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Cost Effective Assessment of Marine Emissions Control Measures for Crude Oil Tanker Shipping in Nigeria Port

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ABSTRACT

The cost effective of marine emission control measures for crude oil tanker vessel shipping in Nigeria was evaluated in this research work. The sources of emissions in crude oil tanker shipping and the associated control measures in Nigeria Ports was investigated, the energy efficiency data for the tanker vessels to determine the extent to which the fuel-saving benefits of energy efficiency are reflected in market prices was analyzed and a cost-effective and energy efficient method for crude oil tanker shipping in Nigeria Ports was established. The Energy Efficiency Operational Indicator (EEOI) and the Ship Energy Efficiency Management Plan (SEEMP) tools were employed to analyze the cost benefit of the voyages between the ships MT Theresa and MT Balasa for promoting their operational measures for fuel-saving and energy efficient shipping. Broad based results revealed that the energy efficiency operation index for MT Theresa is at 14.32×10^{-4} g/ton mile which is more than that of MT Balasa whose EEOI is 1.79×10^{-5} g/ton mile. Also, the amount of money spent on fuel by MT Theresa in 2007 is 2, 450, 000, 00 naira which is less than the amount of money spent on fuel by MT Balasa in the same year which is at 3,500,000.00 naira. This is similar for voyages in the other years under the study period. Conclusions and recommendations were made to improve upon marine emission control measures for crude oil tanker vessel shipping in Nigeria as non-compliant EEOI ship is likely to be less efficient than the EEOI-compliant ship which will translate to additional fuel cost of the vessel over its entire operation lifecycle.

Keyword: Cost effective, Assessment, Emissions, energy, Sources

INTRODUCTION

There are increasing economic and environmental incentives for ship owners and operators to develop tools to optimize operational decisions such as ship exhaust emissions which constitute of around 2% of global CO_2 emissions (Smith et al., 2014) and the energy efficiency of the ship, particularly with the aim of reducing fuel consumption, maintenance triggers and evaluating technological interventions (Cames et al., 2015). Several solutions exist for shipping to mitigate its emissions and transition towards low carbon shipping: improving energy efficiency through cost-effective operational measures and practices as well as using energy efficient technologies (normally resulting in a reduction in fuel consumption); Using renewable energy sources e.g. wind propulsion; Using fuels with lower carbon content such as bio fuels and also using emission reduction technologies such as scrubbers and carbon capture and storage (CCS). Cost-effective operational measures and practices use energy efficient technologies which normally results in a reduction in fuel consumption. Discussions related to reducing greenhouse gas from marine emissions are being held by the Marine Environmental Protection Committee (MEPC) at the International Maritime Organisation (IMO). Methods for reducing greenhouse gas emissions discussed at the MEPC until now and instruments for promoting these methods are discussed in this study. Carbon dioxide (CO_2) accounts for a major part of the greenhouse gases emitted from ships. For this reason, CO_2 has become a target for reduction in the international shipping area. The emission of CO_2 from ships is proportional to the quantity of fuel actually burned on the ship and depends on the type of fuel used. Therefore in order to reduce CO_2 either the amount of the fuel used has to be reduced or the energy efficiency of the ship (fuel consumption per activity) has to be improved. Since the amount of activity is closely linked to the economic growth of the whole world, including that of developing countries such as Nigeria, discussions are being held at the International Maritime Organisation (IMO) with the focus on enhancing the energy efficiency of ships considering a proper balance between the reduction in $_{CO2}$ emissions and economic development.

This dissertation explains the influence that these marine emissions have on the fuel consumption rate of crude oil tanker vessels as well as the vessels operational pressures (e.g. cost of fuelling vessels and freight rates/prices) and consequently on the vessel‘s operational efficiency. A simplified energy efficiency formula designed for a specific purpose need not be the only metric of efficiency in the shipping industry. Notwithstanding the additional technical challenges that arise when considering the existing fleet, the high-stakes policy discussions should not interfere with initiatives to increase economic efficiency through greater awareness of the parameters affecting the energy efficiency (and therefore fuel consumption, fuel costs and carbon emissions) of shipping.

