Short Review Fuel Efficiency for The Ship Energy Management Plan

Muhammad Arif Budiyanto[1*], *Ivan Dewanda* Dawangi[1], *Achmad Riadi* and *Dimas Angga Fakhri* Muzhoffar[1]

[1]Departement of Mechanical Engineering, Universitas Indonesia Depok, Jawa Barat, Indonesia. 16424

Abstract. This paper examines a short review of the literature regarding fuel-efficient operations that can be applied to the development of environmentally friendly shipping both on ships and in ports. The study was conducted using a literature review method, completed through an iterative cycle of defining appropriate search keywords, searching the literature, and ending the analysis. This research stage starts with selecting the topic to be reviewed, tracking and selecting relevant articles, and analyzing and synthesizing the literature. The results of the three types of methods that have been studied, namely ship operator skills training, voyage optimization, and cold ironing, have obtained factors that influence each technique as well as developments that can be carried out in the future and applied to Indonesian ports as well as possible benefits of implementation in medium to small sized ports.

1 Introduction

Developing environmentally friendly shipping operations is still a big challenge for developing countries due to a lack of attention. Meanwhile, the increase in shipping activities, especially cargo delivery, means that CO2 gas emissions resulting from shipping activities are also increasing (Budiyanto, Huzaif, & Juanda Sirait). Ship fuel consumption is influenced by many factors, such as regulations regarding emission control areas, berth allocation, irregular weather and hydrological conditions, fuel prices, sailing time, and shipping speed (Yu, Fang, Liu, & Chen).
Among the available practices, this paper chooses fuel-efficient operation as the focus of SEEMP development because it is easier to adapt. Optimal fuel consumption can reduce bunkering expenditure, energy consumption, and CO2 emissions (Lashgari, Akbar Akbari, & Nasersarraf). Many factors can be considered for fuel-efficient operations, such as the development of shipping planning, which can be achieved using the help of various software, weather routing for specific routes and trade areas, punctuality, or good communication with the port to provide maximum notification regarding the availability of berths and facilitating the use of optimal speed to maximize efficiency and minimize delays, speed optimization while coordinating with berth availability for loading and unloading activities, and shaft

* Corresponding author: arif@eng.ui..ac.id

power optimization using an automatic engine management system to control speed quickly and efficiently. Other factors contributing to SEEMP and needing further research are optimized ship handling (trim, ballast, rudder, hull, and propulsion systems), environmentally friendly fuel types, and even the ship's operational life. (MEPC 70/18/Add.1 Annex 10, 2016 Guidelines for developing a Ship Energy Efficiency Management Plan).
A study on developing a Ship Energy Efficiency Management Plan (SEEMP) using machine learning discusses several options for minimizing CO2 emissions during manoeuvres, port pools, and berthing or loading and unloading, which comprise fuel-saving operations. Although cold ironing can reduce CO2 emissions by up to 20%, not all ports can provide it. Hence, a combination of shipping optimization methods complemented by trained operators is essential to achieve the required level of emission reduction. (Dewanda Dawangi & Budiyanto).
This paper attempts to conduct a short review of several studies that have been carried out previously regarding various fuel-efficient operations, including the development of ship operator skills, shipping optimization systems, and the implementation of cold ironing. It then tries to look at the challenges faced in its implementation along with the available solutions and research potential that needs to be developed in the future.

2 Literature Review

The SEEMP is a ship energy use plan used as a milestone in energy efficiency development by ship owners. It must reflect efforts to improve ship energy efficiency through four steps: planning, implementation, monitoring, evaluation, and improvement. Many companies have implemented environmental management systems under ISO 14001, which contain procedures for selecting the best size for a particular vessel and establishing objectives for relevant parameter measurements, control features, and feedback. (Witten, Frank, & Hall, 2011). Among the many available practices, this paper selects fuel-efficient operations as the focus of SEEMP development because they are easier to adapt. Many factors can be considered for fuel-efficient operations, such as better trip planning, which can be achieved with the help of different software, weather routing for specific routes and trade areas, punctuality, or good communication with ports to provide maximum notice regarding berth availability and facilitating the use of optimal speed to maximize efficiency and minimize delays, speed optimization while coordinating with loading or unloading berth availability, and optimized shaft power using an automatic engine management system to control speed. Other factors contributing to SEEMP and requiring further research are optimized ship handling (trim, ballast, rudder, hull, and propulsion systems), fuel type, and ship operational life. (MEPC 70/18/Add.1 Annex 10, 2016 Guidelines for the Development of a Ship Energy Efficiency Management Plan (SEEMP))

