RESEARCH ON OPTIMIZATION OF MARITIME CARGO TRANSPORTATION IN SOUTHEAST ASIA

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Abstract. Sea freight transport is the cheapest and most accessible, accounting for over 85% of the world's freight turnover. At the same time, sea transport is characterized by significant consumption of hydrocarbon fuel, which leads to economic costs and damage to the environment. The purpose of this research work is to reduce the consumption of marine fuel, optimize the logistics of sea freight transportation in conjunction with the development of multi-purpose vessels that eliminate "ballast" sea crossings. In combination, the implementation of these proposals in sea transport will improve the economic and environmental performance of sea voyages. For the first time, based on scientific research, it was possible to solve the problem of minimizing the consumption of marine fuel depending on the main parameters of sea freight transportation. The developed model for minimizing the consumption of marine fuel was tested on various types of vessels and its adequacy was shown within the permissible error. Also, for the first time, a mathematical model was developed that describes the consumption of marine fuel depending on the speed of the vessel, the effective capacity of the ship's power plant and the parameters of meteorological conditions. The results of the research were tested in the conditions of the most progressive and developing region of the world in the economic direction – Southeast Asia out ballast-free sea crossings in the conditions of Southeast Asia are considered.

1. Introduction

In order to determine the efficiency of maritime transport, the International Maritime Organization introduced the Ship Energy Efficiency Index (EEOI), which includes environmental and economic

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indicators of the voyage. There is no information in the literature on the study and determination of the optimal area of the EEOI depending on the voyage parameters. In this paper, a mathematical model has been developed that allows minimizing energy consumption on board a vessel depending on the main voyage parameters and meteorological conditions. The adequacy of the developed model has been verified under real sea voyages, and sufficient reliability and accuracy of the model have been shown. The developed model leads to the conclusion that "idle" voyages in ballast cannot be allowed in maritime transportation. This conclusion forms the basis for organizing ballastless sea transportation using multi-purpose specialized vessels, which will significantly improve the environmental and economic indicators of maritime transport. In the practice of sea freight transportation, the International Maritime Organization has recently been paying increasing attention to the issues of improving the economic and environmental performance of a voyage. Based on the research conducted, we have developed a mathematical model that allows minimizing the consumption of marine fuel depending on temporary changes in the speed of the vessel, the mass of the transported cargo, the distance of the passage, and the meteorological conditions of the actual voyage. The adequacy of the developed model has been verified under the conditions of actual sea passages, and sufficient reliability and accuracy of the model have been shown.

2. Experimental methodology

The developed mathematical model describing the change in EEOI depending on the vessel speed, the degree of its useful load, the distance of the sea passage, is based on computational studies. The main parameter in the mathematical model of EEOI is the consumption of marine fuel. Based on the research data, an equation was developed for the first time describing the change in fuel consumption depending on the used capacity of the ship's power plant, the speed of the vessel and the parameters of the meteorological conditions of the voyage. The adequacy of the mathematical model was tested under real voyage conditions on four types of vessels, and sufficient accuracy of the model for practical recommendations was shown.

2. Main part

2.1. Research on minimizing marine fuel consumption

Sea transport associated with cargo transportation is the cheapest, but on the other hand, it is characterized by significant consumption of marine fuel obtained from natural raw materials of a non-renewable nature, the reserves of which are limited, and its cost is constantly increasing. In the cost of sea cargo transportation (freight cost), the share of costs attributable to marine fuel is significant and is within 75-80%.

Sea transport, as an integral part of man-made systems, leads to negative consequences, such as:

1) deficiency of natural oxygen contained in the atmospheric air;
2) depletion of non-renewable hydrocarbon resources;
3) increase in the cost of sea cargo transportation;
4) intensive pollution of the marine environment;
5) rapid development of the Planetary "greenhouse" effect.

The purpose of this study is two components:

1) economic and resource-saving, namely, reducing the consumption of marine fuel;

2) environmental – reducing emissions of harmful toxic substances and compounds caused by reduced consumption of marine fuel (p. 1) – components of "greenhouse" gases that contribute to the development of the "climate" crisis on the Planet, its negative consequences, which humanity has been facing quite often lately [1, p. 31].

The work [2, p. 5] analyzes and summarizes the characteristics of "Green" energy in comparison with traditional hydrocarbon energy, taking into account real reserves, efficiency and productivity. Taking into account modern scientific developments, practical experience in using "Green" energy in the countries of the European Union, preference is given to traditional hydrocarbon and nuclear energy instead of traditional and nuclear energy. Based on the completed research work, practical recommendations have been developed to reduce the consumption and cost of marine fuel in real conditions of a sea passage. It is necessary to point out some fragments of research works that lead to the reduction of marine fuel consumption, namely: optimization of sulfur compounds in marine fuel [3, p. 303], an integrated system for cleaning and utilization of heat from exhaust gases of Ship power plants (EG SPP) [4, p. 151], optimization of logistics of

sea cargo transportation, which are based on the conditions for organizing ballast-free sea passages, the use of oxygen instead of air as an oxidizer of marine fuel [5, p. 588].

