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Original Article

Carbon reduction analysis of Malaysian green port operation

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Abstract

With the recently adopted carbon policy in Malaysia to reduce carbon emissions by 45% on the year 2030, this paper analyses the carbon reduction efforts from the port sector. Driven by strong trade growth that fuels the transhipment volume, significant emission is produced from major ports. Therefore, the aim of this paper is to forecast the emissions produced by ports accounting for continuous growth. Then, the projected emission will be compared and analysed to the levels of reduction committed by Malaysia national policy. After analysing the time-series Twenty-Foot Equivalent unit (TEU) trend, Autoregressive Integrated Moving Average (ARIMA) forecasting technique was used to forecast the carbon emissions performance by initiatives of light emitting diode (LED) conversion, adoption of Electric Rubber Tyred Gantry Crane (E-RTG), and Electric Prime Mover (E-PM). The results indicated overall carbon emission growth at an average of 5.73% per year. No reduction in both direct (2.80% per year) and indirect carbon emission (5.91% per year), which leaves the targets of Malaysian Carbon policy unmet. A more robust blueprint of carbon emissions reduction map is recommended with the main component of electrifying the prime mover fleet.

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1 Introduction

Although a lot of country nowadays are producing far less emissions per tonne transported for aviation and road freight, the shipping industry or port still creates around a billion tonnes of carbon emissions per year. With this in mind, carbon emissions from port or shipping industry are projected to rise more than 2% in 2018, according to the Global Carbon Project research which was launched at the UN climate summit in Katowice, Poland, where almost 200 nations have pledged to turn the 2015 vision of tackling climate change in Paris into action [1]. The report was stated the 2% rise of carbon emissions is taking global fossil carbon dioxide emissions to a new record high of 37.1 billion tonnes. This rise in carbon emission certainly includes Malaysia also.

"The global rise in carbon emissions is worrying, because to deal with climate change, they have to turn around and go to zero eventually". Kyoto Protocol was the first international agreement that would stabilise greenhouse gas concentrations in the climate to prevent the damages to the environment. Since the original Kyoto Protocol reduced, the involved countries between 1990 and 2012 saw a decrease of CO2 emissions only by 12.5% [2].

A research paper by [3] summarised the major carbon emission contributors in the Port of Shen Zhen in the year 2017. They suggested the major emission contributors can be categorised into 4 categorises in Table 1.

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Table 1 Main emission contributors in Port of Shen Zhen [3].

Source	Element
Transportation	Moving in terminal's railway
	Loading and unloading efficiency
Heavy Equipment	Use of Rubber Tyred Gantry Crane (RTG)
	Use of Forklift
	Use of Top handler and side handler
	others
Material Consumption	Paper, Plastics, and Wood materials
Energy Consumption	Cold Chain Storage
	Information system operation

The carbon emissions control is proven a possible action that should be taking by all the country. For shipping sector, apart from International Maritime Organisation (IMO) regulating shipping emission at sea, ISO 14001 certification developed by Bureau Veritas (BV) aims to assist managers with appropriate tools and environmental management system (EMS) to improve port safety and environmental protection [4]. Certificates are issued for a 5-year period, while it is internally audited, it is also externally audited by BV on an annual basis. However, the main emphasis and driving force of the code ensures a continual improvement by setting measurable targets and goals.

In this paper, a complete forecasting data is needed from collecting all the time series data from the ministry of transport Malaysia data. Then the national green port practices will be cross-checked against the forecasted carbon emission using Statistical Package for the Social Sciences (SPSS) software to determine the level of carbon reduction contribution by Malaysia's port sector.

2 Methodology

Based on the global green port practices, the green technology extends to Onshore Power Supply (OPS), waste reception infrastructure, and switching cargo handling and transport vehicles into biofuels or electricity powered vehicles [5]. However, green port practices which is already implemented in Malaysian ports also will only be limited to the replacement to Light Emitting Diode (LED), utilization of Electric Rubber Tyred Gantry Crane (E-RTG). Though, Electric Prime Mover (E-PM) is available commercially, Malaysian ports have yet to adopt the technology.

Next, the forecasting technique known as Average Autoregressive Integrated Moving (ARIMA) will be applied leveraging on the accuracy and reliability of the univariate forecasting technique. Forecasting software is related with a lot of different areas such as health sciences, finance, economic, engineering and meteorology [6]. In any case, the improvement of exact gauging frameworks that can generate robust estimation given a similarly steady historical data. Nevertheless, forecast still requires yet an extensive test [7–9]. The ARIMA, Autoregressive (AR) and Moving Average (MA) models have been utilized in a few applications and can be planned by a Box and Jenkins procedure [6]. These measurable techniques are straightforward, adaptable and they can be adjusted to display a few fleeting wonders [6,7,10,11]. Then, AR, MA and ARIMA are direct models and, accordingly, have a constrained exhibition time arrangement displaying, which normally present straight and nonlinear worldly examples [12–15].

