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Original Article

A research on the energy efficiency operational indicator EEOI calculation tool on M/V NSU JUSTICE of VINIC transportation company, Vietnam

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Abstract

Nowadays, the development of science and technology brings the innovations and resolutions in aims with increasing the benefits and incomes for companies and producers. Additionally, the development of nation's economic associates with environmental protection. In the field of shipping transportation, the increasing in a number of ships operates then International Maritime Organization IMO's regulations become gradually more tightly about the environmental protection. EEOI – Energy Efficiency Operational Indicator is an operational measure tool for assessing the ship energy efficiency and CO_2 emission to the environment. Furthermore, the research status is about ships energy efficiency management also has the optimistic trends and more effective. In the world, there are a lot of ships energy efficiency researches in aim with enhancing the energy efficiency and environmental protection. For instance, the voyage optimization, increasing the propulsion efficiency of ships, reducing the resistances, etc. However, in Vietnam, there are a lot of shipping transportation companies with different types of ship but the number of research about ships energy efficiency management also restrict. Since this research was carried out and applied the energy efficiency measure tool of International Maritime Organization (IMO) for assessing all ships in Vietnam. The above workings were conducted by EEOI calculation tool for a certain ship with name M/V NSU JUSTICE 250,000 DWT of the VINIC Shipping Transportation Company, Vietnam.

Keywords: Ship energy efficiency; EOI; SEEMP; IMO; Bulk carrier.

1. Introduction

There are a lot of ships operate and carry a big mass of cargoes over the world. The operation of these ships also has been bringing the benefits and incomes for each nation, especially its border lies near the ocean sea.

Furthermore, shipping is the key point to develop the economy of each nation. The effective operation and creating the green shipping have meaningfully in the field of the energy explosion and environment pollution. In fact that shipping also contributes in the most environmentally friendly form with only 2.7% to the Greenhouse Gases (GHGs) emission. Beside that shipping transportation activities are also emitted 12% to marine pollution.

At present, many large ships become increasingly and more energy efficient per ton of cargo. In particular, 400,000 bulk carrier is about 50% more energy efficient per ton of freight carried than an 180,000 cape size, a 180,000 bulk carrier is about 47% more energy efficient per ton of cargo carried than a 73,000 panamax bulk carrier, a 73,000 panamax bulk carrier is about 25% more energy efficient per ton of goods transported than a 51,000 supermax bulk carrier, a 51,000 supermax bulk carrier is about 37% more energy efficient per ton of cargo carried than a 31,000 handysize bulk carrier. It is clear that the large size ships are more efficient in operation than small ships. Ships operating on international routes should be of the following sizes: from 100,000–200,000 DWT for imported coal; 70,000–100,000 DWT for exported alumina; 30,000–50,000 DWT for export coal, ore, fertilizer and clinker import, etc. For general cargoes, it is advised to use ships

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of 10,000–20,000 DWT for Intra-Asia routes, 20,000–30,000 DWT for longer routes to Europe, Africa, and America. Container ships of 500–3000 TEU are operated on Asian routes, and 4000–6000 TEU for European and American roads [3].

Ship operating on domestic routes should be of the following sizes: 1000–10,000 DWT for general cargoes; specialized barges of 5000–10,000 DWT for the imported coal from transshipment hubs to the docks of plants; Containerships of 20–1000 TEU; Tanker of 10,000–30,000 DWT for oil products, and 100,000–150,000 DWT for raw oil from oil rigs platform to oil refinery plants [3].

In parallel with the development of shipping transportation industries, it is potential for the environmental pollution from equipment operation activities on the ship. One of the main factors from Greenhouse Gases (GHGs) emission is carbon dioxide (CO_2), carbon dioxide (CO_2) emissions from commercial shipping are currently unregulated. Nevertheless, they are a subject of intense scrutiny by the world maritime community. According to the Kyoto Protocol to the United Nations Framework Convention on Climate Change – UNFCCC (1997), specific measures to reduce CO_2 emissions are necessary to curb the projected growth of Greenhouse Gases (GHGs) worldwide. Shipping has thus far escaped including in the Kyoto global emissions reduction target for CO_2 and other GHGs, but it is clear that the time of non-regulation is rapidly approaching its end, and measures to curb future CO_2 growth are being sought with a high sense of urgency. CO_2 is the most prevalent of these GHGs, therefore, clear that any set of measures to reduce the latter should primarily focus on CO_2. In parallel, the broader analysis of the other greenhouse gases (such as CH_4 and N_2O) and other, not greenhouse gases, such as SO_2, NO_x, and others is already very high on the International Maritime Organization's (IMO) agenda. Various analyses of many aspects of the problem have been and are being carried out, and a spectrum of measures is being contemplated. It is clear that a reliable emissions inventory is essential for both scientists and policy-makers to formulate and evaluate the implementation of relevant regulations [1].