The work [6, p. 917] presents the results of studies on minimization of the operational coefficient of energy efficiency of the vessel (EEOI) in the conditions of a real sea passage of the vessel "Warnow Dolphin" on the route Miami, USA – Manzanillo, Panama – Guayaquil, Ecuador – Callao, Peru and back. For a specific selected marine power plant, the parametric dependence of the vessel speed and marine fuel consumption on the share of the used power of the power plant was determined by calculation.

The operational coefficient of the energy efficiency of the vessel (EEOI) was calculated depending on the consumption of marine fuel, the concentration of carbon in the marine fuel with the main parameters adopted for the passage: vessel speed, mass of the transported cargo, distance of the sea passage. Calculation studies were carried out in a wide range of parameters of the sea passage – the distance of the passage within 1,200-3,000 nautical miles, the speed of the vessel 0.01-27.0 knots, the mass of the cargo within 1,200-20,000 mt.

Until recently, sea cargo transportation was carried out on the principle of delivering cargo to the customer in a short time, without taking into account the consumption of marine fuel and pollution of the marine environment. Recently, IMO has adopted Resolutions aimed at reducing marine fuel consumption – carbon dioxide emissions – the main component of "greenhouse" gases [7, p. 37; 8, p. 32; 9, p. 75; 10, p. 11; 11, p. 188]. In the works [12, p. 395], [13, p. 107], under the conditions of a real sea (transoceanic) passage, a parametric relationship was established between the EEOI and the vessel speed, the mass of the transported cargo and the passage distance.

According to the technical data of the vessel "Warnow Dolphin", using a specially developed method, the dependencies of the change in vessel speed and marine fuel consumption on the share of the used power on the crankshaft of the ship's power plant were determined (Figure 1).

Research has established that the dependence of the EEOI on the mass of the transported cargo is described by hyperbolic lines. With an increase in the mass of the transported cargo within the range from 7,000 to 18,000 m.t., the values of the EEOI tend to the value of the design coefficient of energy

efficiency of the vessel (EEDI) and with cargo mass values approaching zero, the values of the EEOI tend to infinity.

Based on the obtained data, additional calculations of the EEOI with approximated parameters for speed and cargo mass, dependencies of the total values of the EEOI were constructed with a simultaneous change in the vessel speed and cargo mass, as a result of which the area of minimization of the EEOI for the specific sea passage studied was determined.

As practical recommendations, based on the results of the studies, the parameters of the sea passage were established, at which the minimum values of the EEOI are achieved, namely: the vessel speed should be within 12-18 knots, the mass of the transported cargo should be within 8,000-12,000 mt.

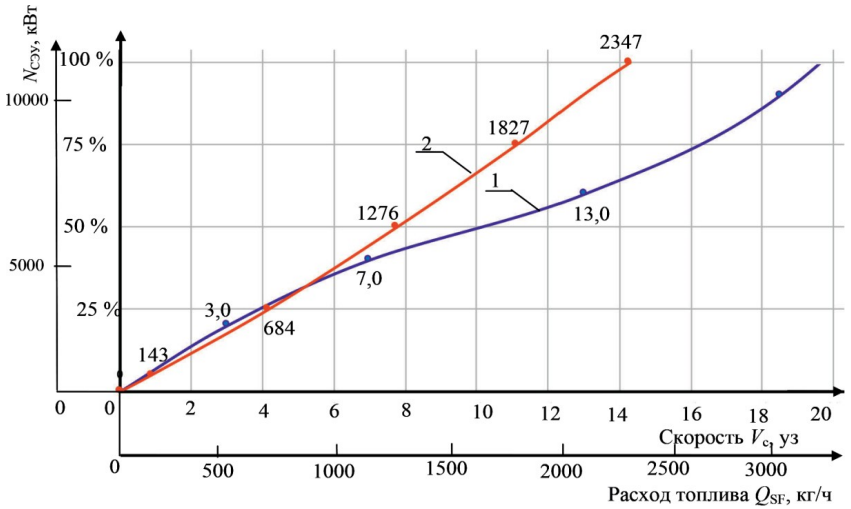

Figure 1. Change in vessel speed (curve 1) and marine fuel consumption (curve 2) depending on the share of the used power of the power plant

Based on the studies, an important conclusion can be drawn – in maritime practice, ballast transitions [6, p. 919] cannot be allowed, since with the mass of the cargo tending to zero, the value of the EEOI tends

to infinity, and this has an extremely negative effect on the economic and environmental indicators of the sea passage.

