Časopis Pomorskog fakulteta Kotor – Journal of Maritime Sciences (JMS)
god. 23, br. 1/2022. Vol. 23, No. 1/2022; May, 2022

DOI: https://doi.org/10.56080/jms220510 UDC: 502.171:656.61
Review paper

GHG Abatement Potential Due to the Implementation of Slow Steaming*

Nastia Degiuli, Andrea Farkas, Ivana Martić, Ivan Gospić

Abstract: All branches of industry as well as the maritime transport industry are encountering the challenge of reducing greenhouse gas (GHG) emissions to prevent hazardous climate change. The ratification of the Paris agreement has set a restrain for global average temperature significantly lower than 2 °C and preferably restrains the growth to 1.5 °C compared to preindustrial levels. Therefore, International Maritime Organization (IMO) has imposed an aim to decrease carbon dioxide (CO_2) emissions per transport work by a minimum of 40 % by 2030 and to 70 % by 2050 compared to 2008. IMO has proposed various short-term, mid-term, and long-term measures for accomplishing this aim. Speed reduction i.e., slow steaming is a crucial short-term measure, that can be effortlessly implemented, and does not depend upon any supplementary infrastructure. Even a slight speed reduction will lead to substantial fuel reduction and therefore substantial CO_2 abatement considering the hypothesis that ship speed and fuel oil consumption are related with the cubic function. The implementation of slow steaming leads to a larger voyage time and consequently to a larger number of ships to attain yearly transport work constant. Therefore, it is essential to analyse the increase in fuel oil consumption and CO_2 emissions due to the larger number of ships engaged in maritime transport. This paper provides an extensive review of slow steaming and GHG abatement potential and points out the disadvantages of its application.

Keywords: ship energy efficiency, GHG emissions, fuel oil consumption, slow steaming, maritime transport industry.

1. Introduction

Climate change represents one of the most important issues in the 21st century and it consists of global warming caused by humans as well as the large-scale impact of global warming on weather patterns. The main cause of climate change is the emissions of greenhouse gas (GHG), mostly carbon dioxide (CO_2) and methane (CH_4), and among other things, one can monitor

---

[*] An earlier version of this paper was presented at the 1st Kotor International Maritime Conference – KIMC 2021, Kotor, Montenegro.

climate change through the increase in the global average temperature. The increase in the global temperatures increases the rate of evaporation, which then leads to more severe storms as well as weather extremes [1]. Furthermore, changes in climate impact ecosystems through the relocation or biological annihilation of species due to changes of the environment, and it endangers humans with food and water scarcities, floods, infectious diseases, high temperatures, financial loss, as well as the forced movement of people. These influences on people have forced the World Health Organization to declare climate change an utmost danger to worldwide health in the 21st century [2]. The increase in the global average temperature can be noticed in Figure 1, where a simulated and observed change in annual average global surface temperature is shown [1]. Currently, the increase in the global average temperature is about 1.2 °C in comparison to pre-industrial levels.

The need for climate action is increasingly emphasized and urgent. One of the most important documents related to climate action is the Paris Agreement adopted in 2015. At the United Nations (UN) Conference on Climate Change held in Paris in 2015, 196 members participated in the negotiations on the Paris Agreement. The ratification of the Paris Agreement started on 22nd April 2016, and it became obligatory on 4th November 2016. Since October 2021, 192 members of the UN Framework Convention on Climate Change are included in the agreement. It should be noted that the United States retracted from the Agreement in 2020 but re-joined in 2021. The ratification of the Paris agreement has set a restrain for global average temperature significantly lower than 2 °C and preferably restrains the growth to 1.5 °C compared to preindustrial levels [3], which would substantially decrease the effects of climate change. To achieve these aims, GHG emissions should be reduced immediately and attain net-zero by 2050.