Statement of the Problem

As long as characterizing energy efficiency is classified as ―too difficult, a number of failings can occur. For example, customers of shipping have an information deficit when identifying which ship to use and how it should be operated. In other cases, owners of ships have no reference data with which to benchmark and compare their fleet. As a result, the industry lacks a detailed understanding of the consequence of energy efficiency interventions on its emissions (e.g. slow steaming). And more broadly, bottom-up estimates of shipping emissions (e.g., those used by the International Maritime Organisation (IMO) and other groups) can potentially lack credibility or sources of validation.

Ports impose several different restrictions on a tanker. Restrictions can originate from several operational and regulatory necessities but can for planning purposes be translated to maximum crude oil weight and volume on board a vessel when it enters or leaves a port. The variable cost of transportation depends on two main components: vessel fuel oil costs and port fees. We do not consider any fixed costs, like manning expenses or charter costs, because we assume a fixed fleet for the transportation task. All fixed costs for the fleet are constant for the planning period and are not subject to optimization. The largest part of a tanker's variable cost on a route is determined by its fuel oil consumption. A tanker burns different fuel amounts per day while sailing, port operations or when waiting. It uses most fuel oil when sailing and least when waiting. The other cost component, port fees, has to be paid whenever a tanker enters a port. While port fees and sailing costs are determined by the actual routing choice, port operation costs and waiting costs are time dependent. The more a tanker loads or discharges in a port, the more costly are the operation. In the same way longer waiting times result in higher cost. This research work utilizes the energy efficiency data to better understand the extent to which the fuel-saving benefits of energy efficiency are reflected in market prices. This can help in the study of whether a split-incentive or other market barriers and failures might be limiting access to what some analysts perceive to be cost-effective energy efficiency interventions.

Aim and Objectives of Study

The aim of this research is to evaluate the cost effective of marine emission control measures for crude oil tanker vessel shipping in Nigeria. The objectives of this research will include:

i. To investigate the sources of emissions in crude oil tanker shipping and the associated control measures in Nigeria Ports.
ii. To analyze the energy efficiency data for the tanker vessels to determine the extent to which the fuel-saving benefits of energy efficiency are reflected in market prices.
iii. To establish a cost-effective and energy efficient method for crude oil tanker shipping in Nigeria Ports.

Research Approach

The data used as inputs to the method come from a variety of sources. Data characterizing ship‘s technical specifications are from Clarksons World Fleet Register. The dataset includes all ships active in 2010 (e.g. including ships built in previous years). The data characterizing ship‘s operational characteristics (speed, loading condition and voyage characteristics) are obtained from individual ship‘s log. The ship log dataset is for the period 1st January 2007 to 31st December 2010 only. Where necessary (e.g. missing data), the technical and operational data is supplemented or compared with data and assumptions from the IMO 2nd GHG study, or in some instances other third party sources (e.g. describing the world fleet in 2007). Market data describing prices in different shipping markets are obtained from Clarksons Shipping Intelligence Network (2007-2010).

Shipping Emissions and Associated Impacts

In the current era of globalization the shipping industry has a key component of the world’s economy. Over 90% of the global trade is carried by sea. The world fleet of sea-going merchant ships of more than 100 gigatonnes (GT) comprises over 104,000 ships. Like other transportation companies, shipping companies require fossil fuel to conduct their operations. The combustion of fossil fuel used by a vessel’s engines produce gas (GHG) as well as non GHG emissions.

GHG Emissions

Under the GHG protocol, six gases are categorized as greenhouse gases: carbon dioxide (C02), Methane (CH4), nitrous oxide (N20), hydro-fluorocarbon (HFCs), per-fluoroctane sulphonate (PFCs) and sulphur hexafluoride (SFs).

Carbone-dioxide (Co2):

CO_2 is the GHG most relevant to the shipping industry. Globally, 1,050 million tonnes of CO_2 were emitted by shipping in 2007, doubling 1990 levels. CO_2 emissions represent approximately 3% of the world total Co2emissions.

Other greenhouse gases:

The shipping industry also emits other GHG such as CH4, N20 and HFCs. Annual aggregated emissions of these GHGs represent 21 million tonnes of Co_2, equivalent. Emission of PFCS and SFs are considered negligible.