A real round-the-world voyage has been studied [14, p. 112], which was carried out along the route: Algeciras, Spain – Marsaxlokk, Malta – Livorno, Italy – Genoa, Italy – Barcelona, Spain – Valencia, Spain – Fort-de-France, Martinique – Pointe-a-Pitre, Guadeloupe – Caucedo, Dominican Republic – Cartagena, Colombia – Kingston, Jamaica – Houston, USA – Veracruz, Mexico – Manzanillo, Panama – Moin, Costa Rica – Cartagena, Colombia – Algeciras, Spain. The total time of the sea voyage was 56 days.

The sea (oceanic) voyage was carried out on the container ship m/v "Katherine". Based on the passport characteristics of the marine power plant SPP One (1) Huyndai MAN B&W 8S80ME-C9-2/33670 kW at 78 rpm, as a result of calculation studies and generalizations, the parametric dependence of fuel consumption and ship speed on the share of the used power of the power plant was determined (Figure 2).

Based on the data of the conducted studies, the dependence of the change in the EEOI value with a simultaneous change in the speed of the vessel and the mass of the transported cargo was constructed (Figure 3). The intersection point A of lines 2 and 3 shown in Figure 3 characterizes the minimum value of the EEOI of the vessel/voyage and, accordingly, the minimum consumption of marine fuel Gmin, mt, and the minimum emission of carbon dioxide, equal to (3.114× Gmin), mt.

According to the methodology given in the work [6, p. 915], the zone of minimization of the EEOI is defined – zone A. As a result of the analysis and generalization of the experimental data, the following conclusion can be made: the minimum area of the EEOI is achieved at a vessel speed within 16.2-22.4 knots, the mass of the transported cargo is 48,000-60,000 mt, the distance of the sea passage is not limited.

$$Rsf = f\left(Nspp\right) \times f\left(Vs\right) \times Pm \times Nspp \times t\ .$$

The next object of research was the motor ship "TRAMMO CORNELL" on the sea passage Singapore (Singapore) – Busan (South Korea), the distance of the passage is 2,500 n.m.

The energy efficiency design index (EEDI) of a ship can be determined using the theoretical model given in IMO Resolution MEPC.212(63) or the experimental equation given in [15, p. 177; 16, p. 151; 17, p. 187].

EEOI is determined using the equation given in [17, p. 147].

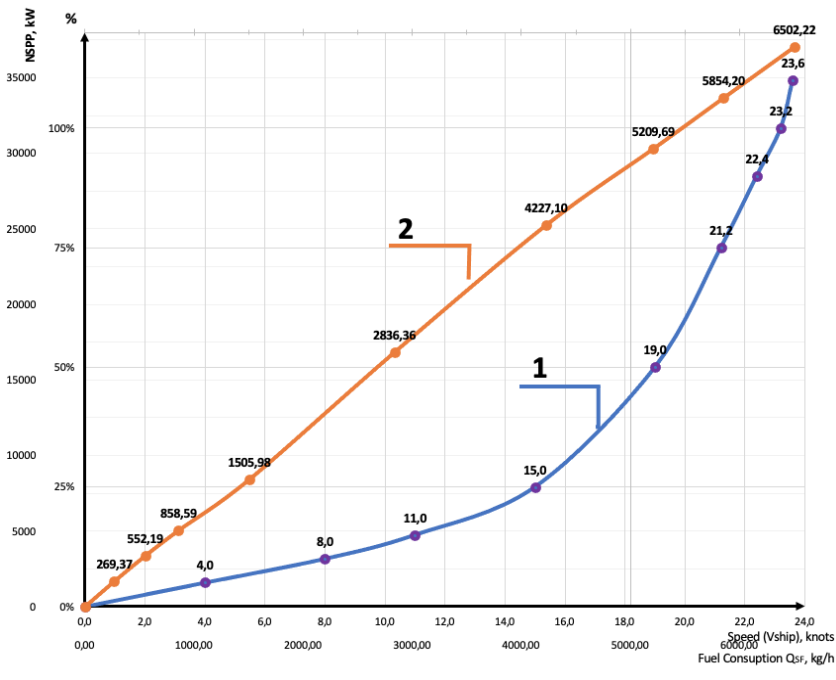

Figure 2. Change in vessel speed (curve 1) and marine fuel consumption (curve 2) depending on the share of the used power of the propulsion plant

We were the first to develop and propose for practical implementation an equation for determining the fuel consumption of a ship Q, mt, depending on the SPP power, ship speed and weather conditions during the passage:

$$Rsf = f\left(Nspp\right) \times f\left(Vs\right) \times Pm \times Nspp \times t$$

where f(Nspp) is the fuel consumption function depending on the degree of use of the SPP power;

f(Vs) is the fuel consumption function depending on the vessel speed;

t is the sea passage time, hours; Pm is the coefficient that takes into account the change in the effective power of the power plant depending on the meteorological conditions, and varies from 1 to 2.5;

Nspp is the effective power of the power plant, kW, and varies from 0 to 14500 (0-100 %);

Vs is the speed of the vessel, knots.