In 2016, 73.2 % of global GHG emissions are caused by the energy sector, 18.4 % from agriculture, forestry, and land use, 5.2 % from direct industrial processes, and 3.2 % from waste. The energy sector is the leading GHG emitter, and these emissions can be classified into several categories. Thus, 24.2 % of global GHG emissions are caused by energy use in industry, 16.2 % from the transport sector, 17.5 % from energy use in buildings, 7.8 % from unlocated fuel combustion, 5.8 % from fugitive emissions from energy production, and 1.7 % from energy use in agriculture and fishing [4].

GHG emissions from the transport sector are very important and their reduction is necessary. Maritime transport is the most important part of globalized trade considering that more than 80 % of world trade is conducted at sea by 98140 ships of 100 gross tons (GT) and above, having more than 2 billion dead-weight tonnage (DWT) and sailing under flags of 150 countries [5]. The majority of the world's fleet uses carbon-based fuels causing GHG emissions. The fourth International Maritime Organization (IMO)

GHG study stated that the portion of emissions caused by ships in global anthropogenic emissions has raised from 2.76 % in 2012 to 2.89 % in 2018 [6]. What is more, it is predicted that emissions will increase from approximately 90 % of 2008 emissions in 2018 to 90-130 % of 2008 emissions by 2050 for various possible long-term economic and energy scenarios. The reduction of emissions growth can be accomplished with further steps regarding the ship energy efficiency and its emissions [6]. Thus, IMO has proposed an aim to decrease carbon dioxide (CO_2) emissions per transport work by a minimum of 40 % by 2030 and to 70 % by 2050 compared to 2008 [7]. In addition to GHG emissions, the maritime transport industry significantly contributes to the non-GHG emissions i.e., sulfur dioxides and nitrogen oxides, which are detrimental to the environment [8].

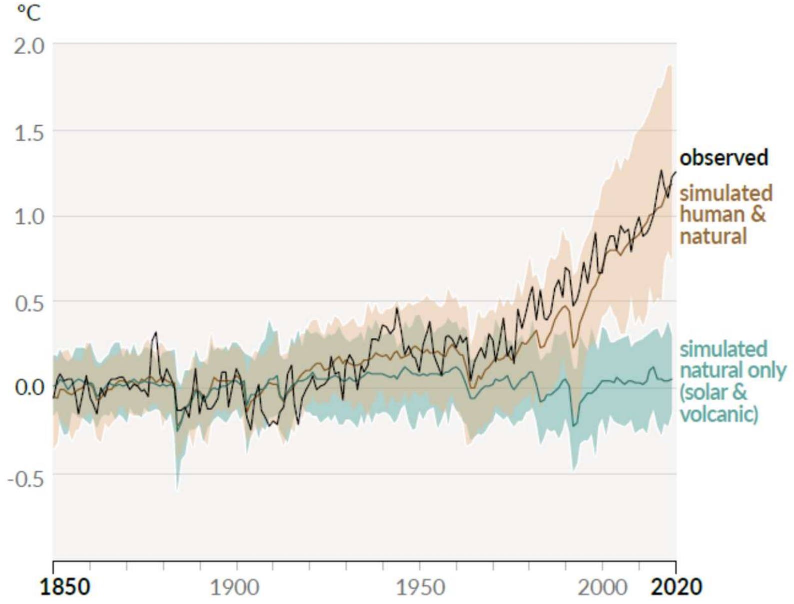

Fig. 1 – *Change in annual average global surface temperature [1].*

2. Measures for reducing GHG emissions in the maritime transport industry

Various measures have been suggested by IMO from 2011 onward to curb CO_2 emissions from the maritime transport industry. Thus, the Energy Efficiency Design Index (EEDI) is introduced for new ships and keeping the Ship Energy Efficiency Management Plan (SEEMP) onboard is obligatory for both new and existing ships. Also, data regarding the fuel oil consumption (FOC), and the other significant data must be collected for ships having 5000 GT and above. Furthermore, it was suggested that the operational performance of ships, which can be examined with the Energy Efficiency Operational Indicator (EEOI) or some additional indicators, should be monitored [9].