The Marine Environment Protection Committee (MEPC), at its fifty-ninth session (13 to 17 July 2009), agreed to circulate the guidelines for voluntary use of the Ship Energy Efficiency Operational Indicator (EEOI) as set out in the annex [2]. Besides that, the International Convention for the Prevention of Pollution from Ships, 1973, as modified in 1978 (MARPOL 73/78) was given out in aims with the environmental pollution prevention and precaution from the maritime operation activities. IMO's policies are related to reducing the harmful gas emissions to the atmosphere, especially Greenhouse Gases (GHGs) emission. The Marine Environment Protection Committee (MEPC) identifies the mechanism to achieve the limitation of the greenhouse gases emission from international shipping. IMO's guidelines are very significant and necessary at this time, need to research about the ship energy efficiency through issues above are given out. EEOI is an operational measure tool than IMO introduced in 2010; it is applied to all existing ships about the evaluation of energy efficiency and CO_2 gas emission to the environment. This article concentrates on researching EEOI index application to assess the large size ship, bulk carriers, in particular, M/V NSU JUSTICE 250,000 DWT due to NAMURA SHIPBUILDING CO. Ltd built in Japan.

2. Ship energy efficiency

2.1. EEOI: Energy Efficiency Operational Indicator

EEOI, Energy Efficiency Operational Indicator (former operational CO_2 – index), this is a tool for measuring the CO_2 gas emission to the environment per the transport work. On the other hand, it represents the actual transport efficiency of a ship in operation. The annual EEOI calculation is a necessary working; this index will be changed after the ship finishes after each voyage due to the outside factors, such as navigation environment condition, sea-going area, weather, environment temperature, carrying-cargo weight, etc.

The EEOI provides an accurate figure for each voyage. The unit of EEOI depends on the measurement of cargo carried or the transport work done, e.g., ton CO_2/(tons/nautical miles), tons CO_2/(TEU/nautical miles) or tons CO_2/(person/nautical miles), etc. The EEOI is calculated by the following formula, in which a smaller EEOI value means a more energy efficient ship: [2].

$$\mathrm{EEOI} = \frac{\mathrm{actual\_CO_2\_emission}}{\mathrm{performed\_transport\_work}} \tag{1}$$

Besides, the EEOI is calculated for a voyage as follows:

$$\mathrm{EEOI} = \frac{\sum_j FC_j \cdot C_{Fj}}{m_{\mathrm{cargo}} \cdot D_j} \tag{2}$$

In formula (2) for computing the EEOI index for all existing ships. Moreover, it is described clearly for formula (1). But for a large number of ships, formula (2) is expressed like as:

$$\mathrm{Average\_EEOI} = \frac{\sum_i \sum_j (FC_{ij} * C_{Fj})}{\sum_i (m_{\mathrm{cargo},i} * D_i)} \tag{3}$$

where:

- j: Fuel type used;
- i: Navigation voyage number;
- FC_{ij}: Mass of consumed fuel j at voyage i;
- C_{Fj}: Fuel mass to CO_2 mass conversion factor with fuel j;
- m_{cargo}: Weight of cargo carried (tons) on ship;
- D_i: Distance of voyage i (nautical miles).

In then, C_F is the fuel mass to CO_2 mass conversion factors that is a non-dimensional conversion factor between fuel consumption measured in a unit of gram and CO_2 gas emission also measured in gram based on the carbon content. The below table is showed the certain value of C_F follows (Table 1):

Table 1.
The value of C_F (t-CO_2/t-Fuel) [2].