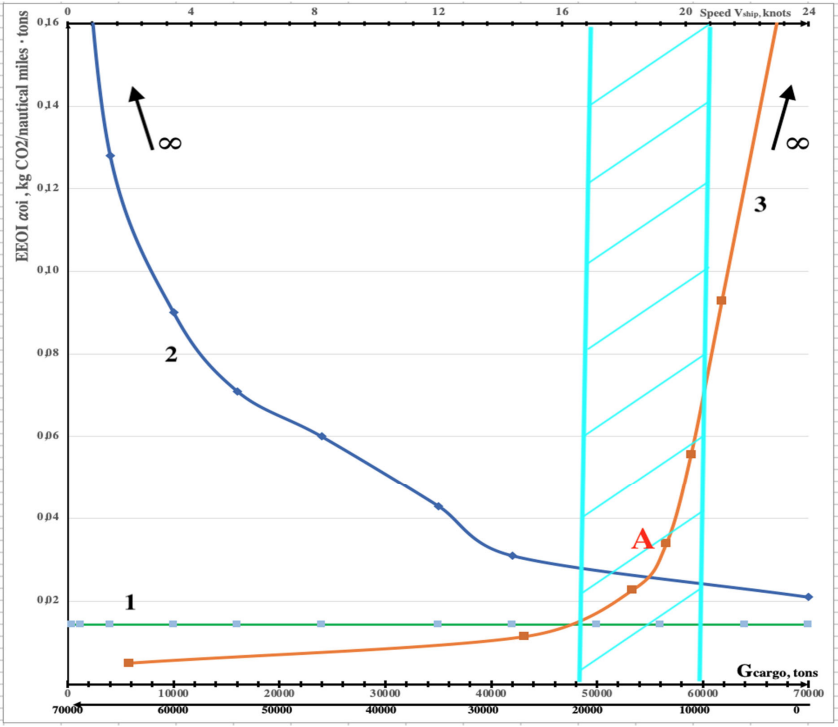

Figure 3. Region of minimization of EEOI (shaded region A)

Research and development work on minimization of the Vessel's Operating Energy Efficiency Ratio was conducted on four different projects of real vessels, in real conditions of sea (transoceanic) passages depending on the passage distance, cargo mass, and vessel speed. According to the developed methodology, using mathematical modeling methods based on the obtained real research results in sea conditions, calculation studies were conducted to minimize the Operating Energy Efficiency Ratio of the Vessel/ Voyage. The results of the research and development work are summarized

and presented in Figure 4. It follows from the data obtained that regardless of the types of vessels and the designs of ship power plants used, the nature of the dependence of EEOI on the vessel's speed, the mass of the transported cargo, and the distance of the sea passage is described by the same qualitative patterns.

2.2. Development of logistics routes for ballastless sea freight transportation [18, p. 59]

Southeast Asia (SEA) is a macro-region covering continental and island territories between China, India and Australia. It includes 11 countries: Vietnam, Cambodia, Laos, Myanmar, Thailand, Malaysia are located on the continental part, and Brunei, East Timor, Indonesia, Singapore, and the Philippines are located on the island part. It should be noted that all SEA countries (except EastTimor) carry out regional cooperation through the Association of Southeast Asian Nations (ASEAN).

For logistical studies related to minimizing the consumption of marine fuel, and accordingly, organizing ballastless ship transportation, we will consider three main ports – 1. Jakarta (Port of Jakarta), Indonesia; 2. Hong Kong (Port of Hong Kong), China; 3. Singapore (Port of Singapore), Singapore.

Indonesia – the main export destinations of goods from Indonesia in 2023 were: China with a share of 19.4% (US$31 billion);

USA with a share of 11.4% (US$18.6 billion);

Japan with a share of 8.36% (US$13.6 billion);

Singapore with a share of 6.55% (US$10.7 billion);

India with a share of 6.37% (US$10.4 billion);

Malaysia with a share of 4.97% (US$8.13 billion);

South Korea with a share of 3.98% (US$6.5 billion);

Philippines with a share of 3.61% (US$5.89 billion);

Thailand with a share of 3.13% (US$5.11 billion);

Vietnam with a share of 3.02% (US$4.94 billion)

The top 10 exported goods from Indonesia in 2023 were:

10.6% ($17.3 billion): 1511 – Palm oil and its fractions, whether or not refined, but not chemically modified;

8.9% ($14.5 billion): 2701 – Coal; briquettes, pellets and similar solid fuels obtained from coal;

3.39% ($5.54 billion): 7108 – Gold (including gold plated with platinum), unwrought or in semi-manufactured forms, or in powder form;

3.33% ($5.45 billion): 2711 – Petroleum gases and other gaseous hydrocarbons 2.9% ($4.74 billion): 7202 – Ferro-alloys;

1.84% ($3.01 billion): 4001 – Natural rubber, balata, gutta-percha, guayule, chicle and similar natural resins, in primary forms or in plates, sheets or strip;

1.83% ($2.99 billion): 7219 – Flat-rolled products of stainless steel, of a width of 600 mm or more;

1.78% ($2.91 billion): 3823 – Industrial monocarboxylic fatty acids; acid oils after refining; industrial fatty alcohols;

1.64% ($2.68 billion): 8703 – Passenger cars and other motor vehicles primarily designed for the transport of persons (other than motor vehicles of heading 8702), including commercial vans and racing cars;

1.47% ($2.41 billion): 2603 – Copper ores and concentrates.