To achieve a reduction in GHG emissions several possible short-term, mid-term, and long-term measures were proposed. Thus, candidate measures listed in Initial IMO Strategy [7] should be within the following timelines: short-term measures should be completed and agreed by the Committee between 2018 and 2023, mid-term measures between 2023 and 2030, and long-term measures beyond 2030. Possible candidates for short-term measures are:

- additional development of EEDI and SEEMP,
- advancement of technical and operational measures for energy efficiency of both new and existing ships,
- introduction of an Existing Fleet Improvement Programme,
- speed optimization/speed reduction,
- addressing CH_4 emissions as well as emissions of Volatile Organic Compounds,
- advancement of policies and strategies to address GHG emissions from international maritime transport,
- continuing and enhancing technical cooperation and capacity-building activities,
- considering and analysing measures to stimulate port developments and activities globally to facilitate the decrease in GHG emissions from maritime transport,
- R&D activities regarding marine propulsion, alternative low-carbon, and zero-carbon fuels, as well as innovative technologies for enhancing ship energy efficiency,
- motivations for first movers to develop and embrace new technologies,
- development of robust lifecycle GHG/carbon intensity guidelines for all types of fuels,
- actively promoting the work of the Organization to the international community, undertaking additional GHG emissions studies, and considering other studies to inform policy decisions.

Possible candidates for mid-term measures are:

- a program for the efficient implementation of low-carbon and carbon-free alternative fuels,
- operational energy efficiency measures for both new and existing ships,

- new mechanism for emissions reduction possibly including Market-based Measures,
- additional continuation and enhancement of technical cooperation and capacity-building activities,
- development of a feedback mechanism to enable lessons learned on the implementation of measures to be collated and shared through possible information exchange on best practices.

Finally, the potential candidates for long-term measures are pursuing the development and supply of carbon-free or fossil-free fuels and stimulation and facilitation of the general adoption of other possible new/innovative emissions reduction mechanisms [7].

Usually, the measures for GHG abatement are classified into technological and operational measures [9]. Additionally, alternative fuels and energy sources represent a third category of mitigation measures, which can be considered the independent one [10]. However, mitigation measures can be classified differently. Bouman et al. [11] presented a classification of mitigation measures in five categories including hull design, power & propulsion system, alternative fuels, alternative energy sources, and operation. The authors also presented the CO_2 reduction potential of each measure from a certain category, based on the detailed literature review. Eide et al. [12] concluded that speed reduction, the utilization of natural gas as a marine fuel, waste heat recovery, and contra-rotating propellers are measures with the highest CO_2 reduction potential, among 25 analysed measures. The classification of mitigation measures is shown in Figure 2.

As explained within [13], technological or technical measures achieve CO_2 reduction through the utilization of enhanced hardware, while operational measures achieve this aim through operational effort. Environmentally friendly fuels and alternative power sources can be considered technological measures since they include modified hardware and new designs. However, commercial and legal frameworks are also very valuable courses for the encouragement of the implementation of mitigation measures. They do not reduce ship's emissions directly; however, they encourage ship owners or ship operators to implement mitigation measures to fulfill these regulations.

