SWOT ANALYSIS OF SHIP ENERGY EFFICIENCY MANAGEMENT PLAN (SEEMP)

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Summary

With large amounts of harmful gases being released into the atmosphere from ships, the maritime industry has come under the scrutiny of regulators, who are becoming increasingly concerned about the problem of global carbon emissions. Carbon emissions could be significantly reduced if operational efficiency on ships is improved, so the International Maritime Organization (IMO) has enacted a series of regulations that will increase the energy efficiency of ships themselves and reduce their environmental impact as much as possible. One of the adopted provisions is the International Energy Efficiency Certificate (IEEC). For a new ship to obtain this certificate (contract placed on or after 1 January 2013), it must meet the Energy Efficiency Design Index (EEDI) and must also have a Ship Energy Efficiency Management Plan (SEEMP). Older ships must have a SEEMP, an operational measure to improve the energy efficiency of ships and applies to all ships of 400 GT or more on international voyages. This paper aims to analyze the plan for improving the energy efficiency management of ships. Furthermore, this paper aims to use SWOT analysis to identify the advantages and disadvantages of SEEMP and propose recommendations for improving energy efficiency management system.

Keywords: SEEMP, EEDI, carbon emissions, shipping

1. INTRODUCTION

As the usage of fossil fuels has accelerated global warming, which has caused many problems, such as climate change, and damage to ecosystems worldwide, there has been a need to reduce emissions [1]. Although the maritime industry is the least polluting of all transport industries, reducing emissions from ships can significantly contribute to solving the problem [2]. Therefore, the International Maritime Organization (IMO) acted through MARPOL and other regulatory instruments to improve ships' energy efficiency, reduce greenhouse gas emissions in shipping, and develop technical (EEDI) and operational measures (SEEMP) for that goal [3,4,5]. Marine Environment Committee (MEPC) deals with environmental issues under the remit of the IMO. The Energy Efficiency Design Index (EEDI) is a technical measure developed to regulate and improve the energy efficiency of newbuild ships and promotes the usage of more energy-efficient and less polluting equipment and marine engines [4,5]. "The EEDI is an index that indicates the energy efficiency of a ship in terms of gCO_2 (generated) / tonne.mile (cargo carried); calculated for a specific reference ship operational condition" [6]. The intention is that by imposing restrictions on this index over time, the need will be created to introduce new energy-efficient technologies in the maritime industry, namely on ships. Shipbuilders and other stakeholders can choose any technology that meets the EEDI requirements for a particular type of ship during shipbuilding. Over time, EEDI will reduce, with plans to create more energy-efficient ships. It applies to all ships engaged on international voyages for which a building contract is placed on or after 1 January 2013. There are Required EEDI and Attained EEDI [6]. To calculate Required EEDI, it is necessary first to obtain Reference EEDI.

Reference EEDI is developed using regression analysis on a large number of data from ships (see Resolution MEPC.231(65) and Resolution MEPC.233(65)). Reference EEDI is calculated using formula (1), where coefficients a, b and c are obtained through regression analysis.

$$Reference\ EEDI = a \times b^{-c} \quad (1)$$

Table 1 presents coefficients a, b and c for some ship types.

Table 1 Coefficients used to determine EEDI Reference value

Ship type	a	b	c
Bulk carrier	961.79	DWT of the ship	0.477
Gas carrier	1120.00	DWT of the ship	0.456
Tanker	1218.80	DWT of the ship	0.488
Container ship	174.22	DWT of the ship	0.201
General cargo ship	107.48	DWT of the ship	0.216
Refrigirated cargo carrier	227.01	DWT of the ship	0.244
Combination carrier	1219.00	DWT of the ship	0.488
Ro-Ro cargo ship (vehicle carrier)	$(DWT/GT)^{-0.7} \times 780.36$ where DWT/GT<0.3	DWT of the ship	0.471
	1812.63 where DWT/GT≥0.3		
Ro-Ro cargo ship	1405.15	DWT of the ship	0.498
Ro-Ro passenger ship	752.16	DWT of the ship	0.381
LNG carrier	2253.7	DWT of the ship	0.474
Cruise passenger ship having non-conventional propulsion	170.84	GT of the ship	0.214