The largest trading partners for imports of goods to Indonesia in 2023 were:

China with a share of 27% ($39 billion);

Singapore with a share of 8.71% ($12.3 billion);

Japan with a share of 7.53% ($10.6 billion);

United States with a share of 6.1% ($8.64 billion);

Malaysia with a share of 4.89% ($6.93 billion);

South Korea with 4.83% share (US$6.84 billion);

Thailand with 4.57% share (US$6.48 billion);

Australia with 3.28% share (US$4.64 billion);

India with 2.65% share (US$3.76 billion);

Other Asian countries with 2.52% share (US$3.57 billion).

TOP 10 imported goods to Indonesia in 2023:

5.62% ($7.96 billion): 2710 – Petroleum and oils obtained from bituminous rocks, other than crude; products, not elsewhere specified or included, containing 70% or more by weight of petroleum or oils obtained from bituminous rocks, these oils being the main constituents of preparations; waste oils;

3.12% ($4.42 billion): 8517 – Telephone sets, including telephones for cellular networks or for other wireless networks; other apparatus for transmitting or receiving voice, images or other data, including apparatus for wired or wireless data communications;

2.39% ($3.39 billion): 2709 – Crude petroleum and crude oils obtained from bituminous minerals;

1.84% ($2.61 billion): 1001 – Wheat and meslin;

1.82% ($2.58 billion): 2711 – Petroleum gases and other gaseous hydrocarbons;

1.6% ($2.26 billion): 8471 – Computers and their units; magnetic or optical reading machines, machines for recording data on data carriers in coded form and machines for processing such data, not elsewhere specified or included;

1.36% ($1.93 billion): 2304 – Cakes and other solid residues from the extraction of soya-bean oil, whether or not ground, granulated or not;

1.36% ($1.93 billion): 1701 – Cane or beet sugar and chemically pure sucrose, in solid form;

1.34% ($1.9 billion): 7108 – Gold (including gold plated with platinum), unwrought or in semi-manufactured forms, or in powder form;

1.3% ($1.84 billion): 8708 – Parts and accessories of motor vehicles of headings 8701 to 8705;

Thus, in 2020 Indonesia's exports amounted to US$61.53 billion and imports amounted to US$30.82 billion, with exports exceeding imports by about two times.

Singapore – the main export destinations of goods from Singapore in 2023 were:

China with a share of 13.7% (US$51 billion);

Hong Kong with a share of 12.3% (US$46 billion);

USA with a share of 10.7% (US$40 billion);

Malaysia with a share of 8.9% (US$33 billion);

Indonesia with a share of 5.73% (US$21 billion);

Other Asian countries with a share of 4.87% (US$18.2 billion);

Japan with a share of 4.77% (US$17.8 billion);

South Korea with a share of 4.48% (US$16.7 billion);

Thailand with a share of 3.77% (US$14.1 billion);

Vietnam with a share of 3.32% (US$12.4 billion).

TOP 10 goods exported from Singapore in 2023:

23% ($86 billion): 8542 – Electronic integrated circuits;

7.32% ($27 billion): 2710 – Petroleum and petroleum products obtained from bituminous rocks, other than crude; products, not elsewhere specified

or included, containing 70% or more by weight of petroleum or petroleum products obtained from bituminous rocks, these petroleum products being the main constituents of preparations; waste oils;

4.21% ($15.8 billion): 7108 – Gold (including gold plated with platinum), unwrought or in semi-manufactured forms, or in powder form;

3.66% ($13.7 billion): 8411 – Turbo-jet and turbo-propeller engines, gas turbines;

2.53% ($9.48 billion): 8525 – Transmitting apparatus for radio or television, whether or not incorporating receiving, recording or reproducing apparatus; television cameras, digital cameras and video recording cameras;

2.47% ($9.28 billion): 8541 – Diodes, transistors and similar semiconductor devices; photosensitive semiconductor devices, including photovoltaic cells, whether or not assembled in modules or mounted in panels; light emitting diodes; piezoelectric transducers;

2.2% ($8.27 billion): 8479 – Machines and mechanical appliances having individual functions, not specified or included elsewhere in this chapter;

2.13% ($8 billion): 8471 – Automatic data processing machines and units thereof; magnetic or optical reading machines, machines for transferring data to data carriers in coded form and machines for processing such data, not elsewhere specified or included;

1.66% ($6.25 billion): 3304 – Cosmetics or make-up preparations and preparations for the care of the skin (other than medicaments), including sunscreen or tanning preparations; manicure or pedicure products.