Sailing optimization is reducing drag below specified limits by optimizing ship routing, speed, scheduling, ballast, and trim. It uses safe handling, fuel consumption, seaworthiness, time spent in port, route and distance from origin to destination, and the service time written in the contract as key constraints (Xing, Spence, & Chen, 2020). Combining weather routing and speed optimization for maneuvering in ports can help reduce the time required and CO2 emissions. Unlike slow steaming, speed optimization will adjust the speed required to arrive at the dock for on-time arrival. At the same time, weather routing creates the most efficient route rather than simply reducing speed to the pier, which doesn't seem desirable in any case. time holds higher importance. This will not only reduce CO2 emissions but also prevent waiting times. Communication with the port in providing schedules and information regarding when and which berths are available will be the primary key to this plan.

Cold ironing is the practice of providing a source of electricity from shore to a ship during the berthing process. Ships can turn off diesel generators during the berthing process, which takes the longest time in port; this will greatly reduce the ship's CO2 emissions. Because cold ironing can be done using low-carbon or zero-carbon energy sources such as wind and solar energy, it even has the potential to reduce ship CO2 emissions in port by up to 40% (Sciberas, 2016).

Human factors are non-technical factors for fuel-efficient operations. Appropriate skills and knowledge are required by crew members and operators, not only to control the vessel well in every situation but also to be able to fully utilize the installed systems for fuel-saving operating measures. Up-to-date vessel operations training is essential for existing and future operators whenever a new system is to be implemented in the fleet. Ship owners must also be able to make the right decisions regarding ship activities and time spent in port. CO2 emissions can be reduced by increasing energy awareness and operating capabilities by up to 10% (Signe & L., 2018).

3 Research Method

The research was conducted using a literature review method, which was completed through an iterative cycle of defining appropriate search keywords, searching the literature, and completing the analysis (Saunders, Mark, Lewis, & Thornhill, 2009). Previously (Ramdhani, Ramdhani, & Amin, 2014) explained four stages in doing a literature review, including (1). Select the topic to be reviewed (2). Tracking and selecting suitable/relevant articles (3). Carrying out literature analysis and synthesis (4). Organizing the review writing The first stage is determining the topic and keywords to include in the literature search. Most searches were carried out in Google Scholar and ScienceDirect; news sites were also considered when searching for events related to keywords as case examples to study. The literature examined is research regarding developments and various cases in ship operator skills training, shipping optimization, and cold ironing. After filtering, 23 articles were obtained with topics that were suitable for use as references, including a regulation from the MEPC (Marine Environment Protection Committee) and two news articles edited directly from the United States government's NTSB (National Transportation Safety Board) news page and Seatrade Maritime News. The articles selected found multiple problems in developing the three types of fuel-efficient operation, along with efforts to overcome them and develop these methods further. The various research results are summarized and then analyzed in each case; following a discussion of the results obtained, conclusions are drawn regarding developments, problems, research gaps, solutions, and possible research trends in the future. The review is then written and carried out by grouping the various cases with the analysis results for each related fuel-efficient operation, then including the overall analysis results for the potential development of the fuel-efficient operation in the future.