No	Type of fuel	Reference	Carbon content	C_F (t-CO_2/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	Liquefied petroleum gas (LPG)	Propane butane	0.819 0.827	3.000000 3.030000
5	Liquefied natural gas (LNG)		0.75	2.750000

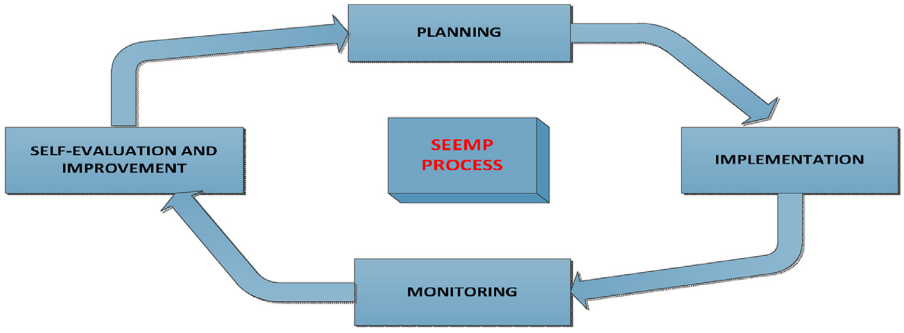

Fig. 1. Ship Energy Efficiency Management Plan (SEEMP) process [5].

2.2. SEEMP: Ship Energy Efficiency Management Plan

SEEMP–Ship Energy Efficiency Management Plan is adopted by IMO (International Maritime Organization), it is referred to Regulations and Measurements. It will be required to all ship over 400 GT on international voyage routes from January 1st 2013. Following that, the operational and technical measures will be implemented on board in aims with improving the energy efficiency and reducing the fuel consumption on ships. Besides that, SEEMP likes as a tool of energy efficiency management for all ships associates with EEOI (Energy Efficiency Operational Indicator). Its concept is assisted to ship operators in the field of ship energy efficiency management and also reduced the greenhouse gas emission to the environment.

SEEMP's guidelines were regulated and agreed at the following session, MEPC 59 in 2009. The regulations themselves were eventually adopted as an amendment to MARPOL Annex VI at MEPC 62 July 2011 as Regulation 22 (*Resolution MEPC.203(62)*) [4].

MEPC 63 in February 2012 adopted revised SEEMP Guidelines as Resolution MEPC.213(63)-2012 Guidelines for the Development of a Ship Energy Efficiency Management Plan (SEEMP) *(Appendix 2 of this Manual)* [4].

The purpose of a Ship Energy Efficiency Management Plan (SEEMP) is to establish a mechanism for a company and/or a ship to improve the energy efficiency of a ship's operation. Preferably, the ship-specific SEEMP is linked to a broader corporate energy management policy for the company that owns, operates or controls the ship, recognizing that no two shipping companies or ship owners are the same, and that ships operate under a wide range of different conditions [5]. Fig. 1 shows the SEEMP process including four key processes: Planning, Implementation, Monitoring, Self-evaluation and Improvement.

All key processes of SEEMP (Ship Energy Efficiency Management Plan) must address and describe together. It is a reason that they form a continuous improvement process and indicated in Fig. 1. Each process was taken from the SEEMP guidelines (MEPC.213(63)) and it has been summarized below.

- Planning

As part of each SEEMP, the ship owner is required to review current practices and energy usage onboard each ship with a view to determining any shortfalls or areas for improvement of energy efficiency. This is a crucial first step to developing an effective management plan and should identify various aspects relating to:

+ Ship-specific measures, for example speed optimization, weather routing, hull maintenance, machinery operation.
+ Company-specific measures, for instance improved communication and interaction with other stakeholders, such as charterers in order to assess the feasibility of 'just in time' operation or traffic management services for the availability of berth, etc.
+ Human resource development.

Awareness and training of personnel is critical in ensuring successful implementation of any measures.

+ Goal setting.

This aspect is voluntary but serves as a mean for a ship owner to provide an incentive for energy reduction both at ship level but also at a corporate level. This is not subject to external inspection.

- Implementation

Upon completion of the planning stage, a system of how each energy improvement measure is to be implemented needs to be developed. The development of the system can be considered under the planning stage and should set out the tasks required to achieve each measure along with who is assigned to them.

The implementation itself needs to be in accordance with the implementation system and should involve a system of record-keeping.

- Monitoring

The only way to assess whether the energy improvement measures are working is to monitor each one quantitatively. A ship owner may have existing systems in place to do this although monitoring should be carried out using established methods, preferably by an international standard.