Source: [6]

Required EEDI is calculated based on the following formula (2) [6]:

$$Required\ EEDI = \left(1 - \frac{x}{100}\right) \times (Reference\ EEDI) \quad (2)$$

X is the EEDI reduction factor as agreed and recorded in Regulation 21, and Required EEDI is the limit of the ship's EEDI as per regulations that the actual EEDI must not exceed. As per Regulation 22, the Attained EEDI, which is the actual one, calculated by the shipyard and verified by the Recognized Organization (RO), must always be equal or less than the Required EEDI (formula 3) [6].

$$Attained\ EEDI \leq Required\ EEDI \quad 3)$$

Attained EEDI is the actual EEDI of a particular ship as calculated by the EEDI formula. According to Regulation 20 of MARPOL Annex VI Chapter 4 [6]:

- "The Attained EEDI must be calculated for each new ship, each new ship when undergoes a major conversion or existing ships that undergo so many changes as according to judgment by Administration can be considered as a new ship".
- "The Attained EEDI is only applicable to a large number of ship types but not all ships. For example, fishing vessels are not required to have an Attained EEDI".
- "The Attained EEDI must be calculated considering relevant IMO guidelines" as set in IMO Resolution MEPC.203(62) Chapter 4, Regulation 20.
- "The Attained EEDI must be accompanied by an EEDI Technical File that contains the information necessary for the calculation of the attained EEDI, and that shows the process of calculation".
- "The Attained EEDI must be verified, based on the EEDI Technical File, either by the Administration or by any organization duly authorized by it".

Besides EEDI, IMO has realized that there is a need to introduce a similar index for older ships. During MEPC 76th session (10-17 June 2021), it was agreed that Energy Efficiency Existing Ship Index (EEXI) would be applicable from the first annual, intermediate or renewal International Air Pollution Prevention (IAPP) survey after 1 January 2023. During the session, MEPC adopted guidelines on the methodology of the EEXI calculation, guidelines on EEXI survey and certification, guidelines on the shaft/engine power limitation system to comply with the EEXI requirements [7].

Because EEDI is required only for new ships and EEXI will be mandatory after January 2023, as already stated, there was a need to improve the energy efficiency of older ships as well. The Ship Energy Efficiency Management Plan (SEEMP) is the operational measure aiming to regulate and promote the energy efficiency of all ships, especially existing ones [4]. The SEEMP enables shipping companies to manage the specific ship and whole fleet efficiency performance over time using the Energy Efficiency Operational Indicator (EEOI) as a monitoring tool, which is not mandatory. The guidance on developing the "SEEMP for new and existing ships incorporates best practices for fuel-efficient ship operation and guidelines for voluntary use of the EEOI for new and existing ships "[8]. The EEOI facilitates operators to measure a ship's fuel efficiency in operation and determine the effect of any changes in operation. The Ship Energy Efficiency Management Plan has been developed through detailed discussions between the Member States and with the advice and assistance of the international maritime industry through a specialized working group on greenhouse gas emissions convened by the MEPC [6]. According to Regulation 22 of MARPOL's Annex VI, all ships involved in international voyages larger than 400 GT, from 1 January 2013 must have a SEEMP, which should be developed following the guidelines prescribed by the IMO [5]. "The vote resulted in the adoption of mandatory measures to reduce greenhouse gas (GHG) emissions from international shipping by Parties to MARPOL Annex VI representing the first-ever mandatory global GHG reduction regime for an international industry sector" [9]. It should indicate some options that should be considered if the efficiency of the ship itself is to be increased. As the amendments to MARPOL Annex VI require straightforward implementation of the rules, Resolution MEPC.213(63) (adopted 2 March 2012) takes the following steps to ensure sufficient time for implementation [10]:

- Adopts guidelines for the development of an energy efficiency management plan (SEEMP)
- Invites relevant administrative bodies to take into account guidelines when developing and prescribing national legislature
- Requests the signatories to Annex VI of MARPOL and other administrative authorities to inform masters, seafarers, shipowners, and those concerned with this guidance.
- Agrees to revise guidelines based on experience gained.
- Revokes previously distributed guidelines MEPC.1/Circ.683.

