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Prediction of CO_2 Emitted by Marine Transport in Batam-Singapore Channel using AIS

M. Rashidi[a], Jaswar[a,b*]

[a]*Department of Aeronautic, Automotive and Ocean Engineering, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia*
[b]*Ocean and Aerospace Research Institute, Indonesia*

*Corresponding author: jaswar@fkm.utm.my and jaswar.koto@gmail.com

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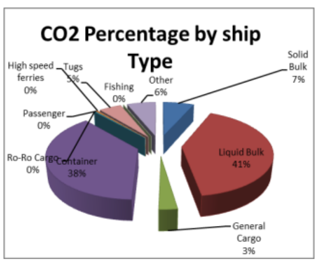
Graphical abstract



Abstract

Global warming and air pollution have become one of the important issues to the entire world community. Exhaust emissions from ships has been contributing to the health problems and environmental damage. This study focuses on the Strait of Malacca area because it is one of the world's most congested straits used for international shipping where located on the border among three countries of Indonesia, Malaysia and Singapore. This study will predict CO2 emission from the marine transport. This is accomplished by developed a ship database in the Straits of Malacca by using the data which obtained from Automatic Identification System (AIS). From the database, MEET methodology is used to estimate the CO2 emission from ships.

Keywords: AIS; CO2; carbon dioxide; emission; distribution

1.0 INTRODUCTION

The Strait of Malacca is one of the most important shipping channels in the world which is connecting the Indian Ocean with the South China Sea and the Pacific Ocean. At approximately 805 kilometers long, the Strait of Malacca is the longest Strait in the world used for international navigation (Wikipedia, 2013). The Strait of Malacca is a narrow stretch of water lying between the east coast of Sumatra Island in Indonesia and the west coast of Peninsular Malaysia, and is linked to Singapore at its southeast end. The Strait of Malacca varies in width from 200 miles to 11 miles with irregular depths from over 70 to less than 10 meters (SJICL, 1998).

The Strait of Malacca remains as one of the world most congested straits used for international shipping. From the study by Jaswar (2013), it shows that daily 1500 vessels approximately pass through the Strait of Malacca which is 42 percent was under Singaporean flag. These consist of a wide spectrum of different types of vessels with 32 percent of Liquid bulk and 11 percent of container ships.

With this number of ship, it will leave environmental impact such as Greenhouse gas emission. CO2 emissions from shipping is estimated to be 4 to 5 percent of the global total, and estimated by the International Maritime Organization (IMO) to rise by as much as 72 percent by 2020 if no action is taken (Vidal, 2007). IMO (2009) study of greenhouse gas (GHG) shows total exhaust emission from shipping from 1990 to 2007 and can see that there are increases of exhaust emission every year.

This paper discusses the prediction of CO2 emission by marine transport.

2.0 AUTOMATIC IDENTIFICATION SYSTEM (AIS)

Automatic Identification System (AIS) firstly has been used to comply with safety and security regulations, functioning as collision avoidance, vessel traffic services, maritime security, aids to navigation, search and rescue and accident investigation. The AIS is meant to be used primarily as a means of lookout and to determine the risk of collision rather than as an automatic collision avoidance system, in accordance with the International Regulations for Preventing Collisions at Sea (IMO, 1998).

Primary data of ships which obtained from an AIS receiver in the study are MMSI of the ship, IMO number, receive time, position of the ship (longitude and latitude), speed of ground (SOG) and COG. These all the data obtained from an AIS receiver installed in Marine Technology Laboratory (Marine Technology Center (MTC)), Faculty of Mechanical Engineering, UniversitiTeknologi Malaysia (UTM). Information of ships based on AIS is not complete to use as the basis for calculation. AIS only provides several initial data such as MMSI, IMO number, position of ships (longitude and latitude), Speed Over Ground (SOG), Centre of Gratify (COG) and true heading of the ship.

Gross Tonnage (GT) data for calculation of emission rate as explained by Trozzi C. (2010) is obtained from other references such as marinetraffic.com, maritime-connector.com, equasis.org, vesseltracker.com and Equasis.org. The combination of all the data will make a complete database that can be used for the calculation.

■3.0 CARBON DIOXIDE

Carbon dioxide (CO2) is a colorless, odorless, non-flammable gas that is a product of cellular respiration and burning of fossil fuels. It has a molecular weight of 44.01g/Mol (NIOSH, 1976). Although it is typically present as a gas, carbon dioxide also can be a solid form as dry ice and liquefied, depending on temperature and pressure (Nelson, 2000). Carbon dioxide is not only a gas which affects the heat flow to and from the atmosphere of the earth, but is also a serious pollutant in its own right (Robertson, 2006). The concentration of this gas in the atmosphere is not known to have risen above 320 ppm over the last 40,000 years (Neftal *et al.,* 1982).