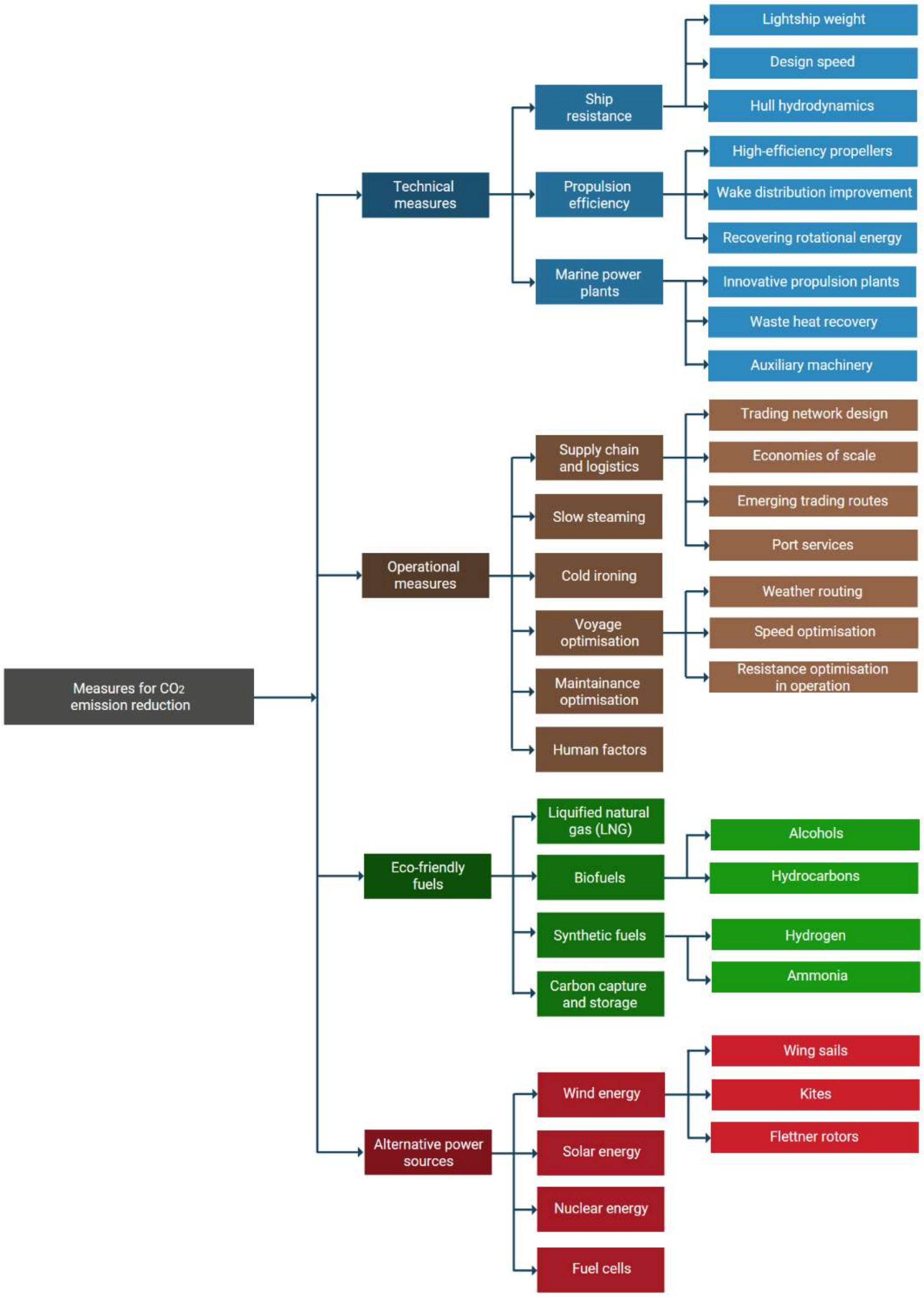

Fig. 2 – *Mitigation measures within the maritime transport industry [13].*

Even though there are a lot of possible mitigation measures, questions are being raised about which pathway could assist the maritime transport industry to accomplish goals defined within the Initial IMO Strategy [7]. Namely, to adopt a particular measure of energy savings, shipping companies consider the return on the investment [14]. Consequently, only a several of the listed measures are practically applied, and the most implemented ones are bulbous bow, energy-saving devices, tuning, derating, and waste heat recovery of ship engines [15]. A comprehensive review of mitigation measures for CO_2 emissions in the maritime transport industry is presented in [13], where the authors reviewed 268 studies. The authors demonstrated that the economic and legal frameworks are so far major challenges for the implementation of mitigation measures. Therefore, the CO_2 emissions reduction potential of certain mitigation measure must be observed from an economic perspective as well. There are also additional parameters that should be taken into account before applying certain mitigation measure. For example, the application of slow steaming has already started, which can be noticed from the obtained containership operating profiles [16]. However, it is crucial to point out that due to the application of slow steaming, ships are operating in conditions significantly different from those for which they were designed and optimized [17]. Therefore, additional investigations related to ship hydrodynamic performance for slow steaming conditions, as well as to the engine operation in such conditions would be beneficial.