4 Result and Discussion

4.1 Ship Operator Skills Training

The development of the IT (Information Technology) field into navigation equipment and ship operations supporting systems such as AIS (Automated Identification System), ECDIS (Electronic Chart Display Information System), IBS (Integrated Bridge System) or the introduction of e-navigation systems requires the inclusion of related IT technology maritime affairs in every MET (Maritime Education and Training) program (Albayrak & Ziarati). Up-to-date vessel operations training is essential for existing and future operators whenever a new system is to be implemented in the fleet. Ship owners must also be able to make the right decisions regarding ship activities and time spent in port. It is possible to reduce CO2 emissions by increasing energy awareness and operating capabilities by up to 10% (Signe & L., 2018)

The effectiveness of new systems and equipment, such as AIS, depends on the competence of those operating them. However, evidence shows that ship crews are often inadequately trained in using equipment installed on board (Bailey, Ellis, & Sampson). In January 2008 it was reported that the injury list of the passenger ship Crown Princess reached 298 passengers in 2006, caused by "inadequate training of the crew in the use of the integrated navigation system (Crew Mistakes Caused Heeling Of Crown Princess Cruise Ship, 2008). Issue others are highlighted by an article in MER [addressing automation, 2007], which states that it is not impossible to bring today's marine engineers up to the required standards if training can be designed to include synchronizers and cyclo-converters, harmonics and others as an addition to the IMO syllabus existing ones (Ziarati & Ziarati).

One of the challenges faced in improving the skills of ship operators is increasing the number of hours dedicated to each unit for classroom theoretical training and the extensive use of simulators for introducing and improving skills. However, onboard training opportunities offered by shipping companies have reduced significantly in recent years and as commercial pressures in recent years have resulted in minimum crew levels along with increasing levels of automation, the nature and quality of onboard training have changed significantly to get worse (Holland & John, 1997)

In the context of socialization and skill improvement on board ships and simulations to improve crew performance, short training programs built on a balanced MET Curriculum appear to be the most effective model for updating seafarers' knowledge and skills. The new MET program should determine the number of simulator hours and subjects that can replace sea training in specific terms and redefine the sea training periods accordingly. Good simulator training is expected to include realistic scenarios based on previous accidents and incidents or near misses. (Albayrak & Ziarati).

One solution to overcome the problem of location and time factors for training when sailing to face rapidly changing legal policies and the maritime environment is continuous learning using E-learning with online assessment and certification in it. Projects undertaken by the European Union are examples of efforts focused on online assessment and certification. Future projects aim to enlarge the course content to higher certificate levels such as ROC (Restricted Radio Operator), GOC (General Radio Operator) and REO (Radio Electronic Operator) to become a certified teaching and examination center on behalf of the national authority (Albayrak & Ziarati).

An appropriate online MET training program equipped with assessments and certification needs to be created and implemented internationally with standardization. The increasingly advanced development of IT has increased dependence on the internet for ease and speed in exchanging information. This shows how big the opportunity for online training and certification is to be developed and implemented by other countries.

4.2 Voyage Optimization

Sailing optimization reduces drag below specified limits by optimizing a ship's sailing route, speed, scheduling, ballast, and trim. This method uses security measures, fuel consumption, seaworthiness, time spent at the port, route and distance from the origin to destination, and also the service time written in the contract as the primary consideration factors (Xing, Spence, & Chen, 2020) so that it does not It is only necessary for safety when sailing but also the efficiency of shipping activity time and engine power which can influence the amount of CO2 emissions from the ship.

The reliability and applicability of optimal routes is related to the accuracy of hydrodynamic estimates, precise weather forecasts, and the quality of optimization algorithms (Lin, Fang, & Yeung, 2013). Optimization of shipping also involves pairing the most suitable crew and ship, minimizing shipping ballast, optimizing fuel and bunker filling, efficient loading and unloading activities, and rapid recovery from schedule disruptions (Ballou, 2013). Installing sensors and software-based decision support systems is a strategic approach. It is recommended to help reduce maneuvering time (E. Bal Beşikçi, 2016) so that it has the potential to reduce CO2 emissions from ships by up to 10% (Xing, Spence, & Chen, 2020).