Evidence demonstrates this to be the case for the past 420,000 years (Petit *et al.,* 1999). Several researches suggest that carbon dioxides also give effect to the Physiological. Although the safe working level of carbon dioxide is presently set at 5000 ppm for an 8 h day 40 h working week, no human ever endures such a level of carbon dioxide in the atmosphere for 24 h a day, 365 days a year, for an entire lifetime nor has any human ever bred offspring under these conditions. This includes workers in breweries and the greenhouse industry, where the concentration of carbon dioxide in the atmosphere either commonly reaches or is set at a maximum of 900 ppm (Robertson, 2006).

Methodologies for estimating air pollutant emissions from ships, in port environment and in navigation have been developed for one of the framework of the MEET project (Methodologies for estimating air pollutant emissions from transport). The methodology has been developed under the transport RTD program of the European Commission fourth framework program (EEA). MEET Methodology was adopted by Trozzi *et al.* (1998), Trozzi *et al.* (1999) and Pitana *et al.* (2010) for estimating emissions from ships.

Methodologies for estimating air pollutant emissions from ships used to estimate of consumption and emissions based on present day statistics of ship traffic (Trozzi *et al.,* 1998). The methodology is used by consider twelve ship class of ship with a gross tonnage above 100 GT. The data need such as emission factors, fuel consumption of ship, type of engine, etc. Fuel consumption of any type of ships are obtained from a linear regression analysis of fuel consumption to gross tonnage as shown in the Table 1.

Table 2 shown the emission factor in each phases and Table 3 shown the fraction of maximum fuel consumption in different mode of the ship. It will be used to calculate the emission rate of each vessel.

Table 1 Average consumption at full power versus gross tonnage

Ship types	Consumption at full power (t/day) as function of gross tonnage
Solid Bulk (SB)	Cjk = 20.1860 + 0.00049 × GT
Liquid Bulk /Tanker (LB)	Cjk = 14.6850 + 0.00079 × GT
General Cargo (GC)	Cjk = 9.8197 + 0.00143 × GT
Container (CO)	Cjk = 8.0552 + 0.00235 × GT
Ro-Ro Cargo (PC)	Cjk = 12.8340 + 0.00156 × GT
Passenger (PA)	Cjk = 16.9040 + 0.00198 × GT
High Speed Ferry (HS)	Cjk = 39.4830 + 0.00972 × GT
Inland Cargo (IC)	Cjk = 9.8197 + 0.00143 × GT
Sail Ship (SS)	Cjk = 0.4268 + 0.00100 × GT
Tugs (TU)	Cjk = 5.6511 + 0.01048 × GT
Fishing (FI)	Cjk = 1.9387 + 0.00448 × GT
Other Ships (OT)	Cjk = 9.7126 + 0.00091 × GT

Table 2 Emission factors (kg/ton of fuel)

Phases	Engine types	CO2
Cruising	Steam turbines - BFO	3200
	Steam turbines - MDO	3200
	High speed diesel engines	3200
	Medium speed diesel engines	3200
	Slow speed diesel engines	3200
	Gas turbines	3200
	Pleasure – Inboard diesel	3200
	Pleasure – Inboard gasoline	3000
	Outboard gasoline engines	3000
Manoeuvring	Steam turbines – BFO	3200
	Steam turbines – MDO	3200
	High speed diesel engines	3200
	Medium speed diesel engines	3200
	Slow speed diesel engines	3200
	Gas turbines	3200
	Pleasure – Inboard diesel	3200
	Pleasure – Inboard gasoline	3000
	Outboard gasoline engines	3000
Hotelling	Steam turbines – BFO	3200
	Steam turbines – MDO	3200
	High speed diesel engines	3200
	Medium speed diesel engine	3200
	Slow speed diesel engines	3200
	Gas turbines	3200
	Pleasure – Inboard diesel	neg.
	Pleasure – Inboard gasoline	neg.
	Outboard gasoline engines	neg.
Tanker load. /off-load.		3200

Table 3 Fraction of maximum fuel consumption in different mode

Mode	Fraction
Cruising	0.8
Manoeuvring	0.4
Hotelling default	0.2
passenger	0.32
liquid bulk	0.2
other	0.12
Tug: ship assistance	0.2
moderate activity	0.5
under tow	0.8