Based on the statistics of port TEU throughput data collected from Malaysian Ministry of Transport (MOT retrieved from 2008 data), calculation of the emission performance will first be generated. Then, the existing emission information will project to 2030 emission levels given no change in current green port governance.

3 Results and Discussion

This section will be presenting the result of the carbon emissions from the ports lighting system, RTG and Prime Mover PM in the port. The overall calculation equation for all three section will be shown with the calculated result. Subsequently, the forecasted result will also be presented as well. For analysis of data, comparisons will be made between original technology and green technology while accounting for land and equipment yearly increment. For the forecasted results, SPSS software will be used to forecast future emission by using the ARIMA technique.

3.1 Malaysian Port's Lighting System

Lighting system is very common equipment used in ports which operates 24 hours a day and seven days a week. Conventionally, port will be using high intensity light (HID) which will produce high amount of carbon emissions. Green practice will dictate that these be replaced by LED. LED has better performance compare to HID as shown in Table 2 [16].

Table 2 Specification of HID and LED

Element	HID	LED
Luminous efficacy	29 (lm/W)	120 (lm/W)
Power rating	30 (W)	10 (W)

Based on the LED specification, the carbon emissions of LED per year can be calculated by area of the port and the operating time that required light as in Eq. (1). The daily operating hours of lighting system is 14 hours.

$$\frac{A}{\frac{\eta}{f_c}\times 1000}\times 14\text{ hours}\times 365\text{ days}\times 1\ \frac{\text{pound of carbon}}{\text{kWh}}\times 0.4535\ \frac{\text{kg}}{\text{pound}} \tag{1}$$

where A is the area of Port in sqft, η is the luminous efficacy in lm/W, f_c is foot-candles in lm/sqft.

3.2 Port Equipment (Rubber Tyred Gantry Crane)

To move the containers around the port area from dock to stack or vice-versa, RTG is the frequent machinery for transverse layout port, as with most Asian ports. However, RTG in the market mostly uses fossil fuel or diesel engine to operate. Based on the combustion of fossil fuel of diesel engine, the amount of the carbon emissions is significant. For an example, in EU and Iceland country the carbon emissions amount is increased from 2010 to 2018 with the amount of at least 0.4g CO_2/km to 2.0g CO_2/km in 2018 [17].

Therefore, an electrification technology has replaced or retrofitted old RTG system which are still using diesel engine into either a hybrid or full electronic rubber tyred gantry crane (E-RTG). E-RTGs are by equipped with a battery pack, running cable or busbar systems to complete stack changes and power auxiliary operate the RTG without using any diesel or fossil fuel. Hence, carbon emissions will be reduced a lot, whilst shifting the carbon emission to its indirect source. Table 3 shows the characteristic of ERTG and RTG [18,19].

Table 3 Specification of RTG and E-RTG.

Element	RTG	ERTG
Hoisting Speed	26-52 m/min	26-52 m/min
Trolley Travel Speed	70 m/min	70 m/min
Gantry Travel Speed	70-130m/min	70-130m/min
Operating Speed	28-56m/min	28-56m/min
Power Consumption	15-26 litre(diesel)/hour	426-709kW per day
Safe Working Load	41 Tons	41 Tons

Using the specification above the carbon emission of RTG and ERTG can be compute. Port Klang and Port of Tanjung Pelepas are using full ERTG while Johor Port, Penang Port and Kuantan Port are still using traditional RTG. Eq. (2) and Eq. (3) is used for computing the total carbon emission for RTG and ERTG respectively.

$$\frac{\text{TEU}}{N_{\text{RTG}}} \times t_{\text{RTG}} \times P_{\text{RTG}} \times 2.64 \ \frac{\text{kg of carbon}}{\text{litre of diesel}} \tag{2}$$

$$\frac{\text{TEU}}{N_{\text{ERTG}}} \times t_{\text{ERTG}} \times P_{\text{ERTG}} \times 0.4535 \ \frac{\text{kg of carbon}}{\text{kWh}} \tag{3}$$

where TEU is average number of TEU per year at each port, N is number of RTG or ERTG, t is the time taken for one complete operation cycle in hour, P is the average power of RTG in litre per hour or ERTG in kW.