Non-GHG Emission

In addition to GHGs, shipping produces other air emissions, most notably sulphur oxides ($S0_x$), nitrogen oxide (NO_2) and particulate matter (PM).

Sulphur Oxides ($S0_2$):

The shipping industry’s among the emitters of $S0_2$. A total of 2.3 million tonne of $S0_2$ (the most common sulphur oxide) was emitted by ships in the seas surrounding Europe in the year 2000 (Rosenthal, 2001). Globally, 15 million tonnes of So_x were emitted by shipping in 2007, representing a 50% increase from 1997 levels (Bode 2002). $S0_2$ emissions from shipping represent between 5% and 8% of the world’s total $S0_2$ emissions.

Nitrogen Oxides (NO_2)

Shipping also accounts for a significant portion of the world’s No_2 emissions. A total of 3.3 million tonnes of No_2 was emitted by ships in the sea surrounding Europe is the year 2000. Globally 25 million tones No_2 were emitted by shipping in 2007, representing a 39% increase from 1997 levels. No_2 emissions from shipping represent around 15% of the world’s total No_2 emissions.

Particulate Matter (PM):

In 2000, 250,000tonnes of PM was emitted by ships in Europe Globally, 1.8 million tonnes of PM are released in 2007, representing a 50% increase from 1997 levels. The amount of PM released by ships is much lower than that of So_x or No_2 emissions.

Note that PM and So_2 emissions are correlated, a decrease in Sox emissions reduces emissions of PM (GHP website, 2013).

Shipping emissions are expected to double by 2050, as are the related social and environmental effects. In order to mitigate environmental and social risks associated with these emissions, regulators around the world have started to act. Generally speaking, when it comes to reducing emissions and supporting incentives /taxes, emissions reporting/ monitoring obligations and energy efficiency/emissions standards. As the most prominent regulators in the shipping industry are the international maritime organization (IMO) and the Europe Union (EU), we will also look at the regulations set by these two bodies. Finally, we will examine the voluntary initiatives that have emerged in some countries (GHP Website, 2013).

Knowledge Gap

The finding referred to above, that there is significant heterogeneity in operational efficiency in a given fleet in a given year, points in turn to the need to understand the drivers of operational efficiency. This study investigates measures that can improve operational efficiency (e.g. Virtual Arrival, slow steaming, voyage optimization, Ship Energy Efficiency Management Plans), some of which may have created change in behaviour. Recent history is therefore a rich, complex, but relatively untapped source deserving further work to extract information that could provide significant insights both for the commercial strategy of shipping‘s stakeholders and also the policy makers attempting to design regulation that will achieve GHG emission reductions in the most cost-effective manner.

In addition to the need for further cross-sectional analysis, this analysis can help to explain the influence that commercial pressures (e.g. fuel prices and freight rates/prices) have on fleet‘s operational efficiency. Relative to the IMO 2nd GHG Study (2007 data), a significant change in many of the parameters (speed, fuel consumption) and ultimately operational efficiency is observed in this study (2011 data). Whilst a difference in fuel price has occurred in that time frame, the larger difference between 2007 and 2010 is in the freight rates/prices, with the shipping industry seeing a widespread reduction in revenues. This study demonstrates there is a large potential for data to be useful for understanding ship operational behaviour and efficiency. However, shortcomings include uncertainty on some of the data (particularly user-entered data such as ship draught), and difficulty with coverage (both sporadic coverage in the open ocean and poor coverage in coastal areas with high density of shipping). Whilst further work can be carried out on the theoretical naval architecture and marine engineering models that deploy the data to calculate fuel consumption, the most important next step is a detailed and transparent validation of such models against actual fuel consumption data from ship operators.

MATERIALS AND METHODS

Analytical Model

In this study we assess the extent to which prices (i.e. time charter rates, newbuild and second-hand prices) take into account the energy efficiency of the ships transacted in each market through both a mean comparison and by performing regression analysis. In the case of the demolition market we implement the first methodology only. Data have been taken from transaction specific information found in the Clarksons World Fleet Register and Clarksons Shipping Intelligence Network. As data availability varies depending on the size of the ship, the shipping markets and the variables of interest, each of the sections presenting our results on a particular variable of interest also discuss any specifics of data availability.