To calculate the emission rate of each vessel based on the assumption of the above tables (Table 1 to 6), Trozzi *et al.* (1998) using the following equation:

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

With

$$E_{ijklm} = S_{jkm}(GT) \times t_{jklm} \times F_{ijlm} \quad (2)$$

where,
i pollutant
j fuel (see Table 4)
k ship class for use in consumption classification (see Table 5)
l engines type class for use in emission factors characterization
s reference reduction scenario (low, medium, high)
E_i total emissions of pollutant *i*
E_{ijklm} total emissions of pollutant *i* from use of fuel *j* on ship class *k*with engines type *l* in mode operation *m*
$S_{jkm}(GT)$daily consumption of fuel *j* in ship class k as a function of gross tonnage
tjklm days in navigation of ships of class *k* with engines type *l* using fuel *j* in mode operational *m*
Fijlm average emission factors of pollutant *i* from fuel *j* in engines type *l* in mode *m*

Table 4 Fuels classification

Codes	Name
RO	Residual oils
DO	Distillate oil
DF	Diesel fuel
GF	Gasoline fuel

Table 5 Engine types classification

Code	Name
SE	Steam turbines
HS	High speed motor engines
MS	Medium speed motor engines
SS	Slow speed motor engines
IP	Inboard engines - pleasure craft(only for detailed methodology)
OP	Outboard engines(only for detailed methodology)
TO	Tanker loading and off-loading(only for detailed methodology)

Table 6 Ship types classification

Code	Name
SB	Solid Bulk
LB	Liquid Bulk
GC	General Cargo
CO	Container
PC	Ro-Ro Cargo
PA	Passenger
HS	High speed ferries
IC	Inland Cargo
SS	Sail ships
TU	Tugs
FI	Fishing
OT	Other

Calculation of emission and the concentration are performed by using programming. The high number of calculation and output of the calculation becomes an issue when it calculated by manually. The programming which used for this step is Microsoft Visual Studio 2010 as seen in Figure 1 to 3.

4.0 CASE STUDY

Calculation of emission is estimated for every ship which is recorded by AIS on September 2, 2011 at 7.00am - 8.00am. There were 813 total number of ships are counted. Calculations of emission based on the standard European (MEET) methodology which adopted by Trozzi et.al (1998). The result is presented in percentage as shown in Table 7, 8 & 9 and Figure 4, 5, & 6. The calculations by considering several factors are:

i. Gross Tonnage (GT)
ii. Type of ship
iii. Mode operation of ship
iv. Fuel type
v. Main engine and auxiliary engine power

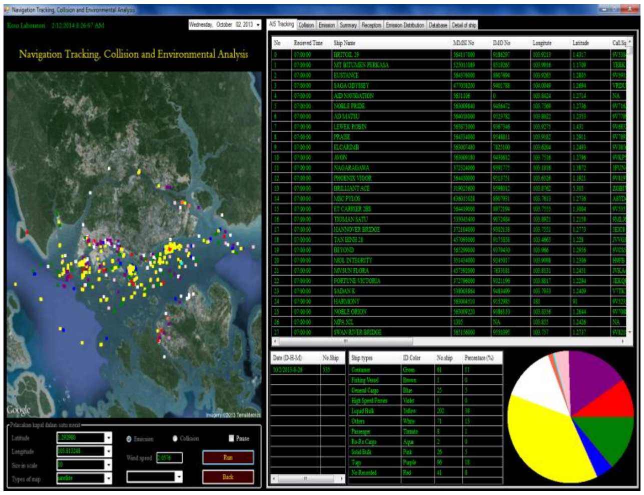


Figure 1 Marine navigation tracking system

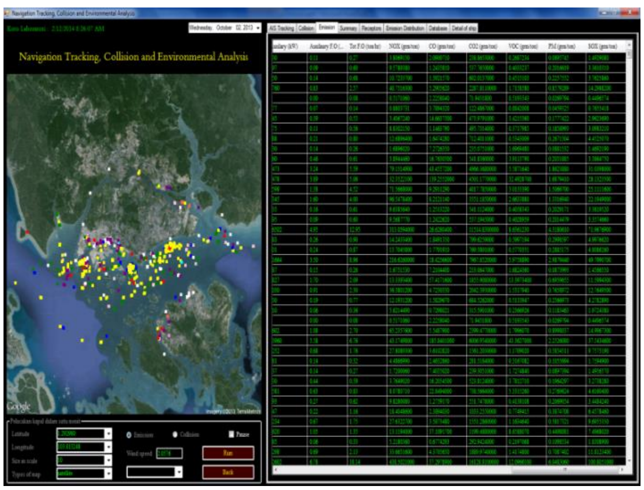


Figure 2 Environmental impact caused by marine navigation in Batam-Singapore channel

