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Efforts to Improve Ship Main Engine Efficiency and Ensure Its Safety

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Abstract: *Efforts to improve ship main engine efficiency and ensure its safety have been ongoing endeavors in the maritime industry, driven by the dual imperatives of economic competitiveness and environmental sustainability. The main engine of a ship serves as its heart, propelling it through the vast expanses of the world's oceans while consuming significant quantities of fuel. Therefore, enhancing its efficiency directly impacts operational costs and reduces the environmental footprint associated with maritime transport. One primary focus of improving main engine efficiency lies in the advancement of engine design and technology. Over the years, there has been a concerted effort to develop engines that offer higher power output while consuming less fuel. This has led to the emergence of more efficient engine designs, such as slow-speed two-stroke engines and high-pressure, common-rail fuel injection systems. These innovations optimize fuel combustion, minimize energy losses, and enhance overall propulsion efficiency. Moreover, ongoing research and development efforts are aimed at harnessing alternative fuels and propulsion technologies to further enhance efficiency and reduce environmental impact. LNG (liquefied natural gas) has gained traction as a cleaner-burning fuel alternative, offering significant reductions in sulfur oxides (SOx) and nitrogen oxides (NOx) emissions compared to traditional marine fuels. Additionally, the exploration of hybrid and electric propulsion systems holds promise for reducing greenhouse gas emissions and improving overall energy efficiency. Ensuring the safety of ship main engines is paramount to the reliability and operability of vessels at sea. A robust maintenance regimen is essential to identify and address potential issues before they escalate into costly failures or pose safety hazards. Routine inspections, preventive maintenance, and condition monitoring play crucial roles in detecting abnormalities, wear, and tear, allowing for timely interventions and repairs. Furthermore, advancements in predictive maintenance technologies, such as remote monitoring systems and data analytics, enable real-time assessment of engine performance and early detection of potential malfunctions. The ARAS method lacks the capability to handle ambiguity, subjective judgments, and coping with incomplete information. It relies on unbiased good judgment to address uncertainty, particularly in unknown and complex conditions, making it a valuable approach. The method provides options for sequencing and analysis based on facts and special cases, allowing selectors to express both optimistic and rational attitudes. While it appears numerical on paper, it offers the flexibility to create e-learning pathways tailored to individual needs, emphasizing the importance of mastery. The proposed integrated software for this method is both cost-effective and validated for suitability, ensuring its practical application. Advanced Engine Designs, Improved Monitoring and Maintenance, Enhanced Fuel Management, Innovative Propulsion Technologies, Automation and Remote Monitoring and Advanced Materials and Coatings. the Rank Efforts to improve ship Main Engine efficiency and Ensure its safety for Additive Ratio Assessment method. Advanced Materials and Coatings is showing the highest rank and Advanced Engine Designs is showing the lowest rank. Fuel Efficiency Improvement, Emissions Reduction, Reliability and Maintenance Costs and Safety Performance.*

Keywords: *Improved Monitoring and Maintenance, Enhanced Fuel Management, Innovative Propulsion Technologies, Automation and Remote Monitoring and Advanced Materials and Coatings*.