General Procedure

When comparing average prices paid for ships of different energy efficiency, in order to ensure comparability across different transactions, we split the sample into a maximum of four periods, depending on data availability, i.e. the first comprising all observations from 2007 and 2008, the second observations from 2009 and 2010. The sample in each time period used in the analysis is then further split on the basis of the fuel efficiency of the ships (high and low) and, when applicable, on the basis of their age (old and new) by identifying the median of the two variables. For each period, we identify the observations belonging to the four groups originated from the partition above (namely: i) old highly efficient ships; ii) old less efficient ships; iii) new highly efficient ships; and iv) new less efficient ships), and we compute the average value of the variable of interest for these groupings. Averages are then compared across values of energy efficiency, e.g. the average for old ships with low energy efficiency is compared to the average paid for old ships with higher energy efficiency. By doing so we take into account the effect of the ship age on the value of the variable of interest. Comparison of average is obtained through the well-known Welch test which allows for the two groups for which the average is computed to have a different number observations and different values of variance3. The hypothesis that we test is: The variance is estimated separately for both groups and degrees of freedom are modified accordingly.

$$H_0 : X_{h,t,a} \rangle X_{t,t,a}$$

Where *X* may indicate the time charterers paid in the fixture, the new build price or the second hand price paid for the ship. The indicators ‗h‘ and ‗l‘ indicate the group of ships with high and low efficiency, respectively, ‗t‘ the period in which the two groups of observations fall and ‗a‘ the age of ship. The comparison above would imply, for example, to compute the average time charters paid in 2007-08 for new ships with high efficiency TCh, 2007-08, new and compare it to the average time charter paid in the same time period for new ships with low efficiency, i.e. TCl, 2007-8, new.

Principle of Marine Emissions Control (Measures) For Low Carbon Shipping

Technical measures, operational measures and economic instruments are being studied as methods for reducing CO_2 emissions according to recent discussions at the IMO. The technical and operational measures mentioned here are direct measures for improving the ship's hardware (equipment) while the latter are implemented by improvements or innovations in the operation of the ship. In contrast economic instrument are not meant to reduce CO_2 emission directly, they may be considered as instruments that offer economic incentives to promote implementation of the technical measures or the operational measures mentioned above. Therefore, for the purpose of this research work, the methods used in marine emission control are the technical and operational measures.

Technical Measures of Controlling Marine Emissions

Technical measures aim to enhance the energy efficiency by hardware (equipment) improvements of the ship as mentioned earlier. Some specific examples of the technical measures are given below

- modified hull form (reduction in propulsion resistance)
- modified propeller (enhanced propulsion efficiency)
- energy saving appendages on hull
- increase in dead weight capacity by increasing the hull size
- use of energy from exhaust heat recovery
- use of renewable energy (wind power or solar power)

Operational Measures

Operational measures aim to enhance the energy efficiency through improvements or innovation in the operation of the ship, as mentioned earlier. The operational measures are applicable to individual ships. There are various kinds of operational measures including those that go beyond the scope of efforts of individual ship management companies and necessitate coordination with relevant personnel. Specific examples of the operational measures are given below

- optimization of operational plan of individual ships and fleets
- operation at reduced speed
- weather routing
- just-in-time entry into port
- hull maintenance (for instance, reduction in propulsion resistance by cleaning the hull)
- machinery maintenance

RESULTS

Calculation of Energy Efficiency Operational Indicator (EEOI) Based on Operational Data

CF is a non-dimensional conversion factor between fuel consumption measured in g and CO2 emission also measured in g based on carbon content. The value of *CF* is as follows:

Table 1. Reference value of CF for different fuel type

TYPE OF FUEL	Reference	Carbon Content	*CF* (t-CO2/t-Fuel
1. Diesel/Gas	Oil ISO 8217 Grades DMX through DMC	0.875	3.206000
2. Light Fuel Oil (LFO)	ISO 8217 Grades RMA through RMD	0.86	3.151040
3. Heavy Fuel Oil (HFO)	ISO 8217 Grades RME through RMK	0.85	3.114400
4. Liquified Petroleum Gas (LPG)	Propane	0.819	3.000000
	Butane	0.827	3.030000
5. Liquified Natural Gas (LNG)		0.75	2.750000

Rolling Average

Rolling average, when used, can be calculated in a suitable time period, for example one year closest to the end of a voyage for that period, or number of voyages, for example six or ten voyages, which are agreed as statistically relevant to the initial averaging period. The Rolling Average EEOI is then calculated for this period or number of voyages by Equation 2 above.