Singapore's largest trading partners for imports in 2023 were:

China with a 14.4% share (US$47 billion);

Malaysia with a 12.7% share (US$41 billion);

Other Asian countries with a 11% share (US$36 billion);

United States with a 10.6% share (US$35 billion);

Japan with a 5.5% share (US$18.1 billion);

South Korea with a 4.73% share (US$15.5 billion);

Indonesia with a 4.23% share (US$13.9 billion);

France with a 3.11% share (US$10.2 billion);

Thailand with a 2.96% share (US$9.77 billion);

Germany with a 2.68% (US$8.84 billion).

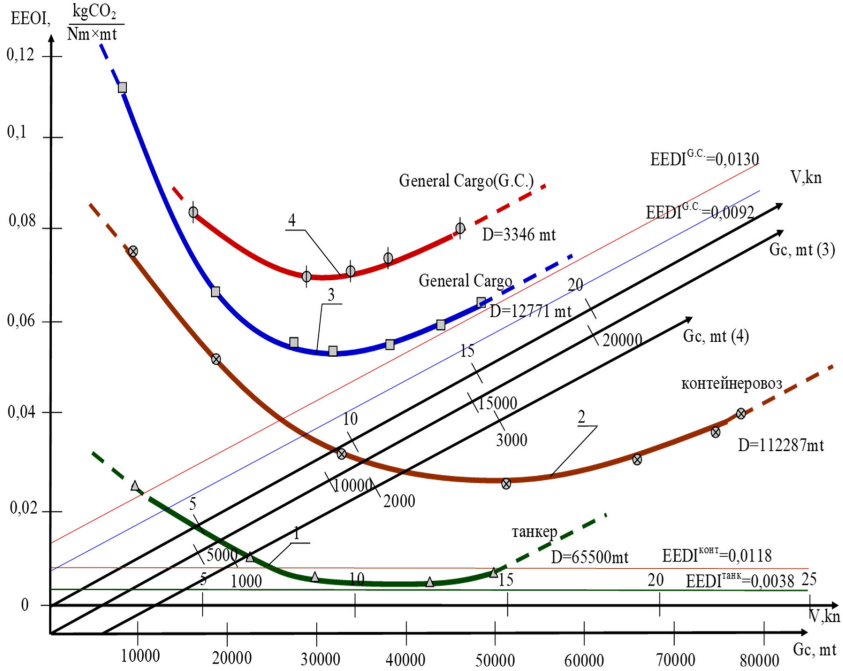

Figure 4. Dependence of EEOI on vessel speed, cargo mass, and transit distance for different vessel designs: line 1 – tanker; line 2 – container ship; line 3 – for general cargo vessel (deadweight – 12,771 mt); line 4 – for general cargo vessel (deadweight – 3,346 mt).

TOP 10 imported goods to Singapore in 2023:

21% (US$72 billion): 8542 – Electronic integrated circuits;

9.51% (US$31 billion): 2710 – Petroleum and oils obtained from bituminous rocks, other than crude; products, not elsewhere specified or included, containing 70% or more by weight of petroleum or oils obtained from bituminous rocks, such oils being the main constituents of the preparations; waste oils;

5.05% ($16.6 billion): 7108 – Gold (including gold plated with platinum), unwrought or in semi-manufactured forms, or in powder form;

4.57% ($15 billion): 8411 – Turbo-jet and turbo-propeller engines, other gas turbines;

4.36% ($14.4 billion): 2709 – Crude petroleum and crude oils obtained from bituminous minerals;

2.87% ($9.46 billion): 8525 – Transmitting apparatus for radio or television, whether or not incorporating receiving, recording or reproducing apparatus; television cameras, digital cameras and video recording cameras;

2.62% ($8.65 billion): 8471 – Automatic data processing machines and their units; magnetic or optical reading machines, machines for recording data on data carriers in coded form and machines for processing such data, not elsewhere specified or included;

1.63% ($5.39 billion): 8473 – Parts and accessories (other than cases, carrying cases and the like) suitable for use solely or principally with the machines of headings 8469 to 8472;

1.57% ($5.2 billion): 8541 – Diodes, transistors and similar semiconductor devices; photosensitive semiconductor devices, including photovoltaic cells, whether or not assembled in modules or mounted in panels; light-emitting diodes; piezoelectric transducers;

1.56% ($5.14 billion): 8803 – Parts of aircraft of heading 8801 or 8802.

Singapore TOP-10: the volumes of exports (US$183.78 billion) and imports (US$182.84 billion) are almost at the same level.