3. Slow steaming as a mitigation measure for GHG abatement

To preserve and encourage the development of the maritime transport industry, which was significantly affected in 2008 because of the worldwide economic recession as well as reduced demands for maritime transport, several measures were adopted by ship owners/ship operators. One of the possible measures is slow steaming i.e., sailing at a lower speed than the design speed [18]. The adoption of slow steaming is directly related to saving fuel costs and is introduced by almost all worldwide shipping companies if the shipping market is slugged. The reduction of fuel costs arises from the fact that required power and consequently fuel consumption is nearly related to ship speed with a cubic function.

The reductions in fuel consumption as well as CO_2 emissions range from 20 % to 40 %, or even above 60 %, depending on the percentage of speed reduction [10, 19]. Slow steaming has other benefits which are related to the adaptability to increase the speed to prevent the detrimental effects of the randomness of port times, which then improves the service quality [20]. The selection of the optimal speed represents a dynamic process that includes balancing advantages and disadvantages. Thus, the benefits of speed reduction largely depend on charter rates and fuel prices, and the highest savings are achieved if the fuel price is high, and charter rates are low [21]. Tillig et al. [22] analysed the impact of speed reduction on a decrease in fuel consumption and on the environment. The study is carried out for a containership sailing on a Pacific Ocean trade route. The authors demonstrated that an increase in fuel price will cause significant economic motivation for speed reduction in liner traffic. Degiuli et al. [23] presented the benefits of slow steaming for a containership on a sailing route through the Mediterranean Sea. The authors estimated the decrease in fuel consumption and CO_2 emissions both in calm water and in waves due to the application of this short-term measure. Shipowners or ship operators will utilize speed reduction, only if the saved fuel cost is higher than the incurred capital and operating costs [24]. Therefore, it is worthwhile to analyse the critical fuel prices at various speeds to determine the optimal speed.

Adland et al. [25] developed an adaptable framework for the assessment of the relationship between fuel consumption and speed. The authors have demonstrated that the cubic relationship between fuel consumption is accurate only around the design speed. Furthermore, the speed exponent can be significantly lower at the speeds which were noticed in noon reports. Berthelsen and Nielsen [26] analysed the relation between speed and required power using a coupled econometric and naval architecture data-driven model based on the operational data from noon reports. The authors showed that the speed power exponent is substantially lower than three at lower ship speeds. This is important for the discussions regarding the advantages of slow steaming since the introduction of slow steaming may not be beneficial as commonly stated. Taskar and Andersen [27] investigated fuel savings related to speed reduction using detailed modelling of ship performance. The authors concluded that the classical cubic law can be a source of a substantial error in the determination of fuel consumption. Furthermore, the authors demonstrated that savings in fuel consumption due to the application of slow steaming depend on weather conditions. Medina et al. [28] estimated the total resistance and the fuel consumption for containerships at full load, taking into account the impact of wind and waves according to the Beaufort scale. Since added resistance in waves has a substantial effect on fuel consumption, the authors presented the wind and wave hindcast climate information as well as the increases in added resistance for these conditions to allow a more accurate ''a priori'' assessment of fuel consumption.

A very important review regarding the ship voyage optimization based on the control of emissions is presented within [29]. In [29] a careful review of the recent articles regarding the voyage optimization driven by emissions is presented and the investigation of the state-of-art and additional identification of possible future work are presented. Lashgari et al. [30] proposed a scenario-based stochastic linear integer programming model which considers routing, sailing speed, and bunkering policy under the uncertainty of fuel price together. They demonstrated that the proposed model could achieve a reduction in total costs and provide acceptable decisions regarding speed and route optimizations. Ng [31] analysed the relationship between the sailing speed and the number of ships required to attain yearly transport work constant. The author demonstrated that there is only a limited choice regarding the number of ships to deploy.