Shipping optimization problems relate to interrelated geographical, technological and mathematical modeling problems. The geographic component involves monitoring the current state of the ocean (i.e., waves, ice, and currents) and forecasting dynamics at various spatiotemporal resolutions. The mathematical problems faced refer to ship navigation modeling which takes into account environmental and operational factors. The technological component relates to the methodology and algorithm to complete the determination of the optimal path through selected criteria with many constraints. There are several limitations to current methods for finding optimal shipping. For example, the A* algorithm relies heavily on heuristic parameters (Jeong, 2019)

The models used today are mostly formulated from the perspective of optimization of a voyage. Optimizing multiple voyages in a global shipping network based on spatiotemporal environmental changes and speed variability is a challenge to be faced. Deterministic and heuristic methods can be used to solve the proposed shipping optimization problem with the help of scenario simulation. However, the robustness of the proposed shipping optimization with both model types and solution approaches under uncertain shipping strategies and environmental disturbances needs to be further confirmed. Virtual arrival is a promising new initiative in maritime shipping that requires timely data sharing and accurate predictions of dock operations between ports and ships to avoid "rush for waiting" and reduce fuel costs as well as emissions. It is necessary to carry out further development regarding virtual arrival and its implementation in order to overcome all technical and cultural barriers to implementing ship emission control measures (Yu, Fang, Liu, & Chen).

Research to develop shipping optimization models by considering various specific factors has been widely carried out. One of them (Wang, Lang, & Mao) proposed a trip optimization method that combines the benefits of genetic algorithms and dynamic programming concepts to enable three-dimensional trip optimization in terms of minimum fuel consumption and air emissions. The advantage and contribution of the proposed method is that it can provide recommendations for sailing routes and engine power settings along the journey as direct output to guide practical ship navigation, resulting in fuel savings and emission reductions of an average of 5.6% compared to the actual sailing route and 3. .4% to the heuristic route. In addition (Lashgari, Akbar Akbari, & Nasersarraf) also developed a scenario-based stochastic linear integer programming model for joint bunkering, speed, and route optimization problems that aims to plan routes following bunker operations. This model can not only reduce CO2 emissions due to shipping optimization but can also provide financial considerations for ship fuel costs. Further research is still needed regarding observations of this model in unstable conditions such as natural disasters, extreme weather changes, ship damage, and when ports are full. This research also has not focused on its effect on the environment, such as the amount of CO2 gas emissions produced.

The development of shipping optimization models is still continuing considering how important this system is for ship-owning companies in saving fuel costs while reducing CO2 emissions in order to comply with applicable regulations. Research regarding increasing the efficiency of existing shipping optimization systems will remain the focus of this topic in the future, adding various variables and using various cases as objects of observation needs to continue. The development of virtual arrival for timely and more fuel-efficient shipping requires precise cooperation in exchanging information between ships and ports, the development of fast data exchange methods along with accurate data processing systems is needed for accurate predictions of ship arrivals.

4.3 Cold Ironing

Cold ironing is the practice of providing an electricity source from land (port) to a ship during the berthing process. Ships can turn off the diesel generator during the loading and unloading process which can take the longest time at the port, this will greatly reduce CO2 emissions from the ship itself (Dewanda Dawangi & Budiyanto). Because cold ironing can be carried out using low-carbon or even zero-carbon energy sources such as alternative energy, namely wind and solar, so it has the potential to reduce ship CO2 emissions while in port by up to 40% (Sciberas, 2016).

Indonesia is one of the countries where it is not recommended to supply energy from land because it still relies heavily on fossil fuels for electricity generation so it can suffer significant transmission losses of up to 12.3%. However, because Indonesia consists of a large number of islands, the impact of coastal power plants on CO2 emissions can vary significantly from region to region (William J.). Even so, PT. Pelindo III has reportedly launched an ambitious plan to install shoreside power at all ports across the country under its management by 2020 as part of efforts to reduce logistics costs and fuel imports. Pelindo III has spent approximately $4.9 million to install 35 cold ironing systems at 13 ports and terminals. Pelindo III plans to install more systems in the remaining 30 ports by the end of 2020 (Pelindo III install cold ironing across all Indonesian ports, 2020). Further research is needed regarding the efficiency data of the cold ironing system run by PT. Pelindo III to determine the benefits in terms of saving ship fuel costs and reducing CO2 emissions after using the cold ironing system at the port. The results of this analysis can serve as a reference for decision making in the future development of cold ironing in Indonesia.

