3 EI activities several important points should be improved for better EI result for the OT 3 Port of Tanjung Priok in the future, which are : (1) Detail data on land side activity of the port; (2) Detail data of the historical ship movements both the OGV and HV; (3) Updated CHE availability, condition and operation; (3) Future plan of the terminal operation especially the electricity facility for the hoteling ship; (4) Detail survey for Head Truck movements and activity. Considering the EI result, theactivities canlso be expanded to include the total area of Port of Tanjung Priok (not only OT3 area).

From the simulation result points of view the EI shows that that the OGV and CHE are the two main source of emission in the OT3 area. The government and port operator should take atttention on the effect of engine and fuel quality on the CHE emission. The EI calculation shows the potential reduction the reduction on the port's air pollution level if the berthed ship dan reduce their hoteling period . Alternatively the electricity facility for berthed ship may further reduce the air pollution level due to the condition where the ship does not need to supply electricity from their own engine power.

The potential of EI capability in providing air polition monitoring is also confirmed. Even in the condition where the available data is restted the emission inventory activity can still provide insights in relatively detail monitoring on air pollution in port area by taken into account the actual activity and business process. The availability of data on all activity that may cause air polution in the monitored area remain the most important aspect for EI method.

It should also to be noted that In the longer term considering the nature of chalenges for the environmental protection program, it is important that for EI to be implemented as standard emission motoring. Government's approval of the method should be the key.

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