The use of ECDIS equipment to achieve an optimum value for energy efficiency operation index

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Abstract. To reduce air pollution produced by ships, the International Maritime Organization has developed a set of technical, operational and management measures. The subject of our research addresses the operational measures for minimizing CO₂ air emissions and the way how the emission value could be influenced by external factors regardless of ship-owners’ will. This study aims to analyse the air emissions for a loaded voyage leg performed by an oil tanker. The formula that allows us to calculate the predicted Energy Efficiency Operational Index involves the estimation of distance and fuel consumption, while the quantity of cargo is known. The electronic chart display and information system, ECDIS Simulation Software, will be used for adjusting the passage plan in real time, given the predicted severe environmental conditions. The distance will be determined using ECDIS, while the prediction of the fuel consumption will consider the sea trial and the vessel experience records. That way it will be possible to compare the estimated EEOI value in the case of great circle navigation in adverse weather condition with the estimated EEOI value for weather navigation.

1. Introduction
The studies related to the marine pollution show that it takes years from the proposal till the moment of ratification [1], even if the problem is recognized worldwide and thoroughly investigated [2]. After several years of debate, the concept of Energy Efficiency Operational Index (EEOI) was introduced, representing the amount of emissions related to vessel's performance [3, 4]. Considering the main purpose of the vessel, to carry goods for different distances, this recommended instrument for determination of air emissions is more a qualitative than a quantitative measure.

The main parameters that influence the value of EEOI being the quantity of cargo, fuel consumption and distance, the paper emphasizes the importance of using electronic navigational charts and Electronic Chart Display and Information System - ECDIS Simulator functions to choose the optimum route from the environmental point of view.

2. Concept of EEOI
In order to assess the level of CO₂ emissions resulted from marine traffic, the International Maritime Organization created and recommend the use of EEOI indicator, as resulted from Guidelines for voluntary use of the ship energy efficiency operational indicator - MEPC.1/Circ.684 (2009) [5, 6]. The main factors that affect its value are the voyage distance, comprising of various voyage legs, in
nautical miles, the quantity of cargo in tonnes and the amount of marine fuel consumed for
transporting the above-mentioned cargo, in tonnes. The EEOI formula expresses the CO2 emitted per
unit of transport work (equation (1)):

\[
\text{EEOI} = \frac{\text{MCO}_2}{\text{Transport _ Work}}
\]

(1)

where

- the quantity of CO2 emitted is calculated based on fuel type and quantity, consumed per
  voyage, as recorded in Engine Log Book,
- the transport work represents the quantity of cargo in tonnes multiplied by total distance of the
  voyage in nautical miles.

For a single complete voyage where the vessel carries a certain quantity of cargo, the ship-owner uses
the formula equation (2), considering different types of fuel (j), as required by navigation area and
types of consumers: main engine, boilers.

\[
\text{EEOI} = \sum_j \frac{\text{FC}_j \times C_F}{m_{c, o} \times D_i}
\]

(2)

To calculate the Energy Efficiency Operational Index for multiple voyages (i – the number of voyage),
the International Maritime Organization recommends the use of Average EEOI, formula Eq. 3, by
introducing the sum of cargo as per Bill of Lading, carried for each voyage recorded in Bridge Log
Book.

\[
\text{AverageEEOI} = \frac{\sum_i \sum_j \left( \text{FC}_j \times C_F \right)}{\sum_i m_{c, o} \times D_i}
\]

(3)

where:

- FC – fuel consumption [tonnes],
- m – quantity of cargo [tonnes],
- D – distance [nautical miles]
- C_F – conversion factor corresponding to fuel type as per IMO [6].

A smaller value of EEOI as calculated by the use of equation (2) or equation (3) represents a more
energy efficient ship.

A typical voyage comprises of a succession of voyage legs, performed by the vessel from the end
of the previous voyage, when the vessel departed the discharge port facility, to the next end of voyage.
Such voyage legs include primarily the ballast voyage from the previous discharge port to the loading
port and the loaded voyage from the loading port to the next discharge port. Each of these include
periods of port stays, anchor and manoeuver, which do not incur distance sailed, but add to the total
fuel consumption. The paper aims to emphasize the influence of the distance sailed comparatively for
a voyage performed on the shortest distance in adverse weather, compared to a longer distance
adjusted to align to the weather navigation principles.

The first distance was calculated using the initial passage plan of the voyage, created before
starting the voyage and the second passage plan was adapted as the marine environmental conditions
required. For the second passage plan, the speed was determined considering the initial ETA of the
vessel – estimated time of arrival. The type of marine fuel has not been changed during the voyage and
the same applies to the quantity of cargo carried out.