1. INTRODUCTION

The Ship Energy Efficiency Management Program (SEEMP) stands out as the sole global regulatory framework aimed at enhancing energy efficiency in shipping. Predicted rises in CO2 emissions from maritime activities are anticipated to impact emissions in the near term. This article delves into the current SEEMP guidelines, comparing them with internationally recognized standards like ISO 50001 for Energy Management Systems (EMS) and the International Safety Management (ISM) Code, which outlines safety management prerequisites for shipping companies. While SEEMP lacks significant elements found in EMS and ISM, such as comprehensive policy requirements and administrative reviews, it does address best practices like monitoring, energy audits, and procurement procedures. Nevertheless, SEEMP could benefit from incorporating more detailed protocols akin to those in ISO 50001 for a more robust energy efficiency management system [1]. The disparity in expertise exists within the realms of shipping and energy. Development-oriented entities express concern over a perceived deficiency in skills. It appears evident that optimizing energy efficiency holds considerable potential for enhancing the bottom line, notwithstanding inherent barriers within markets and organizational failures. A retrospective glance at the oil crisis of the 1970s, as scrutinized by researchers such as Blumstein et al., underscores the necessity of addressing societal and institutional impediments to energy efficiency. Among the hurdles identified were misaligned incentives between landlords and tenants regarding energy costs allocation, contingent upon the scarcity of information regarding energy-related activities. Sebon delved into the behavioural dimensions of energy management within educational institutions, contending that organizational dynamics play a pivotal role in either facilitating or impeding energy efficiency endeavors. Diganio posited that insufficient managerial resources, coupled with a myopic focus on specific organizational facets, hinder the adoption of energy-efficient practices. This underscores the significance of recalibrating organizational priorities, whether by expanding market reach, bolstering product innovation, or ensuring regulatory compliance, as integral components of corporate sustainability strategies [2]. A modern approach to managing energy efficiency on ships involves leveraging internal sensors for data acquisition (DAQ) encompassing vessel performance and navigational systems. This data set undergoes rigorous analysis under various maritime conditions to assess ship performance, a crucial component of the Ship Energy Efficiency Management Plan (SEEMP). Within SEEMP, the analysis of these data sets, referred to as SEEMP-related results, is integral. Proposed on board analyses under SEEMP are designed to facilitate decision-making aimed at enhancing energy efficiency based on the respective data sets. Such data analyses are poised to play a pivotal role in merchant shipping operations in the coming years as part of SEEMP initiatives. SEEMP serves as a compelling mechanism driving ships towards improved operational practices and the adoption of technological advancements for achieving high energy efficiency across fleets. The Energy Efficiency Operational Indicator (EEOI) serves as a scale for monitoring ship performance within the SEEMP framework. Consequently, the proposed approach entails leveraging ship performance and navigational data to fulfil energy efficiency objectives through analytical support facilitated by SEEMP [3]. The typical electrical load of the ship averages around 785 kW, reaching a maximum of 857 kW, excluding fuel tank heating. Initially, two four-stroke diesel generators, each capable of generating up to 900 kW of power, suffice to meet this demand. In this operational scenario, a single marine turbogenerator, offering a full 1 MW of power, adequately fulfils the ship's electrical requirements. For the simulation study proposed, the authors modeled a steam turbine from Fincantieri, neglecting the dynamics of the synchronization engine in their analysis. Consequently, the variability in the ship's electricity demand was simulated, accounting for sudden increases or decreases in engine power and their impact on the overall capacity of the generator shaft to accommodate such changes [4]. The rising and consequential increase in fuel oil prices within the shipping sector have been exacerbated by the growing severity of emissions regulations, particularly concerning greenhouse gases. Consequently, the industry has intensified its endeavors to mitigate both fuel consumption and gas emissions associated with shipping operations. This heightened focus has naturally drawn the attention of numerous research groups and industry stakeholders toward achieving substantial performance enhancements across various facets, including energy consumers such as propulsion plants and hull/propeller systems. However, it is notable that certain components of ships, particularly the sub-settings, have not received proportionate attention despite their significant contributions to overall energy consumption compared to the propulsion system alone [5]. In our experiments, we measured pain levels encompassing the femur's response to various loads imposed on the muscle-tendon units (MTUs), taking into account additional factors beyond just the actual load. In clinical practice, proprioceptive neuromuscular facilitation (PNF) is often employed to enhance flexibility, typically at high intensity. However, repeated high-intensity stretching can lead to muscle tissue injuries, as evidenced by our findings. Our experiment demonstrated that high-intensity stretching can induce severe pain in muscle tissue, potentially causing discomfort during exercise and subsequent interference with muscle function. It is advisable to opt for moderate-intensity stretching to ensure