The SEEMP guidance (MEPC.213(63)) recommends one internationally established tool in particular, that can be used for monitoring; the Energy Efficiency Operational Indicator (EEOI). This has been developed by the IMO to quantify the energy efficiency of a ship in terms of CO_2 production per cargo tonne-nautical mile (gCO_2/t.nm) and its use and calculation is given in MEPC.1/Circ.684. In addition, it suggests that, if appropriate, a Rolling Average Index of the EEOI may be used to monitor energy efficiency of the ship over time.

- Self-evaluation and improvement

This is the final stage in the cycle and is the means by which each measure can be assessed and the results fed into the planning stage of the next improvement cycle. Self-evaluation and improvement not only identifies how effective each energy improvement measure is, but it also determines whether the process by which it is implemented and monitored is suitable and how it can be improved. Each measure needs to be evaluated individually on a periodic basis and the results should be used to understand the level of improvements seen for each ship.

3. EEOI free calculator by Totem Plus

EEOI plays a key role in assessing the ship energy efficiency in the field of reducing the fuel consumption of equipment and Greenhouse Gases (GHGs) emission. Since ship efficiency measures become compulsory to all vessels 400 GT above that are operating on the international routes with an enhancement of the large size ships. In a result, to provide the EEOI Free calculator is necessary nowadays, Totem Plus has been represented a new Energy Efficiency Operational Indicator (EEOI) for the shipping industry.

In Fig. 2, it describes the interface of EEOI calculator that developed by Totem Plus. This is effective for ship owners and ship operators by its application. In the interface of EEOI calculator, it will achieve the EEOI index that must admit the outside parameters including: Ship name, ship type, voyage number, voyage type, fuel type used, the mass of cargo carried, voyage distance, etc. On another side, its calculator has got the function of the gained result export (EEOI) by means of load, save or print. In summary, EEOI Free calculator is an effective tool in the calculation the EEOI (Energy Efficiency Operational Indicator) for all ships 400 gross tonnages above.

4. Operational parameters on M/V NSU JUSTICE 250,000 DWT

M/V NSU JUSTICE is a large deadweight tonnages with 250,000 DWT. It is a big ship of the VINIC shipping transportation company which laid at Vietnam Maritime University, Hai Phong, Vietnam. This company is managed by Japanese. However, all of the seafarers include Captain, Chief Engineer, Master, Officers who are good lecturers at Faculty of Navigation and Faculty of Marine Engineering. M/V NSU JUSTICE has specific parameters and indicates in Fig. 3.

On the other hand, the machinery particulars of Main Engine such as MAN B&W 7S80MC-C, two strokes, single acting, crosshead, exhaust gas turbocharger (Fig. 4).

This is a modern ship of VINIC transportation company with the equipment in good condition. They are carefully maintained by the Crews in an engine room.

5. Result

The calculation of EEOI index needs to carry out in aims with assessing the fuel consumption of voyage and reducing the greenhouse gas emission. The EEOI index is influenced by a lot of the outside conditions. Nonetheless, by using EEOI calculator that given by Totem Plus, it is effective in calculation and reducing the time by computing the manual calculation.

M/V NSU JUSTICE usually sails on line Japan–West Australia–Brazil, to assess the EEOI calculation by Totem Plus software, it is necessary to assume the certain voyage with voyage 16 that started on November 12, 2015 and finished on January 4, 2016. In particular, it sailed the ballast voyage with no carrying cargo from Nagoya, Japan to Port Walcott, Australia in during 11 days. It consumed both the Heavy Fuel Oil (HFO) and Diesel Oil (DO). After that, the cargo was loaded in Australia after coming back KIMITSU Port, Japan in 13 days. And it continued sailing in mainland Japan to MUROZAN Port to discharge the cargo left. In detail, the experimental data was collected and recorded in noon report of M/V NORD VENUS (Fig. 5).

From the experimental data was collected, it is fundamental to calculate EEOI index through the EEOI calculator by Totem Plus. The collected results were indicated in Fig. 6, the input parameters need to take from the experimental data includes: name of ship, type of ship, an amount of cargo carried, distance of sailing, type of fuel used and some fuel used then EEOI index will present.