China – the main export destinations of goods from China in 2023 were:

USA with a share of 17.4% (US$452 billion);

Hong Kong with a share of 10.5% (US$272 billion);

Japan with a share of 5.5% (US$142 billion);

Vietnam with a share of 4.39% (US$113 billion);

South Korea with a share of 4.34% (US$112 billion);

Germany with a share of 3.35% (US$86 billion);

Netherlands with a share of 3.04% (US$79 billion);

Great Britain with a share of 2.8% (US$72 billion);

India with a share of 2.57% (US$66 billion);

Other Asian countries with a share of 2.32% (US$60 billion).

TOP-10 goods exported from China in 2023:

7.23% ($187 billion): 8471 – Automatic data processing machines and units thereof; magnetic or optical reading machines, machines for

transferring data to data carriers in coded form and machines for processing such information, not elsewhere specified or included;

7.22% ($187 billion): 8525 – Transmitting apparatus for radio or television broadcasting, whether or not incorporating receiving, sound recording or sound reproducing apparatus; television cameras, digital cameras and video recording cameras;

4.56% ($118 billion): 8542 – Electronic integrated circuits;

2.13% ($55 billion): 6307 – Other manufactured articles, including patterns for wearing apparel;

1.8% ($46 billion): 8517 – Telephone sets, including telephones for cellular networks or for other wireless networks; other apparatus for transmitting or receiving voice, images or other data, including apparatus for communication over a wired or wireless data network;

1.45% ($37 billion): 9405 – Lamps and lighting equipment, including spotlights, spotlights, headlamps and parts thereof, not elsewhere specified or included; illuminated signs, illuminated name or title or address plates and similar articles having a permanent light source;

1.37% ($35 billion): 8541 – Diodes, transistors and similar semiconductor devices; photosensitive semiconductor devices, including photovoltaic cells, whether or not assembled in modules or mounted in panels; light-emitting diodes; piezoelectric sensors;

1.29% ($33 billion): 9503 – Tricycles, scooters, pedal cars and similar wheeled toys; dolls' carriages; dolls; other toys; scale models and similar models;

1.27% ($32 billion): 8708 – Parts and accessories for motor vehicles of headings 8701 to 8705;

1.23% ($32 billion): 8473 – Parts and accessories (other than cases, carrying covers and the like) suitable solely or principally for use with machines of headings 8469 to 8472.

The largest trading partners for imports of goods to China in 2023 were:

Other Asian countries with a share of 9.76% (US$200 billion);

Japan with a share of 8.5% (US$174 billion);

South Korea with a share of 8.4% (US$172 billion);

United States with a share of 6.61% (US$135 billion);

Other (hidden partners) with a share of 6.19% (US$127 billion);

Australia with a share of 5.58% (US$114 billion);
Germany with a share of 5.12% (US$105 billion);
Brazil with a share of 4.09% (US$84 billion);
Vietnam with a share of 3.81% (US$78 billion);
Malaysia with a share of 3.63% (US$74 billion).

TOP-10 goods imported to China in 2023.

17% (US$351 billion): 8542 – Electronic integrated circuits;

8.57% (US$176 billion): 2709 – Crude petroleum and crude petroleum products obtained from bituminous minerals;

5.78% (US$118 billion): 2601 – Iron ores and concentrates, including calcined pyrite;

2.18% ($44 billion): 8703 – Passenger cars and other motor vehicles primarily designed for the transport of persons (other than motor vehicles of heading 8702), including commercial vans and racing cars;

2.04% ($42 billion): 2711 – Petroleum gases and other gaseous hydrocarbons 1.92% ($39 billion): 1201 – Soya beans, whether or not crushed;

1.74% ($35 billion): 8517 – Telephone sets, including telephones for cellular networks or for other wireless networks; other apparatus for transmitting or receiving voice, images or other data, including apparatus for communication in a wired or wireless data transmission network;

1.74% ($35 billion): 8471 – Automatic data processing machines and their units; magnetic or optical reading machines, machines for the transfer of data onto data carriers in coded form and machines for processing such data, not elsewhere specified or included;

1.66% ($34 billion): 2603 – Copper ores and concentrates;

1.48% ($30 billion): 7403 – Refined copper and unwrought copper alloys.

China TOP-10: exports – $762 billion, imports – $904 billion, import volume exceeds export volume by $142 billion.

Thus, based on the nomenclature of exported and imported goods in Southeast Asia, they can be divided into: bulk (solid, loose), liquid, gaseous, the transportation of which can be carried out by multi-purpose specialized vessels – MPV. Optimization of the logistics of sea freight transport carried out by MPV will increase the economic efficiency of transport movements of goods in Southeast Asia.

Particular attention should be paid to the high financial level of export-import operations in Southeast Asia.

In some cases, cross-export-import of the same goods is observed, which contradicts the economic theory and practical feasibility of sea freight transport.