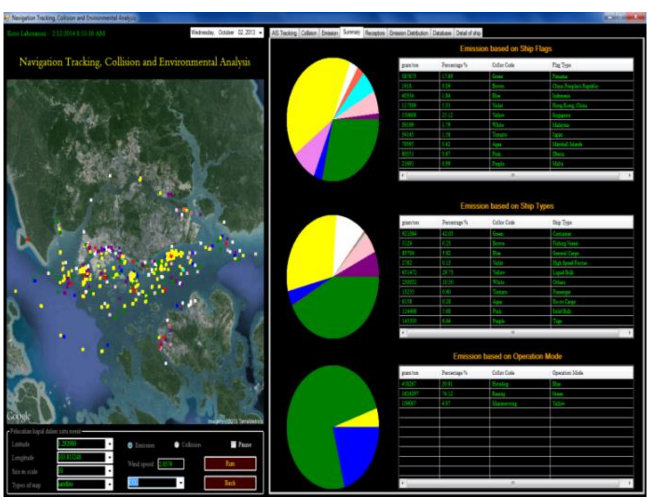


Figure 3 CO2 Emission caused by marine navigation in Batam-Singapore Channel

Table 7 CO2 emission by type of ship in Batam-Singapore channel

Code	Type	Number of Ship	CO2 g/ton of fuel per-second	CO2 Percentage by ship Type
SB	Solid Bulk	49	729.930	6.580%
LB	Liquid Bulk	372	4549.125	41.009%
GC	General Cargo	51	305.843	2.757%
CO	Container	124	4220.972	38.051%
PC	Ro-Ro Cargo	3	28.233	0.255%
PA	Passenger	12	45.098	0.407%
HS	Highspeed ferries	1	3.257	0.029%
TU	Tugs	138	524.526	4.728%
FI	Fishing	1	8.548	0.077%
OT	Other	62	677.468	6.107%
Unknown		360	Unknown	Unknown
Total Number of Ship		1173	11092.999	100.000%
Total correspondent ship		813		

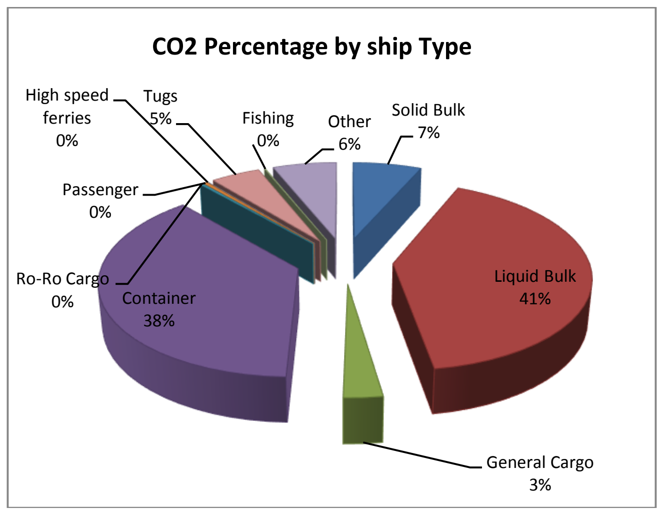


Figure 4 Percentage of CO2 emission by types of ship

Table 8 CO2 emission by flag caused by marine navigation in Batam-Singapore channel

Flag	Number of Ship	CO2 g/ton of fuel) per-second	CO2 % by Flag
Singapore	344	2513.719	22.66%
Malaysia	28	183.373	1.65%
China People's Republic	8	151.466	1.37%
Cyprus	11	206.808	1.86%
Bahamas	14	384.639	3.47%
Hong Kong, China	21	523.411	4.72%
Indonesia	28	163.281	1.47%
Liberia	54	1440.845	12.99%
Marshall Islands	29	566.050	5.10%
Panama	110	2346.478	21.15%
Vietnam	11	96.492	0.87%
Malta	13	189.227	1.71%
Others Flag	142	2327.211	20.98%
Total Ship	813	11092.999	100.00%