Through the EEOI index result with $9{,}2 \times 10^{-7}$ for voyage 16; it ensures that the Energy Efficiency Operational Indicator (EEOI) is low with a collected value. In purpose, the need of the EEOI tool with computing the certain value and comparing the EEOI permits. Especially, it is considered as the

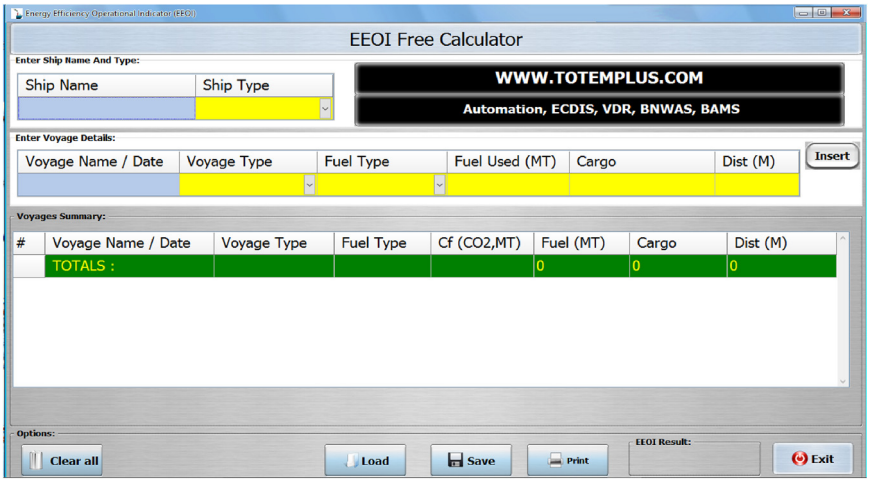

Fig. 2. EEOI Free Calculator Interface [7].

Fig. 3. M/V NSU JUSTICE.

outside factors that affected to the fuel consumption of ship. M/V NSU JUSTICE is a modern ship with its equipment is remained in good condition associates with experienced operation by Seafarers of this company. It is a main reason that leading to the EEOI index is low due to rising the ship energy efficiency management.

6. Conclusion

This article is a model to compute and assess the energy efficiency for all ships. In addition, the development of international shipping industries, it is necessary to support the calculation tool for using the energy efficiency at the existing ships. The energy crisis and harmful gases emissions always are laid firstly along with economic development. The effects of climate changes are happening dramatically influence on the life environment and humans. They cause the negative impacts and become a big issue that the next researches must

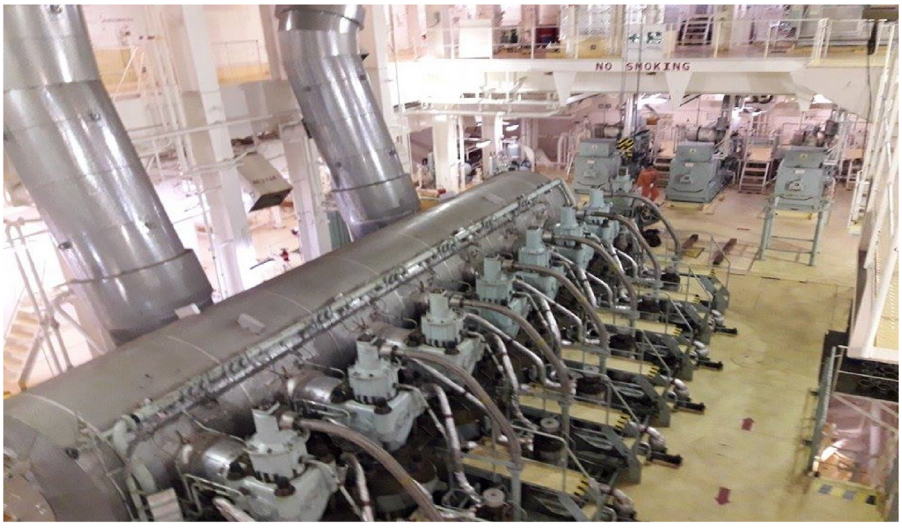

Fig. 4. Main engine of M/V NSU JUSTICE.