Even though there are lots of benefits related to the introduction of slow steaming, there are many concerns related to a mandatory slow steaming policy. The most important concern is related to the fact that slow steaming will result in an increased voyage time, weakened just-in-time delivery service, and reduced yearly ship's number of voyages, which could result in the risk of distorting the market. The increase in voyage time is of particular importance for cold chain logistics, such as fresh fruit, vegetables, and meats since increased voyage time could lead to degradation of product quality and higher energy consumption for refrigeration [32]. Furthermore, slow steaming could alter transport because of increased voyage time, and traders could choose air or road transport as an alternative, which is inopportune from an environmental point of view [13]. Also, the world fleet could expand, and capital investments could increase due to the mandatory slow steaming since a higher number of ships would be necessary to attain the yearly transport work constant [13]. Even though increased voyage time associated with lower speeds means more ships or load is required to attain yearly transport work constant, a 10 % reduction in speed may result in a total average emissions reduction of 19 % [33, 34]. Finally, ships would operate in conditions that are significantly different from those for which they were designed and optimized [17]. This is of particular importance for engine operation since the application of slow steaming causes the engine to operate at lower loads. Guan et al. [35] demonstrated the significance of blower activation at lower loads, and the fact that without it, a significant increase in exhaust gas temperature and thermal loading would occur. Besides the operation of the main engine, which needs to be carefully investigated under the lower loads, there is the requirement for optimization of auxiliary systems to improve the energy efficiency [36].

Consequently, several technical, market, and economic factors including voyage number, chartering time, customer demand, and additional operational costs will impact the slow steaming. Mandatory slow steaming would result in reduced CO_2 emissions from the maritime transport industry. However, the imposition of mandatory application of slow steaming would significantly impair the sustainable growth of the maritime transport industry in the longer term since the application of slow steaming does not encourage innovative novel technologies for emission mitigation [13]. On the other hand, policies regarding speed reduction could be introduced within the regulatory framework based on fair markets and voluntary actions, without the necessity of becoming a mandatory regulation [37]. To familiarize the application of slow steaming, several future studies should be carried out. These studies should be related to the investigations of off-design conditions, firstly from a hydrodynamic point of view, but from an engine and structural point of view as well.

4. Conclusion

One of the most important issues in the 21st century is climate change, which is caused by the emissions of greenhouse gas and as a result has the rise in the global average temperature. To preclude detrimental climate change all branches of industry including maritime transport are dealing with the challenge of reducing emissions. The important step regarding the climate action is surely the ratification of the Paris agreement, which has set a restrain for global average temperature significantly lower than 2 °C and preferably restrains the growth to 1.5 °C compared to preindustrial levels. Since the maritime transport industry produces 2.89 % of global anthropogenic emissions, it is very important that certain steps towards curbing shipping emissions are made. Therefore, International Maritime Organization (IMO) has imposed an aim to decrease carbon dioxide (CO_2) emissions per transport work by a minimum of 40 % by 2030 and to 70 % by 2050 compared to 2008. Furthermore, several mitigation measures are proposed, which can be classified into short-term, mid-term, and long-term measures. It should be noted that only a few of them are applied in practice since shipping companies consider the return on the investment before adopting a particular measure of energy savings. What is more, many mitigation measures are in the early stage of development, and the maritime transport industry accepts their application very gradually. Speed reduction i.e., slow steaming is a crucial short-term measure, that can be effortlessly implemented, and does not depend upon any supplementary infrastructure. This paper provides an extensive review of slow steaming and GHG abatement potential and points out the disadvantages of its application. Also, it includes the discussion of whether the mandatory slow steaming policy should be introduced. Finally, some proposals for further considerations of the slow steaming policy are provided.

5. Acknowledgments

This study has been fully supported by the Croatian Science Foundation under project IP-2020-02-8568.

References

[1] Intergovernmental Panel on Climate Change, Climate Change 2021. The Physical Science Basis. Working Group I contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, 2021.