3.3 Malaysian Port's Equipment (Prime Mover)

By moving the containers around the port area before RTG can stack them, Prime Mover (PM) as known as truck are the frequent equipment. Cutting-edge machinery such as AGV or electric prime movers are available. However, prime mover in the market today are still operates on fossil fuel or diesel engine. Though new technology is available to replace the old prime mover, electric prime mover still lacks the infrastructure necessary and perhaps the appropriate policy from the local port authority. EPM is a full electrified machine, a luxury that may need further commercialisation before a more comprehensive deployment world port wide.

Table 4 shows the characteristics of normal diesel prime mover [20] and E-prime mover which is fully electric [21].

Table 4 Specification of Prime Mover and Electric Prime Mover.

Element	PM	EPM
Fuel Tank/Battery Capacity	420 litres	144 kWh
Motor Power	254	152kW
Travel Speed	60-110 km/h	50-90 km/h
Average Power Consumption	28 litre/hour	130 kW

Using the specification in Table 4, carbon emission of can be calculated using Eq. (4). All the port in Malaysia is still using traditional PM. Thus, the calculation is only computed for PM for all the ports.

$$\frac{\text{TEU}}{N_{\text{PM}}} \times t_{\text{PM}} \times P_{\text{PM}} \times 2.64 \ \frac{\text{kg of carbon}}{\text{litre of diesel}} \tag{4}$$

where TEU is average number of TEU per year at each port, N is number of PM, t is the time taken for one complete operation cycle, P is the average power of PM.

3.4 Forecasted Result for carbon Emission

The data of TEU of the year 2008 to 2019 were retrieved from the ministry of transport official website [20]. The calculation of historical result from the year 2008 to 2019 for each aspect in each port is summarised into Table 5. The total amount of carbon emission of all ports combined for each year is also included in Table 5 as well. Table 6 further categories the carbon emission type into indirect emission and direct emission. Indirect carbon emission refers to equipment that are mainly using electrical source for their power. On the other hand, direct carbon emission represents equipment that are using fuel and directly generate carbon emission on the use. In this case, indirect emission is coming from LED and ERTG while direct emission is coming from RTG, and PM.

From the year 2008 to 2019, the total carbon emission increased by 70.3% (6.39% annually). While total carbon emission from 2019 to 2030 increase by 63% (5.73% annually), according to forecasted value. On the other hand, indirect carbon emission increased by 51% (4.64% annually) from the year 2008 to 2019 and will increase by 30.8% (2.8% annually) from the year 2019 to 2030. Direct carbon emission for year 2008 to 2019 increased by 71% (6.45% annually) and will increase by 65% (5.91%) from the year 2019 to 2030.

From Fig. 1, the total carbon emission in the ports of Malaysia will reach 63000 metric tons by the year 2030. Most of the carbon emission are contributed by indirect sources which are from electricity. On the other hand, small amount of carbon emission contributed by direct carbon emission which are machine that are using fuel as power.

As majority of the carbon emission are generated from indirect sources. Malaysia needs to accelerate the development of clean and renewable energy into the electricity supply sectors. This does not only benefit the ports but also reduces carbon generation throughout the country.

Despite green technologies was utilised in the port, the forecast does not seem to reduce at any time in the future. This is due to the number of TEU will increases every year. Thus, the ports are responsible to apply machine that utilise fully on electricity into their working environment. To consume green electricity instead of fuel.

Table 5 Carbon emission amount of each aspect in each port by year.

Year	Johor Port			Port of Tanjumg Pelepas			Penang Port			Port Klang			Kuantan Port			Total Carbon Emission
	LED	RTG	PM	LED	ERTG	PM	LED	RTG	PM	LED	ERTG	PM	LED	RTG	PM	
2008	1559	136	25	11227	17	151	1247	82	47	6407	28	264	1583	69	29	22871
2009	1637	126	23	11789	18	161	1310	85	49	6727	25	242	1662	72	30	23956
2010	1719	131	24	12378	20	174	1375	95	55	7064	31	293	1745	78	32	25214
2011	1805	124	23	12997	23	201	1444	107	62	7417	33	312	1832	73	30	26483
2012	1895	120	22	13647	23	207	1516	104	60	7788	34	328	1924	74	31	27773
2013	1990	113	21	14329	23	205	1592	110	64	8177	36	342	2020	69	29	29120
2014	2090	119	22	15046	26	227	1672	112	65	8586	38	362	2121	72	30	30588
2015	2194	120	22	15798	28	243	1755	117	68	9015	41	393	2227	77	32	32130
2016	2304	124	23	16588	25	221	1843	128	74	9466	46	437	2338	77	32	33726
2017	2419	135	25	17417	26	228	1935	131	76	9939	41	396	2455	80	34	35337
2018	2540	141	26	18288	28	247	2032	134	78	10436	43	407	2578	82	34	37094
2019	2667	156	29	19203	28	250	2134	133	77	10958	47	449	2707	84	35	38957

Note: Unit for all LED, RTG, PM, ERTG, and Total Carbon Emission is 10^3 kg

Table 6 Carbon emission by indirect emission and direct emission.