The guidelines adopted by this resolution serve primarily to assist in the preparation of the SEEMP. The guidelines also contain measures that have proven effective in practice to improve ship efficiency. It should be emphasized that the guidelines should be adapted to the characteristics and needs of individual companies and ships, as the same measures may not be appropriate for different companies and different ships of the same company. The final adopted resolution on guidelines for developing a ship's energy efficiency management plan was adopted on 28 October 2016 under MEPC.282(70), replacing the previous MEPC.213(63) [11]. During MEPC 76th session, it was adopted that the SEEMP will have to be enhanced (EEXI), whereby an approved SEEMP needs to be kept onboard from 1 January 2023 [7].

Compliance with the new regulations on air emissions will be one of the biggest challenges for the shipping industry in the future. Shipping companies are already under pressure to reduce energy consumption to meet SEEMP, EEOI and EEDI regulations. Voluntary standards such as ISO 50001, *Energy management systems – Requirements with guidance for use* and associated standards among others ISO 50002, *Energy audits – Requirements with guidance for use* ISO 50003, *Energy management systems – Requirements for bodies providing audit and certification of energy management systems* ISO 50004, *Energy management systems – Guidance for implementation, maintenance and improvement of an energy management systems* are increasingly being used to demonstrate achievements in reducing consumption to third parties.

In this paper Ship Energy Efficiency Measures are presented and elaborated. The novelty of this paper is the presentation of strengths and weaknesses of SEEMP implementation through SWOT analysis. Another valuable contribution of this paper is shortly elaborating on EEXI, which is the latest IMO measure towards more energy-efficient and environmentally friendly ships.

2. GOALS OF SEEMP

Guidelines adopted for developing a ship's energy efficiency management plan should help steer ships towards reducing global carbon emissions. It is predicted that implementing the measures could significantly reduce fuel consumption and thus CO_2 emissions by 45-50 million tons per year.

The purpose of the SEEMP is to establish a working system for the company and/or ship to improve the energy efficiency of the ship's operation. Therefore, the SEEMP should be ship-specific linked to a broader corporate energy management policy for the ship management company, recognizing that no two shipping companies are the same and that ships operate in a wide range of different conditions.

Many companies already have an Environmental Management System (EMS) in place under ISO 14001 that contains procedures for selecting the best measures for specific ships and then set targets for measuring relevant parameters, along with relevant management features and feedback. Therefore, monitoring the operational environment efficiency should be treated as an integral element of a company's management system.

In addition, companies already developed, implemented, and maintained a ship safety management system (SMS), and the SEEMP may be part of the ship's SMS.

SEEMP seeks to improve the ship's energy efficiency through four steps (Figure 1) [12]:

- Planning,
- Implementation,
- Monitoring
- Self-Evaluation and Improvement

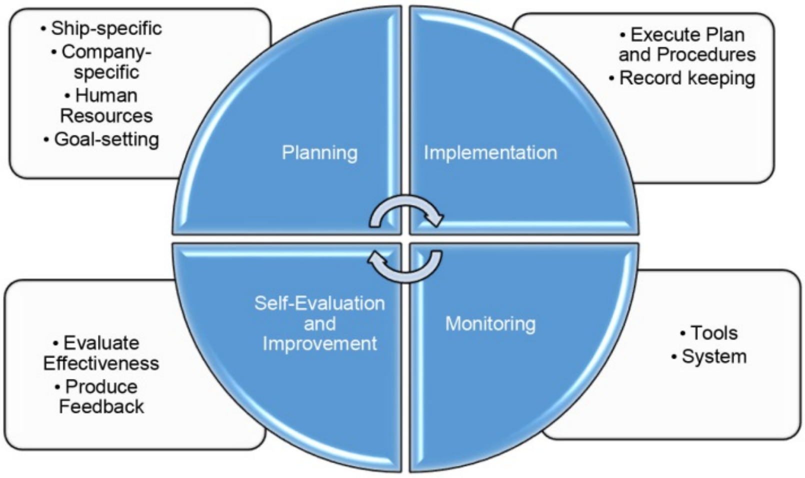

Figure 1 SEEMP phases

Source: Authors as per [13]

SEEMP, therefore, represents a continuous cycle of improving ship energy management. With each iteration of the cycle, some elements of the SEEMP will necessarily change, while some may remain the same. Therefore, it is important to emphasize that safety considerations should always be paramount and always have priority [13].

2.1. Planning

Planning is the most critical phase of the SEEMP, as it primarily determines both the current status of the ship's energy use and the expected improvement in the ship's energy efficiency. Therefore, it is recommended that sufficient time be devoted to planning to develop an appropriate, practical and feasible plan. It is essential to determine and understand the ship's current state of energy consumption during this process. Then SEEMP is used to identify the energy-saving measures taken and determine how effective these measures improve energy efficiency. The SEEMP also determines what measures can be adopted to improve the energy efficiency of a ship further. However, it should be noted that a ship should be viewed as a separate and specific unit when applying specific measures and that measures generally do not have to be the same for every ship.

Improving the energy efficiency of a ship does not necessarily depend only on the shipboard management of a ship itself. It can depend on many factors, including shipyards, ports, shipowners, operators, charterers, cargo owners, and other stakeholders. Increasing coordination among these factors can also contribute to improving the efficiency of the ship itself. Therefore, it is recommended that shipping companies, besides having a ship plan relating to a particular ship, also have a fleet management plan to increase the efficiency of the company's entire fleet.

Human resource development is also an essential element for the effective and stable implementation of the measures adopted, raising awareness and providing the necessary training for staff onshore and onboard ships. Therefore, such human resource development is encouraged and should be an important component of planning.

The last part of planning is setting a goal. It is important to emphasize that the achievement of the goal is not subject to external review, but its purpose should be a signal of whether a particular plan is adequately implemented and whether it brings the expected results in terms of expected energy efficiency.

The target can take any form, such as annual fuel consumption or any other specific target of an operational energy efficiency indicator (EEOI). Whatever the goal is, it should be measurable and easy to understand [13].

2.2. Implementation

Once the ship and the company have determined the measures to be implemented, it is necessary to establish a system for implementing the identified and selected measures by developing energy management procedures. That is achieved by defining specific tasks and appointing qualified staff to carry them out. Therefore, the SEEMP should describe what the measure should be and who is responsible for its implementation.

Also, the period envisaged for implementation must be indicated. The planned measures should be implemented following a predetermined implementation system. Keeping records of the implementation of each measure is helpful for self-evaluation at a later stage and should be encouraged. If a measure cannot be implemented, it is necessary to have written records for internal use [13].

2.3. Monitoring

The energy efficiency of a ship should be monitored quantitatively. Preferably, it should be done by an established method, preferably according to international standards. The EEOI developed by the IMO is one of the internationally established tools for obtaining quantitative indicators of the energy efficiency of a ship and/or fleet and can be used for this purpose. If used, it is recommended that the EEOI should be calculated following MEPC.1/Circ.684 guidelines adapted as necessary for a particular ship or specific ship trading areas. If another tool is used, the concept of the tool and the monitoring methods should be determined in the planning phase. It should be borne in mind that, regardless of which measurement tools are used, continuous and consistent data collection is the basis of monitoring. To enable meaningful and consistent monitoring, a monitoring system, including data collection procedures and the scheduling of responsible staff, needs to be developed. Such a system can be considered part of the planning and should therefore be completed at the planning stage. It should be noted that, in order to avoid unnecessary administrative burdens for shipboard personnel, monitoring should be carried out by as many as possible shore-based personnel, using data obtained from the ship. When a ship deviates from its intended route to engage in search and rescue, it is recommended that data obtained during such operations not be used to monitor energy efficiency and that such data be recorded separately [13].