Analysis of Data

For a voyage or period, for a day, data on fuel consumption/cargo carried and distance sailed in a continuous sailing pattern could be collected as shown in the reporting sheet in Table .2 below.

A one ballast voyage for MT Theresa is provided below from 2007 to 2010. The application of the formula based on the data reporting sheet.

Table .2: Ship Voyage Report Sheet

NAME AND TYPE OF SHIP- MT Theresa					
Voyage or Year	**Fuel consumption (FC) at Sea and in Port in tonnes**			**Voyage or Time Period Data**	
(i)	Fuel type (HFO)	Fuel type (LFO)	Fuel type	Cargo (m) (tonnes or units)	Distance (D) (NM)
2015	20	5		25,000	300
2016	20	5		0	300
2017	50	10		25000	750
2018	10	3		15000	150

Source: Azubuike, 2018

EEOI in: tonnes CO2/(tons • nautical miles) becomes

$$EEOI = \frac{100x3{,}114\ +23x3.151}{(25000x300)+(0x300)+(25000x750)+(15000x150)}$$

$$EEOI = \frac{311400\ +72.473}{(25000x300)+(0x300)+(25000x750)+(15000x150)}$$

$$EEOI = \frac{311400 + 72.473}{(750000) + (0) + (18750000) + (2250000)}$$

$$EEOI = \frac{311472.473}{21750000}$$

$$EEOI = 14.32 x 10^{-4} \text{ g/ton mile}$$

The Energy Efficiency Operational Indicator based on data from the operation of the ship is determined to be at 13.74^{-6} g/ton mile

For a voyage using diesel and LPG Fuels in a CODAG Engine, we have ship voyage report sheet for MT Balasa as shown in Table .3 below:

Table 3. Ship voyage report sheet

NAME AND TYPE OF SHIP- MT Balasa					
Voyage or Year	**Fuel consumption (FC) at Sea and in Port in tonnes**			**Voyage or Time Period Data**	
(i)	Fuel type (MDO)	Fuel type (LPG)	Fuel type	Cargo (m) (tonnes or units)	Distance (D) (NM)
2015	20	5		25,000	300
2016	20	5		0	300
2017	50	10		25000	750
2018	10	3		15000	150

EEOI in: tonnes CO2/(tons • nautical miles) becomes

$$EEOI = \frac{100 x 3.206000 + 23 x 3.000000}{(25000 x 300) + (0 x 300) + (25000 x 750) + (15000 x 150)}$$

$$EEOI = \frac{320.6 + 69}{(25000 x 300) + (0 x 300) + (25000 x 750) + (15000 x 150)}$$

$$EEOI = \frac{389.6}{(750000) + (0) + (18750000) + (2250000)}$$

$$EEOI = \frac{389.6}{21750000}$$

$$EEOI = 1.79 x 10^{-5} \text{ g/ton mile}$$

From the results gotten for amount of emission from the different marine fuel types using the Energy Efficiency Operational Indicator method based on data from the operation of the ship shows that more emission was produced in the voyage which HFO and LFO Marine fuel was used as compared to Marine diesel oil and LPG fuels.

Cost Benefit Analysis

To analyze the energy efficiency data for the tanker vessels so as to determine the extent to which the fuel-saving benefits of energy efficiency are reflected in market prices, we will determine the cost of the fuel consumed during different voyages. The fuel prices used by Eide and others (2011) were US$ 350/tonne for heavy fuel oil and US$ 500/tonne for marine distillate. With higher prices (the price today for marine distillates is over US$ 600/tonne), it is obviously possible to reduce CO_2 emissions even further while simultaneously reducing costs. Marginal Abatement Cost Curves are very sensitive to assumptions such as discount rates, investment costs, vessel service life and annual transport work (Kesicki and Ekins, 2012).