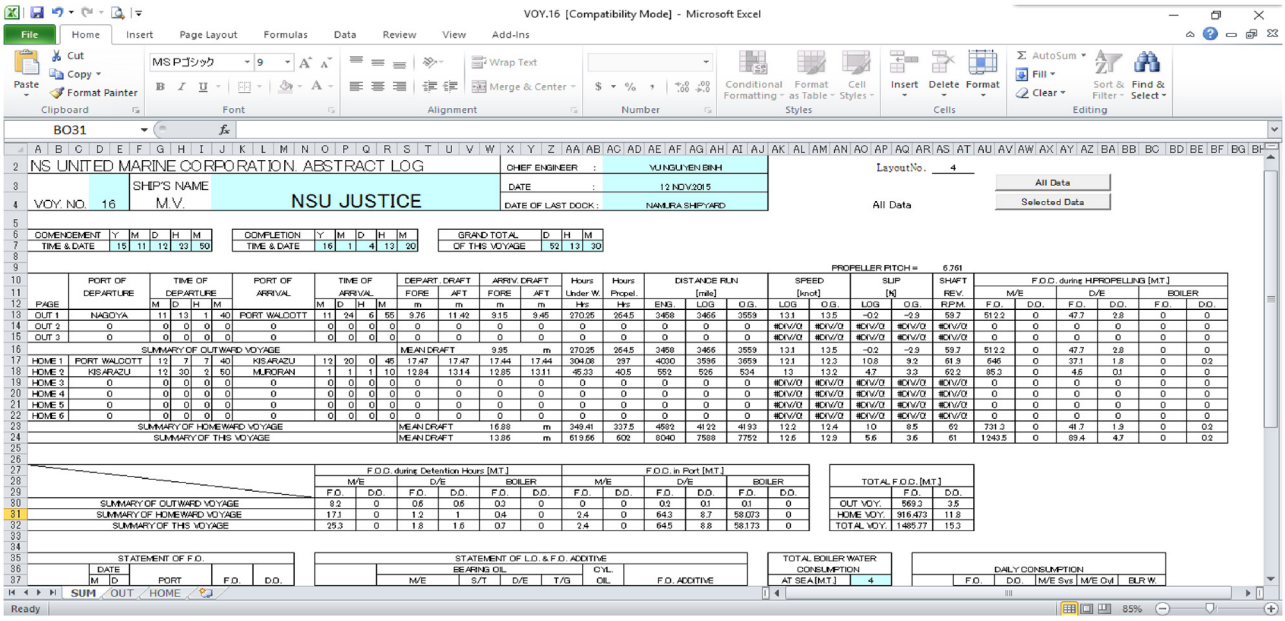

Fig. 5. No. 16 abstract voyage of M/V NSU JUSTICE [6].

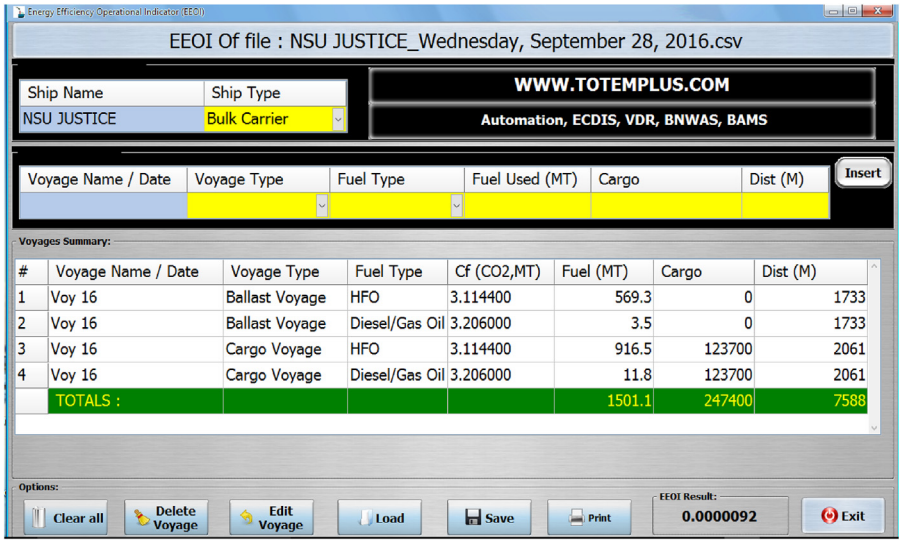

Fig. 6. EEOI index calculation.

be concentrated on this. In a result, the above issue needs to refer and continue the enhancement in the future.

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