2.4. Self-Evaluation and Improvement

The final phase of the SEEMP cycle is Self-Evaluation and Improvement. It should produce profound feedback for the upcoming first phase, i.e. planning the phases of the next improvement cycle. The purpose of the self-evaluation is to assess the effectiveness of the planned measures and their implementation to deepen the understanding of the overall energy-efficient operation of the ship. It includes types of measures, their reasons for effective (or ineffective) functioning, understanding the efficiency improvement trend for a specific ship, and developing the improved SEEMP for the next cycle.

For this process, shipboard energy management self-evaluation procedures should be developed. Furthermore, self-evaluation should be conducted periodically using data collected through monitoring. In addition, it is recommended that some effort be made to identify the causes and consequences of the impact during the estimated period to improve the next phase of the management plan [13].

The SEEMP is subject to verification and company audits, and its review must be done by 1 January 2026, during which evaluation of the following will occur:

- Strengthened corrective actions,
- Need for enhancement of the enforcement mechanism.

As the EEXI is being introduced, SEEMP will need to be enhanced and approved [6].

3. ENERGY EFFICIENCY MEASURES ONBOARD SHIPS

The measures adopted and implemented onboard ships in order to increase energy efficiency may relate to the following:

- Optimization of the navigation,
- System optimization in the engine room.

When optimizing for the voyage, the first essential element is the speed of the ship. Upon the ship's departure from the port, the speed is gradually increased to the agreed one (charter party speed). The weather conditions and loads and the manufacturer's recommendations must be taken into account. During the trip, the speed will not fall below the agreed unless weather conditions exceed the agreed descriptions. Then the speed will adjust to the best compromise between energy-saving and safety. These conditions must also be reported to the responsible persons ashore. If the ship was chartered, any change in speed from the contracted one should be confirmed by the charterer and approved by the shipowner.

Another vital element for voyage optimization is passage planning, which may include a weather tracking service. The voyage is planned to take into account all weather conditions, current and available information on the tides in the areas through which the ship will sail, and crewmembers' personal experiences. Selected routes are the shortest routes unless otherwise recommended by publications, a weather service, or for passing through areas prone to piracy. It should be noted that the shortest routes across the ocean may not be the safest at times. Regardless of the routes recommended by the various weather services, the final decision on the voyage route is up to the master. In case of conflict of the chosen route with the route recommended by the weather service, the master is obliged to inform the company to explain his decision.

Furthermore, it is very important to optimize the control of the ship's course and the automatic control function. The steering response is adjusted so that turning movements are limited to a minimum not to increase sailing distance. However, the autopilot settings should not be too stiff; otherwise, frequent rudder movements will increase the load on the main engine and result in an overall lower speed. Depending on the sailing regime (whether the ship is in ballast or loaded condition), the settings of the automatic rudder will need to be adjusted to the conditions. Basically, the setting for economic mode should not change.

An essential element that affects the ship's energy efficiency is the condition and maintenance of the ship's hull. The hull of the ship must be as clean as the ship's propeller. If the ship's speed drops, the ship's hull and propeller cleaning must be considered immediately. Also, if he notices any reduction in speed for which there is no logical explanation, the master must inform those responsible in the company. The last element that significantly affects the ship's efficiency concerning the navigation venture is the amount of ballast on board. This primarily depends on the nature of the trip. However, whenever possible, it should be ensured that the ship's propeller is wholly immersed and that the ship's bow is sufficiently immersed, especially during storms. An additional thing that can be done onboard during the voyage is to pay attention to the energy savings that will significantly save marine fuel for a more extended period.