Table 4.4 Cost benefit Analysis for MT Theresa

NAME AND TYPE OF SHIP- MT Theresa						
Voyage or year	**Fuel consumption (FC) at Sea and in Port in tonnes**				**Voyage or Time Period Data**	
(i)	Fuel type (HFO)	Fuel type (LFO)	Cost of HFO in market price @ US$ 350/tonne (Dollars)	Cost of HFO in market price @ 350Naira/$(Naira)	Cargo (m) (tonnes or units)	Distance (D) (NM)
2015	20	5	7, 000.00	2,450,000,00	25,000	300
2016	20	5	7, 000	2,450,000,00	0	300
2017	50	10	17, 500	6,125,000.00	25000	750
2018	10	3	3, 500	1,225,000.00	15000	150

Table 5Fuel Cost Analysis for MT Theresa

Voyages at year	**Cost of HFO in market price @ 350Naira/$ (₦)**
2015	2,450,000,00
2016	2,450,000,00
2017	6,125,000.00
2018	1,225,000.00

Source: Azubuike, 2018

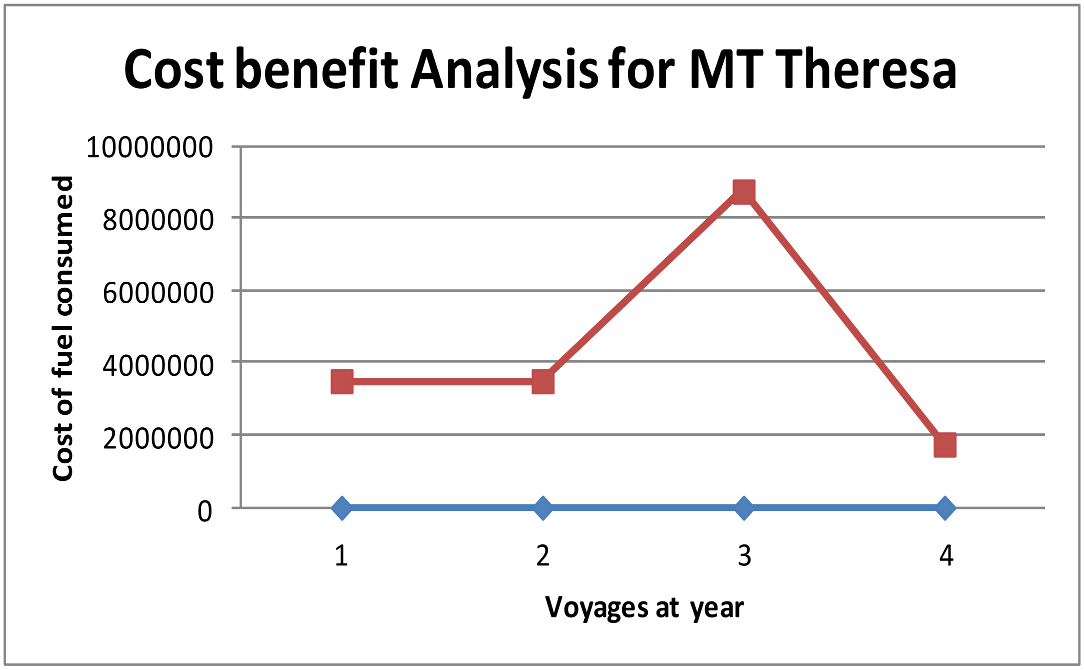

Fig 1. Cost benefit Analysis for MT Theresa

Table 6. Cost benefit Analysis for MT Balasa

NAME TYPE OF SHIP- MT Balasa						
Voyage at Year	**Fuel Consumption (FC) at Sea and in Port in tonnes**				**Voyage or Time Period Data**	
(i)	Fuel type (MDO)	Fuel type (LPG)	Cost of MDO in market price @ US$ 500/tonne (Dollars)	Cost of MDO in market price @ 350Naira/$ (Naira)	Cargo (m) (tonnes or units)	Distance (D) (NM)
2015	20	5	10,000.00	3,500,000.00	25,000	300
2016	20	5	10,000.00	3,500,000.00	0	300
2017	50	10	25,000.00	8,750,000.00	25000	750
2018	10	3	5,000.00	1,750,000.00	15000	150