Year	Total Carbon Emission (10^3 kg)	Indirect Carbon Emission (10^3 kg)	Direct Carbon Emission (10^3 kg)
2008	22871	22068	803
2009	23956	23168	788
2010	25214	24332	882
2011	26483	25551	932
2012	27773	26827	946
2013	29120	28167	953
2014	30588	29579	1009
2015	32130	31058	1072
2016	33726	32610	1116
2017	35337	34232	1105
2018	37094	35945	1149
2019	38957	37744	1213

From the historical value from 2008 to 2019, observations are that the total emission is increasing. The forecasted results are segmented by the total emission, indirect and direct carbon emission in Fig. 1. Forecasting method ARIMA model by is used to forecast the result in Fig. 1 by using the statistical software known as SPSS.

3.5 Malaysia Policy to the Green Development

Johor Port Authority (JPA) had developed a Green Port Policy framework which was planned for the period from 2014 to 2020. Act as a reference guideline in developing green initiatives for JPA, port operators and stakeholder. Green Port Policy stated series of principles, strategies and practices in port development and operation that suit the goals of environmentally friendly and commercially viable. Another green policy also done by Ministry of Transport (MoT) where they plan reduce carbon emissions by up to 45% by the year 2030 which utilise green technology across the sectors including land, aviation and maritime.

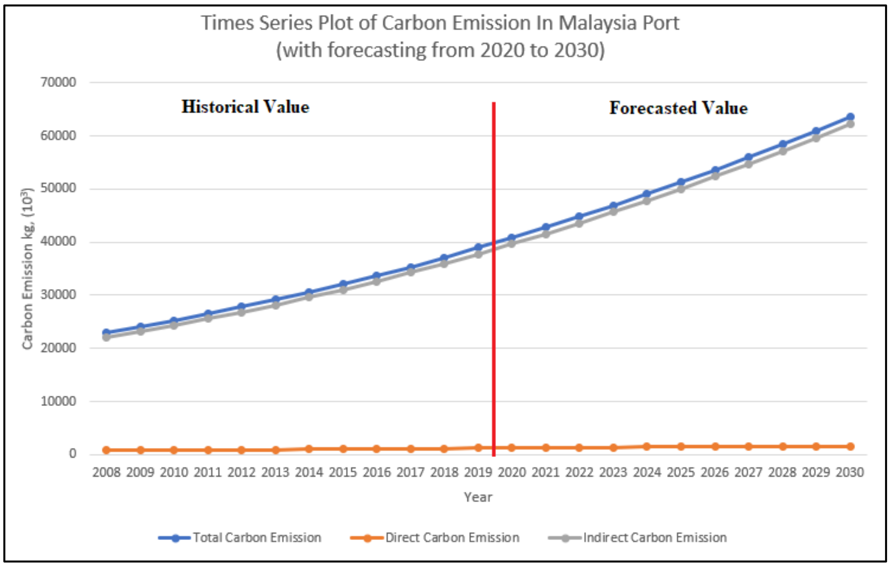

Fig. 1 Forecasting of carbon emission from year 2020 to 2030 for total, indirect, direct carbon emission.

4 Conclusion

In conclusion, electrical sources contributed to the majority of the carbon emission in the port. Most of them are coming from the lighting system. The aim of the green policy by MoT is to reduce carbon emission up to 45% in 2030. However, according to forecasted value, the rate of increase of carbon emission only drops from 70.3% to 63% by the year 2030 if no further action taken by respective parties. In fact, electrical or fuel consumption cannot be eliminated or reduced in the future due to the increase of TEU every year.

Nevertheless, in order to bring down the curve of direct carbon emission, respective port authority must fully utilise on green technology to convert Malaysia port to fully utilise electricity as the main power source. Novel adoption of green technologies in Malaysia are not limited to electric powered tugboat, marine shore power, efficient container park area usage and any energy-saving devices. On the other hand, Malaysia should start harvesting renewable and green energy sector especially on solar energy in supplement to power generation. In the near future where, electrified equipment becomes normative practice in the deployment of container handling fleet, ports will achieve zero-carbon status. The remaining crucial source of emission will be from the ships docking at ports, which will see more ground-breaking technology to replace fuel oil.

Declaration of Conflict of Interest

The authors declared that there is no conflict of interest with any other party on the publication of the current work.

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