[2] World Health Organisation, WHO calls for urgent action to protect health from climate change – Sign the call, https://www.who.int/news/item/06-10-2015-who-calls-for-urgent-action-to-protect-health-from-climate-change-sign-the-call , accessed 26th October 2021.

[3] United Nations, The Paris Agreement, https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement , accessed 26th October 2021.

[4] Our World in Data, Emissions by sector, https://our-worldindata.org/emissions-by-sector , accessed 26th October 2021.

[5] United Nations Conference on Trade and Development, 2019. Review of Maritime Transport. Geneva: United Nations.

[6] International Maritime Organisation, 2014. Third IMO Greenhouse Gas Study 2014. IMO, London.

[7] Marine Environment Protection Committee, 2018. 72/71/Add.1. Initial IMO Strategy on Reduction of GHG Emissions from Ships. IMO, London.

[8] Farkas, N. Degiuli, I. Martić, and M. Vujanović, “Greenhouse gas emissions reduction potential by using antifouling coatings in a maritime transport industry,” J Clean Prod, Vol. 295, 2021, 126428.

[9] S. Zhang, Y. Li, H. Yuan, and D. Sun, “An alternative benchmarking tool for operational energy efficiency of ships and its policy implications,” J Clean Prod, Vol. 240, 2019, 118223.

[10] V. N. Armstrong, “Vessel optimisation for low carbon shipping,” Ocean Eng, Vol. 73, 2013, pp. 195-207.

[11] R. A. Halim, L. Kirstein, O. Merk, L. M. Martinez, “Decarbonization Pathways for International Maritime Transport: A Model-Based Policy Impact Assessment,” Sustainability, Vol. 10, No. 7, 2018, 2243.

[12] E. A. Bouman, E. Lindstad, A. I. Rialland, and A. H. Strømman, “State-of-the-art technologies, measures, and potential for reducing GHG emissions from shipping–A review,” Transport Res D-Tr E, Vol. 52, 2017, pp. 408-421.

[13] M. S. Eide, C. Chryssakis, and Ø. S Endresen, “CO2 abatement potential towards 2050 for shipping, including alternative fuels,” Carbon Manag, Vol. 4, No. 3, 2013, pp. 275-289.

[14] H. Xing, S. Spence, and H. Chen, "A comprehensive review on countermeasures for CO2 emissions from ships," Renew Sust Energ Rev, Vol. 134, 2020, 110222.

[15] A. Farkas, N. Degiuli, and I. Martić, "Impact of biofilm on the resistance characteristics and nominal wake," P I Mech Eng M-J Eng, Vol. 234, No. 1, 2020, pp 59-75.

[16] N. Rehmatulla and T. Smith, "Barriers to energy efficient and low carbon shipping," Ocean Eng, Vol. 110, 2015, pp. 102-112.

[17] C. Banks, O. Turan, A. Incecik, G. Theotokatos, S. Izkan, C. Shewell, and X. Tian, "Understanding ship operating profiles with an aim to improve energy efficient ship operations," In Proceedings of the low carbon shipping conference, London (Vol. 9), September 2013.

[18] T. Tezdogan, Y. K. Demirel, P. Kellett, M. Khorasanchi, A. Incecik, and O. Turan, "Full-scale unsteady RANS CFD simulations of ship behaviour and performance in head seas due to slow steaming," Ocean Eng, Vol. 97, 2015, pp. 186-206.

[19] H. Lindstad and G. S. Eskeland, "Low carbon maritime transport: how speed, size and slenderness amounts to substantial capital energy substitution," Transport Res D-Tr E, Vol. 41, 2015, pp.244–256.

[20] IMO. Introduction to IMO. http://www.imo.org/en/About/Pages/Default.aspx, accessed 26 October 2021.

[21] C. Y. Lee, H. L. Lee, and J. Zhang, "The impact of slow ocean steaming on delivery reliability and fuel consumption," Transport Res E-Log, Vol. 76, 2015, pp. 176-190.