2.3. Development of Multipurpose Vessels Providing Ballast-Free Marine Logistics Routes in Southeast Asia

A multipurpose vessel (MPV) is a seagoing vessel designed to carry a wide range of cargo: timber, steel, construction materials, paper rolls and bulk cargo, oil, petroleum products [19, p. 121], frozen food products. Multipurpose vessels can be divided into the following categories: vessels with and without cargo equipment, coastal trade liners and river-sea vessels. Larger multipurpose vessels can carry different types of cargo on the same voyage. Smaller multipurpose vessels do not have this advantage, but they are used to enter small harbors due to their limited draft. Due to the various operating conditions, these vessels have a complex design, the creation of which is characterized by high energy, material and labor resources. Their versatile design must be able to carry heavy cargo, large items and packaged cargo as bulk cargo. These cargoes can be moved or lifted on board, so this also requires different types of loading equipment.

In the work [20, p. 7] five types of multi-purpose MPV vessels are distinguished:

Coasters – small vessels with a shallow draft, designed for short passages:

1. Between ports, sometimes including passages along rivers and canals. Usually they carry bulk and general cargo.
2. General Dry cargo ships – these types of vessels are designed to carry any type of cargo not in containers, such as wood, steel products, bulk cargo or cargo in packages. They are built with a tween deck, using a double hull scheme.
3. MPV – dry cargo vessels equipped with cranes with a lifting capacity of up to 100 tons, capable of carrying cargo in containers and bulk cargo. Typical design features include a tween deck and pontoons with cargo hold covers.
4. Multi-purpose project carriers – often called heavy-lift MPVs. Designed to carry non-standard cargo, turbines and blades, the design

features one or two box-shaped holds and a pair of cranes for tandem operation.

5. Open-hatch general dry cargo ships – large dry cargo ships with U-shaped holds, designed to carry timber, paper, bulk cargo, and non-standard cargo. Usually equipped with ship cranes.

The future of sea freight is in MVPs, multifunctionality and targeting of transportation, together with optimization of transportation, market research and export-import procedures, as well as route optimization and high-quality and also modern ship designs will reduce fuel consumption and carbon dioxide emissions into the atmosphere.

In relation to the Southeast Asian market, any of the five MPV types is appropriate and effective to use in this environment and with these import-export relations in this region, since they are multifunctional and suitable for the transportation of most cargo in this region. Of course, in combination with an effective and optimized logistics scheme and transportation chains. It is also possible to imagine the development of multi-purpose vessels, research of these vessels and their construction in Southeast Asia, since the manufacturing concerns of Southeast Asia have the necessary capacity to produce any of the above types of vessels.

Coaster "Willson Dublin" is a multifunctional vessel, capable of transporting both bulk cargo and packaged cargo (cellulose, coal and magnesite in bags), as well as containers. Taking into account the experience – each cargo transportation is ballastless, for loading the maximum mass of cargo, and also taking into account the modern service of the engine room, market monitoring by the Norwegian company Wilson, which implies optimization of logistics transportation to the most possible economically advantageous voyages, together with qualified personnel, optimization of the route planning of sea passages and the most efficient use of the propulsion system of the vessel will reduce the consumption of marine fuel.

3. Conclusion

1. It has been established that with an increase in the vessel speed, the EEOI increases and the deviation from the design coefficient of the vessel's energy efficiency also increases. A decrease in the vessel speed leads to a decrease in the EEOI, which characterizes the transition as energy efficient,

which is a positive factor both for improving the economic indicators of the voyage and for protecting the environment.

2. It has been determined that with an increase in the cargo mass, the EEOI decreases and asymptotically approaches the EEDI, with a decrease in the cargo mass, the EEOI value increases and with a further decrease in the cargo mass down to zero, the EEOI tends to infinity, which negatively affects the economic and environmental indicators of the sea passage.

Possible to imagine the development of multi-purpose vessels, research of these vessels and their construction in Southeast Asia, since the manufacturing concerns of Southeast Asia have the necessary capacity to produce any of the above types of vessels.

3. It has been determined that with an increase in the cargo mass, the EEOI decreases and asymptotically approaches the EEDI, with a decrease in the cargo mass, the EEOI value increases and with a further decrease in the cargo mass down to zero, the EEOI tends to infinity, which negatively affects the economic and environmental indicators of the sea passage. Based on the conducted research, it has been determined that in the practice of sea cargo transportation, "ballast", "idle" transitions should be abandoned and sea transportation should be carried out only with the maximum load of ships.

4. It has been established that regardless of the types and designs of the vessels used and the designs of the ship power plants, the dependences of the EEOI on the vessel speed, the mass of the transported cargo, as well as their additive values are qualitatively described by the same congruent regularities, the quantitative vaues of the EEOI should be determined by calculation studies separately in each specific case.

5. In the future, it is necessary to develop a feasibility study for "ballast-free" sea cargo transportation in each specific case, design and create multi-purpose specialized vessels intended for “ballast-free” sea cargo transportation.

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