The first element to be monitored in the engine room is the operation of the main engine. The main engine is maintained according to the manufacturer's recommendations as shown in the ship's Planned Maintenance System (PMS) so that its consumption is as close as possible to the nominal figures measured during experiments in workshops and sea trial, taking into account differences between conditions in which the engine actually operates. It should be borne in mind that the environment of the engine room alone can be up to 50% worse than in the workshop, especially in terms of fuel quality.

The next step is to monitor the operation of all auxiliary engines in the engine room. Auxiliary engines are maintained according to the manufacturer's recommendations to keep their consumption as close as possible to the nominal figures measured during the workshop test and consider the conditions of the actual operating environment of the engine (operating condition and fuel quality). If no more than one generator is required for electricity consumption, then the number necessary for regular operation and life on board shall be kept in operation, and auxiliary engines which are not necessary shall be switched off or put into a standby mode (following manufacturer's procedures for stopping auxiliary engines).

The consumption of cylinder oil and oil required for the operation of the main engine is under constant monitoring to detect any more significant loss than expected at the earliest stage.

One of the more critical factors affecting the energy efficiency system in the engine room is the fuel used by the ship. Reputable suppliers should be used for fuel supply to prevent any fuel quality problems that may adversely affect the performance of the main engine. New fuel received on board is sent for analysis, and only after receiving the results and confirmation that the fuel is of good quality can it be used. Therefore, it is imperative to continuously monitor all major systems in the engine room to act on some negative indicators promptly. Also, the ship's air conditioning system must be regularly maintained to achieve the best ambient air cooling in the range of 22-25 °C. The doors of rooms that are cooled or heated should be kept closed to minimize energy waste.

Training and familiarisation of crewmembers should include instructions on the application of best energy-saving practices. Adequate training is primarily provided as part of the shipboard familiarisation and the duties that each crew member should receive when boarding the ship according to the available schedule in the appropriate manual for the company's safety management system.

The officer responsible for managing the energy efficiency onboard is usually the chief engineer. In addition, he is responsible for the implementation of SEEMP measures. His duties include the following [2]:

- Ensuring the safety of the ship and crew in terms of energy efficiency;
- Ensuring that performance measures are complied with and keeping records of their implementation;
- Ensuring that the ship's crew is educated and aware of the ship's energy efficiency;
- Ensuring that adequate SEEMP records are kept and updated, including energy conservation records;
- Ensuring the availability of the SEEMP and relevant records to the competent authorities;
- Ensuring that the ship's equipment is correct, including the availability of automatic operation mode of all systems having this mode.

He must also inform the master on the following:

- Progress of energy efficiency management operations, and
- Any anticipated deviations from the agreed plan.

The training of crewmembers onboard a ship is made following the company's safety management system through:

- Periodic safety meetings
- Familiarisation of new crewmembers.

Also, the relevant literature (equipment manuals, various publications and legislative) found on ships can be used as a supplement to education related to this issue. Each crewmember must be aware of the importance of applying energy efficiency measures onboard ship because only in a way that everyone onboard acts in accordance with them can result in the satisfactory achievement of planned goals.

Energy-saving record logs are kept on each ship. They include the details of all energy-saving related actions taken onboard to reduce energy wastage and improve the ship's energy efficiency. In the first place, this is necessary to facilitate the analysis of the shipboard energy-saving through specific inspections. During such shipboard inspections, the person authorized by the company will assess the effectiveness of these measures by analyzing record logs and inspecting SEEMP.

The data recorded in the energy-saving logs include the following:

- Replacement of insulation and clamping materials (various seals);
- Installation of equipment with less environmental impact (for example, air compressors with better performance);
- Effective application of new energy-saving practices onboard a ship (lights switched off in uninhabited cabins, radars off when their work is unnecessary, etc.);
- Reporting any problems related to energy efficiency to the company;
- Hand over notes of officers in charge of the shipboard energy efficiency;
- Records of inspections performed by authorized persons of the company;
- Records of SEEMP reviews by the competent organizations;
- Training and education of the ship's crew in order to improve their energy-efficiency awareness;
- Important communication related to this issue.