Cold ironing technology has also been proven feasible for use in medium-sized ports for smaller vessels than those traditionally connected to shore power. (Innesa & Monios) concluded in a case study of the port of Aberdeen that if all ships could connect to shore power, 108 tonnes of NOx, 2.7 tonnes of PM and 4767 tonnes of CO2 emissions could be saved each year, which is equivalent to £1 .3m external costs.

Regarding the challenges in terms of cable design in small ports, the most efficient system with the least voltage losses is to install individual OPS units for each berth. This system will also save costs by reducing cable requirements. Even so, sufficient space is still needed at the dock for the installation of the substation and the cable reels needed for it to function properly (Innesa & Monios).

Research regarding the influence of policy between each stakeholder is also important to be further developed, as has been done by (Xu, Di, Chen, Shi, & Yang) where the choice of policy regarding land supply systems between the government, ports and shipping companies was observed using evolutionary game method. It was found that each party can change its strategy by observing the strategies taken by other parties, where the government has quite a big influence so that if the government adopts an incentive policy, the port will choose to implement cold ironing more quickly, this will influence shipping companies to make modifications so that can follow this strategy. However, this research only considers whether each party is balanced and can follow each other's strategies, apart from that there are other parties that are no less important, such as companies providing electricity and manufacturing equipment for cold ironing. Research on other parties' policies and their analysis models could be something that will be widely researched in the future for the development of cold ironing implementation.

The amount of capital required to build and operate a cold ironing system is still a problem, especially for medium to small sized ports in developing countries. The participation of the government or local authorities in carrying out environmentally friendly shipping activities by carrying out gradual development through financial assistance or implementing environmentally friendly shipping regulations can be a solution for providing cold ironing systems for ports. Further research on systems that can connect power sources from land to ships with the best possible efficiency could be the focus of future research on cold ironing. Further research regarding the installation of cold ironing for medium to small sized ports can also be considered.

5 Conclusion

Training of ship operators to increase shipping efficiency and awareness for preserving the marine environment is hampered by shipping time problems resulting in a lack of time to conduct training on land. The use of simulators on board ships can be a solution, but the number of shipping companies providing these services has decreased and resulted in a decrease in quality, so the solution that has quite large potential at this time is to take advantage of IT developments, namely through appropriate online MET training programs equipped with assessments. and certification as has been done in Europe. Research is needed regarding the implementation of online training that can be imitated by other countries with standards that can adapt to international standards.

Cruise optimization using sensors and software based on decision support systems is a strategic and recommended approach to help reduce CO2 emissions by increasing maneuver time efficiency. The problems faced include geographic modeling with dynamic forecasting, mathematical problems in shipping modeling which take into account environmental and operational factors, as well as technological components related to methodologies and algorithms for determining optimal routes using selected criteria. The development of a shipping optimization model by considering various factors, such as combining the benefits of genetic algorithms and dynamic programming concepts, as well as developing a scenario-based stochastic linear integer programming model, can not only reduce CO2 emissions as a type of fuel efficient operation but can also help save ship operating costs. taking into account the location and time for bunkering. The development of virtual arrival predictions will have a big role in saving fuel costs and reducing emissions in the port area as part of the development of SEEMP.

Cold ironing is a fuel efficient operation solution method with great potential, but its development and implementation is hampered by the capital problem required to build and run a cold ironing system, especially for medium to small sized ports in developing countries. Government participation in carrying out environmentally friendly shipping activities by carrying out gradual development through financial assistance or implementing environmentally friendly shipping regulations can be a solution for procuring a cold ironing system because government policy has quite a big influence in luring other stakeholders to adopt a cold ironing implementation strategy. Policies taken by other parties such as electric power supply and manufacturing companies as well as the development of cold ironing system designs for medium to small sized piers can be topics for further development.

6 Acknowledgment

The authors also would like to express our gratitude to Directorate Research and Development (DRPM) Universitas Indonesia in providing publication support.