[22] C. C. Chang and C. M. Wang, "Evaluating the effects of speed reduce for shipping costs and CO2 emission," Transport Res D-Tr E, Vol. 31, 2014, pp.110–115.

[23] F. Tillig, J. W. Ringsberg, H. N. Psaraftis and T. Zis, "Reduced environmental impact of marine transport through speed reduction and wind assisted propulsion," Transport Res D-Tr E, Vol. 83, 2020, 102380.

[24] N. Degiuli, I. Martić, A. Farkas and I. Gospić, "The impact of slow steaming on reducing CO2 emissions in the Mediterranean Sea," Energy Reports, Vo. 7, 2021, pp. 8131-8141.

[25] W. M. Wu, "The optimal speed in container shipping: Theory and empirical evidence," Transport Res D-Tr E, Vol. 136, 2020, 101903.

[26] R. Adland, P. Carriou, and F. C. Wolff, "Optimal ship speed and the cubic law revisited: Empirical evidence from an oil tanker fleet," Transport Res D-Tr E, Vol. 140, 2020, 101972.

[27] F. H. Berthelsen and U. D. Nielsen, "Prediction of ships' speed-power relationship at speed intervals below the design speed," Transport Res D-Tr E, Vol. 99, 2021, 102996.

[28] B. Taskar and P. Andersen, "Benefit of speed reduction for ships in different weather conditions," Transport Res D-Tr E, Vol. 85, 2020, 102337.

[29] J. R. Medina, J. Molines, J. A. González-Escrivá and J. Aguilar, "Bunker consumption of containerships considering sailing speed and wind conditions," Transport Res D-Tr E, Vol. 87, 2020, 102494.

[30] H. Yu, Z. Fang, X. Fu, J. Liu and J. Chen, "Literature review on emission control-based ship voyage optimization," Transport Res D-Tr E, Vol. 93, 2021, 102768.

[31] M. Lashgari, A. A. Akbari, and S. Nasersarraf, "A new model for simultaneously optimizing ship route, sailing speed, and fuel consumption in a shipping problem under different price scenarios," Appl Ocean Res, Vol. 113, 2021, 102725.

[32] M. Ng, "Vessel speed optimisation in container shipping: A new look," J Oper Res Soc, Vol. 70, No. 4, 2019, pp. 541-547.

[33] P. Balcombe, J. Brierley, C. Lewis, L. Skatvedt, J. Speirs, A. Hawkes, and I. Staffell, "How to decarbonise international shipping: Options for fuels, technologies and policies," Energy Convers Manag, Vol. 182, 2019, pp. 72-88.

[34] J. Faber, H. Wang, D. Nelissen, B. Russell, and D.S. Amand, "Reduction of GHG emissions from ships: marginal abatement costs and cost effectiveness of energy-efficiency measures," London, UK: International Maritime Organization (IMO), 2011.

[35] C. Guan, G. Theotokatos, P. Zhou, and H. Chen, "Computational investigation of a large containership propulsion engine operation at slow steaming conditions," Appl Energ, Vol. 130, 2014, pp. 370-383.

[36] C. Dere, and C. Deniz, "Load optimization of central cooling system pumps of a container ship for the slow steaming conditions to enhance the energy efficiency," J Clean Prod, Vol. 222, 2019, pp. 206-217.

[37] H. N. Psaraftis, "Speed Optimization vs Speed Reduction: the Choice between Speed Limits and a Bunker Levy," Sustainability, Vol. 11, No. 8, 2019, 2249.

Submitted: 14/03/2022
Accepted: 23/04/2022

Nastia Degiuli
Email: nastia.degiuli@fsb.hr

Andrea Farkas
Email: andrea.farkas@fsb.hr

Ivana Martić
Email: ivana.martic@fsb.hr

University of Zagreb,
Faculty of Mechanical Engineering
and Naval Architecture,
I. Lučića 5, 10002 Zagreb,

Ivan Gospić
University of Zadar,
Department of Maritime Sciences,
Ulica Mihovila Pavlinovića 1, 23000 Zadar,
Email: igospic@unizd.hr