2.1. Description of the Voyage

The analysed scenario represents the legs of the voyage performed by the ships model of
an Oil tanker 82078 TDW (figure 1), equipped with Diesel Engine 1x9847kW, having the
following characteristics Length 228.0 [m], Breadth 32.2 [m], between:
- loading port, Angra Dos Reis, Brazil, and
- port of discharge, Cape Town, South Africa

![Figure 1. Oil Tanker characteristics.](image)

2.2. Method

ECDIS represents an excellent software developed for the safety of navigation. During ECDIS training period, the students are required to create routes, conduct and monitor navigation using different ships’ models. One function of the ECDIS Simulator allows the instructor to track record the own ship’s manoeuvre and the ships’ evolution relative to different marine environmental conditions (figure 2), by selecting the parameters from a drop down menu. For this study, the analysed parameters were (figure 3): current direction, current speed, wind direction, wind speed, wave amplitude and sway.

The initial passage plan has been created using ECDIS Simulator. Using the same software, it was possible to create the marine environment condition depending on instructor’s option: Weather type Force 5, Wind speed 19 knots, Wind direction 080°, Wave height 2.5 m, Visibility 10 nautical miles, Current direction 220°, Current speed 7 knots.

![Figure 2. Environmental conditions.](image)
3. Comparative analysis

Considering the fuel consumption for the two situations, using the direct and the alternative route it is emphasized the variation of the EEOI, taking into account the environmental conditions. The Oil tanker carried 75,000mt of cargo during the considered voyage leg. The initial distance calculated for normal environmental conditions was 3,327.6 nautical miles representing the first scenario, red line on the figure 4. Due to severe environmental conditions predicted, the vessel considered a second scenario as an alternative route of 3,389.6 nautical miles, represented with the blue line (figure 4).

The first situation considered a speed of 12.5knots to meet the estimated time of arrival (ETA), with an average consumption of 40mt/day, while the second situation met the same ETA requirement on a longer distance, with a different average speed of 12.73knots and a fuel consumption of 37.7mt/day. Both consumptions were considered according to the vessel’s fuel consumption experience records and the ship trials for the particular speed and weather conditions.

Figure 3. Ships parameters relative to different marine environmental conditions.

Figure 4. Ship’s voyage, 1st scenario (red), 2nd scenario (blue).
A commercial software calculates both the EEOI and the average EEOI based on the following entries: type of fuel, distances and the quantity of fuel. The free software calculator developed by Totem Plus Company is used for both scenarios: 1\textsuperscript{st} scenario (figure 5) and 2\textsuperscript{nd} scenario (figure 6).

For different types of fuel, there are different carbon content and, consequently, different correction factor \[1\]:

![Figure 5](image1.png)

**Figure 5.** The interface of the EEOI Software calculator, 1\textsuperscript{st} scenario (Source: TotemPlus, 2013).

![Figure 6](image2.png)

**Figure 6.** The interface of the EEOI Software calculator, 2\textsuperscript{nd} scenario (Source: TotemPlus, 2013).
Table 1. The Carbon content per fuel type.

| Type of fuel          | Reference               | Carbon Content | $C_F$ (t-CO$_2$/t-Fuel) |
|-----------------------|-------------------------|----------------|--------------------------|
| Diesel / Gas Oil      | ISO8217Grades DMX through DMC | 0.875          | 3.206000                 |
| Light Fuel Oil (LFO)  | ISO8217Grades RMA through RMD | 0.86           | 3.151040                 |
| Heavy Fuel Oil (HFO)  | ISO8217Grades RME through RMK | 0.85           | 3.114400                 |

4. Conclusions

The results of this study reveal the importance of using ECDIS software functions for achieving relevant values for Energy efficiency operational index and CO$_2$ emissions and they represent a measure of changing EEOI related to meteorological condition. Comparing the values obtained for EEOI by applying the free commercial software for the voyage, having the same departure and arrival ports but using two different routes, can be noticed a difference of the EEOI values per voyage, of about 7.3%. This difference between the two values of the EEOI resulted from choosing an alternative route due to severe environmental conditions. The variation of distances was 62 nautical miles longer for the second scenario, but due to environmental condition encountered during the first route, even if the total distance was shorter, the total fuel consumption would have exceeded the total consumption of using the alternative route. The results show that the weather conditions encountered by vessels could greatly influence the value of the EEOI, and a good weather prediction, followed of accurate weather navigation while considering the fuel consumption experience records could reduce the EEOI and, consequently the CO$_2$ emissions.

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