7 References

1. Albayrak, T., & Ziarati, R. (n.d.). Training: Onboard And Simulation Based Familiarisation And Skill Enchancement To Improve The Performance Of Seagoing Crew.
2. Bailey, N., Ellis, N., & Sampson, H. (n.d.). Training and Technology Onboard Ship: How seafarers learned to use the shipboard Automatic Identification System (AIS).
3. Ballou, P. (2013). Ship energy efficiency management requires a total solution approach. Mar. Technol. Soc. J. 47 (1), 83–95.
4. Budiyanto, M. A., Huzaif, M. H., & Juanda Sirait, S. (n.d.). Estimating Of CO2 Emissions In A Container Port Based On Modality Movement In The Terminal Area.
5. Dewanda Dawangi, I., & Budiyanto, M. A. (n.d.). Ship Energy Efficiency Management Plan Development Using Machine Learning : Case Study of CO2 Emissions of Ship Activities at Container Port.
6. E. Bal Beşikçi, O. A. (2016). An artificial neural network based decision support system for energy efficient ship operations. Computers & Operations Research Volume 66, 393-401.
7. Holland, & John, L. (1997). Making Vocational Choices: A Theory of Vocational Personalities and Work Environments, Psychological Assessment Resources Inc.
8. Innesa, A., & Monios, J. (n.d.). Identifying the unique challenges of installing cold ironing at small and medium ports – The case of Aberdeen.
9. Jeong, S. J. (2019). A voyage optimization model of LNG carriers considering boil-off gas . In: OCEANS 2019 MTS/IEEE SEATTLE, IEEE. , 1-7.
10. Lashgari, M., Akbar Akbari, A., & Nasersarraf, S. (n.d.). A new model for simultaneously optimizing ship route, sailing speed, and fuel consumption in a shipping problem under different price scenarios Mahsa Lashgari, Ali Akbar Akbari , Saba .
11. Lin, Y.-H., Fang, M.-C., & Yeung, R. W. (2013). The optimization of ship weather-routing algorithm based on the composite influence of multi-dynamic elements. Applied Ocean Research,Volume 43, 184-194.
12. MEPC 70/18/Add.1 Annex 10, 2016 Guidelines for the Development of a Ship Energy Efficiency Management Plan (SEEMP). (n.d.).
13. Ramdhani, A., Ramdhani, M., & Amin, A. (2014). Writing a Literature Review Research Paper : A step-bystep approach. Insan Akademika Publications, 03(01), 47-56.
14. Saunders, Mark, Lewis, P., & Thornhill, A. (2009). Research methods for business students. Pearson education.
15. Sciberas, E. A. (2016). Cold ironing and onshore generation for airborne emission reductions in ports. . Proceedings of the Institution of Mechanical Engineers, Part M: Journal of Engineering for the Maritime Environment..
16. Signe, J., & L., M. (2018). Energy-efficient operational training in a ship bridge simulator. Journal of Cleaner Production Volume 171, 175-183.
17. Wang, H., Lang, X., & Mao, W. (n.d.). Voyage optimization combining genetic algorithm and dynamic programming for fuel/emissions reduction.
18. William J., H. (n.d.). Assessment of CO2 and priority pollutant reduction by installation of shoreside power.
19. Witten, I., Frank, E., & Hall, M. (2011). Data Mining: Practical Machine Learning Tools and Techniques.
20. Xing, H., Spence, S., & Chen, H. (2020). A comprehensive review on countermeasures for CO2 emissions from ships. Renewable and Sustainable Energy Reviews 134.
21. Xu, L., Di, Z., Chen, J., Shi, J., & Yang, C. (n.d.). Evolutionary game analysis on behavior strategies of multiple stakeholders in maritime shore power system.

22. Yu, H., Fang, Z., Liu, J., & Chen, J. (n.d.). Literature review on emission control-based ship voyage optimization.
23. Ziarati, R., & Ziarati, M. (n.d.). Review of Accidents with Special References to Vessels with Automated Systems – A Forward.