the preservation of muscle extension while minimizing the risk of injury [6]. Interacting with industrial robots involves ensuring safety measures are in place. This includes consulting various aspects such as creating safer human-robot workplaces, discussing designs incorporating augmented reality systems for secure human-robot interaction, and integrating diverse sensor types to confirm human safety during contact with robots. Additionally, documents on special robot control techniques and secure controllers are consulted. In the human-robot era, assessing potential injuries considers factors like robot speed, mass, and communication of environmental restrictions [7]. Shipping is an exceptionally efficient and environmentally conscious method of transporting goods on a large scale worldwide. However, despite its recognized efficiency, the maritime industry contributes significantly to greenhouse gas emissions. Annually, maritime transport emits approximately 1000 million tons of CO2, accounting for about 2.5% of global greenhouse gas emissions (International Maritime Organization, 2015). Projections indicate that emissions from ships could increase by 50%–250% by 2050 due to global economic growth. Recognizing the detrimental impact of these emissions on climate change and global warming, the Marine Environment Protection Committee (MEPC) of the International Maritime Organization (IMO) adopted a series of international regulations in 2011 after extensive deliberations (International Maritime Organization, 2009, 2011a). These regulations aim to control greenhouse gas emissions from ships and include provisions for various equipment and measures [8]. Since 2002, the International Maritime Organization (IMO) has prioritized addressing issues related to greenhouse gas emissions and promoting low-carbon activities in the maritime sector. In 2003, the IMO established principles aimed at reducing greenhouse gases and combating climate change in line with the United Nations Framework Convention on Climate Change (UNFCCC). At the 57th Meeting of the IMO Secretary-General in April 2008, a proposal to accelerate the reduction of greenhouse gas emissions from sea-going ships was accepted. Following numerous discussions, the IMO introduced the Energy Efficiency Design Index (EEDI) and the Ship Energy Efficiency Management Plan (SEEMP) as amendments to Annex VI of the MARPOL Convention during the 62nd Session of the Marine Environment Protection Committee (MEPC) in July. These efforts encompass technical, operational, and market-based measures aimed at enhancing energy efficiency. The resolution outlining these measures was ultimately adopted, emphasizing the importance of the EEDI as a standard for measuring energy efficiency in the design and construction of ships. A high EEDI value indicates greater energy consumption by a ship, and the regulations specify maximum allowable EEDI values with reference to design standards [9]. The reduction of material consumption in shipbuilding, decreased energy usage in shipping, and avoidance of toxic substances are crucial for mitigating oceanic impacts. Industries are engaged in activities such as enhancing production, optimizing machinery efficiency, and refining overall ship design to minimize environmental harm. During voyages, efforts are made to reuse ship parts and conduct maintenance, as outlined by Raunekk (2010). End-of-life (EoL) ships resulting from accidents may be repurposed in various ways, including scrapping, repurposing as artificial reefs, or preservation in ship museums. However, adopting circular practices is imperative as awareness grows, not just for environmental reasons but also for economic and social considerations. Currently, recycling, particularly of materials like timber and steel, stands as the prevailing EoL strategy in the maritime sector, with recovered steel being treated as a valuable resource [10]. Shipping companies are currently facing a host of new challenges and opportunities within the global economy, driven by factors such as globalization, resource security, and environmental concerns. The discussion surrounding these issues highlights the impact of maritime transport pollution and the need for research to delve deeper into the problems it poses and potential solutions, particularly through the adoption of green ship technologies. The transition towards a sustainable economy is crucial for improving environmental performance in the shipping industry, yet there remains limited understanding of why some shipping companies embrace environmentally-friendly practices while others do not. While numerous studies have explored the financial benefits of cleaner transportation technologies, many other factors influencing green shipping adoption remain unaddressed. Additionally, there is a lack of understanding about the various factors influencing the development of green shipping practices [11]. Efforts to enhance ship main engine efficiency are multifaceted and driven by economic and environmental imperatives. Advanced engine designs continually optimize combustion processes and reduce frictional losses, while energy-efficient propulsion systems like controllable pitch propellers and hybrid propulsion match engine power output with demand. Technologies such as waste heat recovery systems capture and utilize exhaust heat for additional power generation. Alternative fuels like LNG and biodiesel offer cleaner alternatives, though adoption faces infrastructure challenges. Hull design optimizations minimize hydrodynamic resistance, reducing fuel consumption. Emissions reduction technologies, including scrubbers and selective catalytic reduction systems, ensure compliance with stringent regulations while potentially improving efficiency. Data analytics and predictive maintenance techniques further optimize engine performance, ensuring operations remain cost-effective and environmentally sustainable [12].