Source: Azubuike, 2018

Table 7 Fuel Cost Analysis for MT Balasa

Voyages at Year	Cost of MDO in Market Price @ 350Naira/$ (₦)
2015	3,500,000.00
2016	3,500,000.00
2017	8,750,000.00
2018	1,750,000.00

Source: Azubuike, 2018

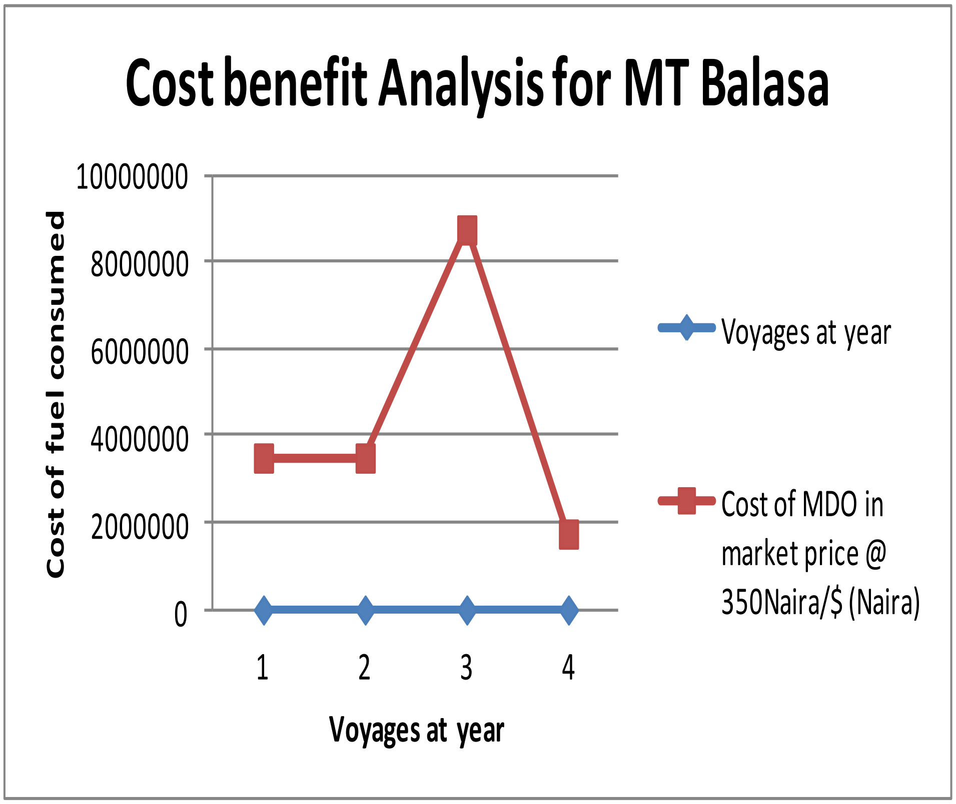

Fig. 2: Cost Benefit Analysis of MT Balsasa

DISCUSSION

From the EEOI analysis and cost benefit analysis of the voyages between the ships MT Theresa and MT Balasa, it is discovered that the energy efficiency operation index for MT Theresa is at 14.32 x 10^{-4} g/ton mile which is more than that of MT Balasa whose EEOI is 1.79 x 10^{-5} g/ton mile. Also, the amount of money spent on fuel by MT Theresa in 2007 is 2,450,000,00 naira which is less than the amount of money spent on fuel by MT Balasa in the same year which is at 3,500,000.00 naira. This is similar for voyages in the other years in the study period.

Establishing an Energy Efficiency Operational Indicator (EEOI)

The EEOI should be a representative value of the energy efficiency of the ship operation over a consistent period which represents the overall trading pattern of the vessel. In order to establish the EEOI, the following main steps will generally be needed:

- define the period for which the EEOI is calculated
- define data sources for data collection;
- collect data;
- convert data to appropriate format; and
- calculate EEOI.

Ballast voyages, as well as voyages which are not used for transport of cargo, such as voyage for docking service, should also be included. Voyages for the purpose of securing the safety of a ship or saving life at sea should be excluded.