Each ship needs to have specific measures developed within SEEMP, but it depends on shipboard leadership and crewmembers to implement them and effectively

4. SWOT ANALYSIS OF SEEMP

Although SEEMP was designed to improve ships' energy efficiency and facilitate the shipping industry's transition to a more environmentally friendly one, it has several shortcomings that need to be pointed out. Therefore, the authors compiled its strong and weak points and summarised them in Table 2.

Table 2 SWOT analysis of SEEMP

Strength	*Reduction of CO_2 emissions from shipping*	Weakness	*Significant investments in more sophisticated technologies and more efficient ships*
	Savings in fuel consumption		*Additional paperwork acts as a burden*
	Encouraging the development of new technologies to reduce CO_2 emissions from shipping		*EEOI is not mandatory*
	Improvement of sustainability in shipping		*Additional energy efficiency training for all crewmembers*
	Subject to verification and company audits		*No approval from RO or Flag Administration needed (until the first annual, intermediate or renewal IAPP survey after 1 January 2023)*
Opportunity	*Development of tailored company-specific training ashore*	Threat	*Inadequate energy efficiency familiarisation onboard a ship*
	Introduction of new technologies (blockchain) for shipboard data reports essential for energy efficiency		*Inaccurate and falsified shipboard data reports used to set SEEMP ship specific goals and for implementation control*
	Shipboard leadership sets an example in energy conservation and acts as a role model for crewmembers		*Crewmembers might be unwilling to put extra effort during daily jobs for energy conservation*
	Commitment to implementation and following of SEEMP measures as a tool for marketing strategy (customers might recognize pro-ecological commitment from the company)		*Shipowners' investment in energy-saving devices depends on Return of Investment (ROI) and is highly subject to fuel prices and demand for specific devices and equipment on the market (higher demand - higher price)*

As can be seen from Table 2, SEEMP is a tool enabling and facilitating savings in fuel consumption, which has a double effect: it helps to preserve the marine environment and at the same time saves shipowners or charterers money. Also, new technologies are developed to be able to meet emission regulations and improving energy efficiency. However, significant sums of money need to be invested in new technologies and fuels initially, which might present difficulties for some shipowners. Also, there is a need for crewmembers training to enable adequate implementation of SEEMP measures. Another barrier that might be presented as unfavourable is additional paperwork, which is seen as additional work and presents a headache for some seafarers. The next downside of SEEMP is that it does not need to be approved by Flag Administration or Recognized Organization; it needs to be prepared following IMO recommendations and placed onboard a ship. However, it has to be verified during internal audits, which can be considered as an improvement. Finally, a significant problem might be introducing non-mandatory EEOI, a tool for monitoring energy efficiency over time. It might be argued that without mandatory monitoring tool, there will be ships which will not improve their performance and continue to impact on environment negatively.

5. DISCUSSION AND CONCLUSION

To effectively implement SEEMP into shipping practices, seafarers have to be adequately trained and, if possible, involved in ship-specific SEEMP development. However, one of the weaknesses recognized in our study was additional SEEMP training for all crew members, as Hansen et al. [14] found. In addition, they found that many seafarers were not involved in SEEMP development nor received adequate SEEMP training. Lack of training might result in wrong decisions and thus prevent effective energy efficiency measures.