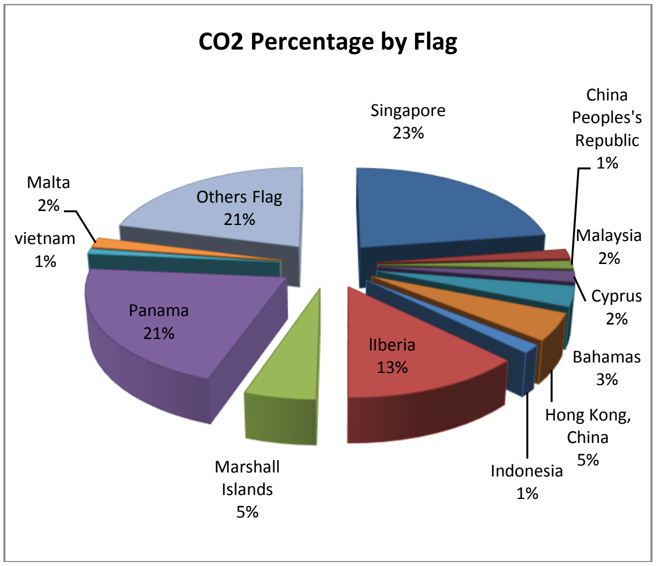


Figure 5 Percentage of CO2 emission by flag in Batam-Singapore channel

Table 9 CO2 emission by mode operational in Batam-Singapore channel

Mode Operational	Ship Number	CO2 g/ton of fuel) per second	CO2 % by Mode Operational
Manoeuvring	96	1366.06	12.33%
Cruising	71	2015.78	18.20%
Hotteling	644	7692.95	69.46%
Unknown	2	0	0.00%
Total Ship	813	11074.8	100.00%

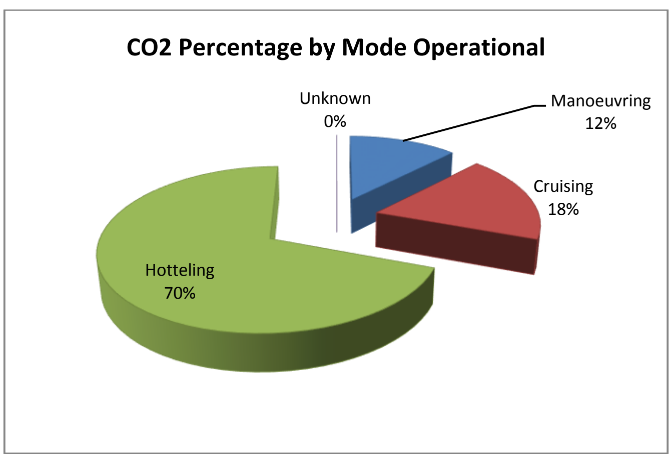


Figure 6 Percentage of CO2 emission by mode operational in Batam-Singapore channel

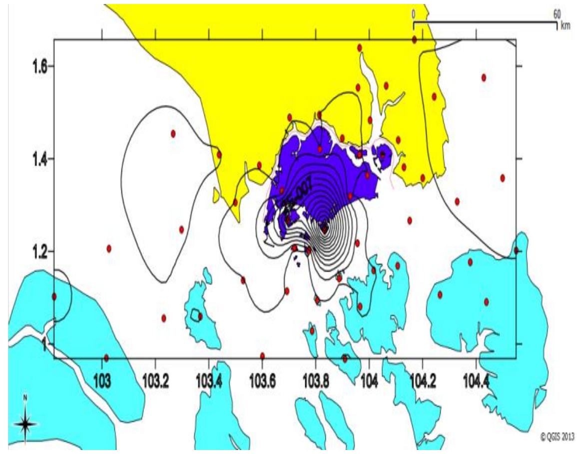


Figure 7 Distribution of AIS Receptor and CO2 emission caused marine navigation

4.0 CONCLUSION

Based on the result shown in Table 8 and Figure 5, ships under the Singapore flag is the high number of ships in the Strait of Malacca on September 2nd 2011 at 7.00 am-08.00 am. There 344 numbers of Singapore's ships and produces the highest emission of CO2 by amount of 2513.718 g/second. Other than ships under Singapore flag, ships under Panama and Liberia flag are the followed ships that most produces the emission. Ships under Malaysia and Indonesia rank of sixth and seventh which produces the emission at the time. In addition, container ship is the highest which produces emission followed by liquid bulk ship (tanker), solid bulk (bulk carrier) and Tugboat. Figure 7 show the distribution of AIS receptor and CO2 emission in the study area.

Acknowledgement

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