General Data Recording and Documentation Procedures

Ideally, the data recording method used should be uniform so that information can be easily collated and analysed to facilitate the extraction of the required information. The collection of data from ships should include the distance travelled, the quantity and type of fuel used, and all fuel information that may affect the amount of carbon dioxide emitted. For example, fuel information is provided on the bunker delivery notes that are required under regulation 18 of MARPOL Annex VI. If the formula given in previous chapter is used, then the unit used for distance travelled and quantity of fuel should be expressed in nautical miles and metric tonnes. It is important that sufficient information is collected on the ship with regard to fuel type and quantity, distance travelled and cargo type so that a realistic assessment can be generated.

The distance travelled should be calculated by actual distance travelled, as contained in the ship's log-book. Amount and type of fuel used (bunker delivery notes) and distance travelled (according to the ship's log-book) could be documented by the ship based on an equivalent company procedure.

Monitoring and Verification

Documented procedures to monitor and measure, on a regular basis, should be developed and maintained. Elements to be considered when establishing procedures for monitoring could include:

- Identification of operations/activities with impact on the performance;
- Identification of data sources and measurements that are necessary, and specification of the format;
- Identification of frequency and personnel performing measurements; and
- Maintenance of quality control procedures for verification procedures.

The results of this type of self-assessment could be reviewed and used as indicators of the system's success and reliability, as well as identifying those areas in need of corrective action or improvement. It is important that the source of figures established are properly recorded, the basis on which figures have been calculated and any decisions on difficult or grey areas of data. This will provide assistance on areas for improvement and be helpful for any later analysis.

In order to avoid unnecessary administrative burdens on ships' staff, it is recommended that monitoring of an EEOI should be carried out by shore staff, utilizing data obtained from existing required records such as the official and engineering log-books and oil record books, etc. The necessary data could be obtained during internal audits under the ISM Code, routine visits by superintendents, etc.

Rolling average indicator

As a ship energy efficiency management tool, the rolling average indicator, when used, should be calculated by use of a methodology whereby the minimum period of time or a number of voyages that is statistically relevant is used as appropriate. "Statistically relevant" means that the period set as standard for each individual ship should remain constant and be wide enough so the accumulated data mass reflects a reasonable mean value for operation of the ship in question over the selected period.

CONCLUSION

Ship energy efficiency plays a significant role in field of creating the green shipping now-a-days, especially the world is facing the great problems about the climate changes from enhancement of economics and industrials in parallel with the population explosion. This research was geared to evaluate the cost effective of marine emission control measures for crude oil tanker vessel shipping in Nigeria. Objectively, to achieve this aim, the sources of emissions in crude oil tanker shipping and the associated control measures in Nigeria Ports was investigated and the energy efficiency data for the tanker vessels to determine the extent to which the fuel-saving benefits of energy efficiency are reflected in market prices was analyzed. Ultimately, a cost-effective energy efficiency method for crude oil tanker shipping in Nigeria Ports was generated.

RECOMMENDATIONS

Centered on the results and outcome of the entire study, the following recommendations are made to boost efficient marine emission control measures for crude oil tanker vessel shipping in Nigeria.

1. Technologies which are available to significantly improve energy efficiency in the short, medium and long-term including: Ship capacity enhancement, Hull optimisation for less resistance and improved sea margins, Advanced underwater hull coatings and monitoring, Reduced air drag

through improved aerodynamics of hull and superstructure, More hydro-dynamically efficient aft-ship, propeller and rudder arrangements, use of Alternative fuels and sources of energy should be employed by shipping companies.

2. A non-compliant EEOI ship is likely to be less efficient than the EEOI-compliant ship. This will translate to additional fuel cost of the vessel over its entire operation lifecycle. Therefore shipping companies should employ the EEOI in their operation.
3. A ship without an EEOI is likely to have lower second have value as this will imply that it is not an energy efficient ship and a non-EEOI ship may loose on future EEOI-based incentives and where EEOI is used for chartering, port discounts, flag registration discounts, etc. Incentives could be driven by ports, Flag States, charterers and Port States, thus shipping companies should ensure that their fleet come with an EEOI system.

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