Another issue that might diminish the complete success of the SEEMP's target could be additional paperwork that acts as a burden on seafarers, who must spend time filling various forms needed to track energy consumption. Ballou, in his paper, proposed a *Total Solution* Approach to the evaluation of the operating efficiency of the ship [15]. SEEMP should be comprehensive and help operators to achieve better performance and facilitate operation. According to him, SEEMP might become just another piece of paper that meets MARPOL Annex VI requirements, or it might generate significant cost savings, on the other hand, constituting profitable ROI. For the best results of SEEMP, the *Total Solution* Approach, amongst others, includes shipboard data acquisition (automated and manual), a method for transmitting the data to shore promptly and continuous "user training and awareness-raising programs" [15]. As recognized in our study, manual data acquisition might constitute an additional paperwork burden for seafarers, and ways to facilitate it must be found and implemented. In this study, the authors proposed introducing new technologies like blockchain, which might be helpful since they could facilitate data collection and enable more accurate and real-time data that could improve ship-specific energy-saving procedures.

Furthermore, additional shore-based and shipboard training and familiarisation are needed to introduce seafarers to possibilities and ways of energy savings onboard ships. Besides training and familiarisation, shipboard leadership should drive necessary changes in crewmembers behaviour to achieve the target set by the SEEMP. According to [16] Master of a ship is responsible for SEEMP training onboard a ship. The Chief Engineer is responsible for monitoring and documenting ship energy efficiency [16]. However, it must be noted that without clear guidance from the company side and development of step-by-step training methodology, inadequate or uncompleted training might be detrimental. In this study, leadership actions might represent opportunities to develop improved energy efficiency actions onboard ships. Therefore, besides training, guidance on documentation needed from Chief Engineer should be clearly stated from the company.

One of the threats recognized in this paper is inaccurate and falsified shipboard reports (noon report, for example). Vorkapić et al., in their paper [17], proposed a machine learning model aiming to predict the energy efficiency of ships. The machine learning model was "learned from shipboard automation system measurement data, noon logbook reports, and related meteorological and oceanographic data" [17]. One of the threats to obtaining accurate and relevant data in the model is shipboard noon reports. One of the developed model's weaknesses was that "part of the data retrieved from the ship's noon reports is based on subjective perception", as the authors recognized in [18]. Human factors and the possibility of changing data should be minimized, and one of the possible solutions is the introduction of sensors and new technologies for obtaining all necessary data for measuring the energy efficiency of a ship.

There are numerous benefits of SEEMP, but the most important one is the significant savings in fuel and thus a significant reduction in harmful gas emissions into the atmosphere. Proper use and monitoring of all marine systems using higher quality fuels and lubricants prolongs the service life of the systems and increases their efficiency. As it can be seen, SEEMP was introduced as an operational measure where the ship's operator was developing a ship-specific energy efficiency plan, following IMO guidelines, but there was no need for a plan to be approved by the Flag state nor the RO. Its presence onboard was only verified during inspections, not its contents, which might present a significant failure. If already implemented by the IMO, SEEMP should be adequately prepared (ship-specific) and include all measures (procedures and systems) needed to improve shipboard energy savings efficiently. Without approval from RO, the SEEMP target itself might be unachievable due to inadequately prepared measures within. The latest MEPC session (76th) realized potential shortcomings and adopted enhancing and approval of SEEMP during the first annual, intermediate or renewal IAPP survey after 1 January 2023. That might positively affect energy savings on existing ships and significantly reduce emissions of harmful gases from ships.

The introduction of EEXI might significantly improve energy savings and environmental protection since it will be a mandatory technical measure included in SEEMP. As EEOI is not mandatory, EEXI will enable the implementation of ship-specific measures and track their effectiveness.

The company's commitment to the SEEMP implementation, continuous monitoring and improvement will undoubtedly result in achieving the set goals. By applying the prescribed measures, ship systems become more efficient, and thus costs are reduced, which are reflected in the company's overall business results. Furthermore, it should be made clear that measures should never be implemented if there is any suspicion that this would jeopardize the ship's safety, as safety nevertheless remains a major and priority factor in the maritime business. The success of SEEMP largely depends on the commitment and effort of the company itself that adopted the SEEMP measures. Thus, the expected success of energy efficiency measures requires the commitment and participation of all stakeholders.

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