2. MATERIALS AND METHOD

Advanced Engine Designs: Enhancing performance and minimizing emissions involves optimizing the fuel-air mixture, employing techniques such as lean-burn or advanced methods like stratified combustion. These combustion techniques significantly enhance efficiency and power output in machinery. To further improve fuel efficiency and reduce noise, advancements like geared turbofans or innovative designs such as open rotors are being implemented, alongside advancements in turbine designs. Efforts to reduce weight and production costs while enhancing efficiency and durability involve utilizing lightweight materials and additive manufacturing techniques for mechanical component integration.

Improved Monitoring and Maintenance: Implementing predictive maintenance procedures and real-time monitoring systems aids in anticipating potential issues and reducing downtime. Conditional-based maintenance strategies, based on component status rather than scheduled intervals, improve maintenance schedules and decrease unnecessary inspections. Remote diagnostics tools and Augmented Reality Interfaces provide detailed instructions and support for maintenance, optimizing efficiency and reducing errors.

Enhanced Fuel Management: In terms of fuel consumption and emissions reduction, optimizing fuel atomization and combustion efficiency through methods like direct injection or common rail systems integration is essential. Electronic engine control systems, adapted to various operating conditions, ensure optimal fuel delivery and performance. Research into alternative fuels such as biofuels or hydrogen aims to reduce dependency on fossil fuels and enhance machine flexibility.

Innovative Propulsion Technologies: For aircraft, hybrid-electric and all-electric propulsion systems research focuses on reducing fuel consumption and emissions while improving performance through battery technology and electric motors. Investigating aerodynamic efficiency enhancements like distributed propulsion or boundary layer injection alongside alternative propulsion concepts aims to increase speed and efficiency.

Automation and Remote Monitoring: Automation and remote monitoring systems enhance air route optimization, reduce pilot workload, and improve flight security and autonomy through intelligent decision-making integration. Unmanned Aerial Vehicle (UAV) technologies are being implemented for various applications to reduce costs, increase capabilities, and enhance automation.

Advanced Materials and Coatings: Utilizing lightweight composite materials such as carbon-fiber-reinforced polymers or ceramic matrix composites reduces aircraft weight and fuel consumption. Research on durable coatings, surface treatments, and self-healing materials improves component durability, corrosion resistance, and aerodynamics, extending component life and reducing maintenance requirements with real-time updates for enhanced reliability and security.

Fuel Efficiency Improvement: Advanced engine technologies such as turbocharging, direct injection, variable valve timing, and cylinder deactivation enhance engine performance. Hybridization and electrification supplement conventional combustion engines, reducing reliance on fossil fuels and benefiting operations of trains and electrical systems. Lightweight materials like aluminum, carbon fiber, and high-strength steel decrease vehicle weight, thus improving fuel efficiency. Additionally, aerodynamic design minimizes drag, saving fuel and enhancing vehicle aerodynamics.

Emissions Reduction: Transitioning to cleaner fuels like biodiesel, ethanol, or hydrogen fuel cells reduces emissions. Advanced exhaust gas treatment methods such as Selective Catalytic Reduction (SCR) and Diesel Particulate Filters (DPF) further diminish harmful emissions. Electric vehicle adoption, despite generating zero tailpipe emissions, is encouraged for environmental benefits.

Reliability and Maintenance Costs: Ensuring regulatory compliance with stringent emission regulations remains paramount. Manufacturing vehicles to high standards with rigorous quality control measures minimizes defects. Predictive maintenance, employing analytics and conditional monitoring, pre-emptively addresses costly breakdowns. Standardizing components and simplifying maintenance procedures reduce costs.

Safety Performance: Investing in durable components prolongs their lifespan, reducing replacement frequency. Advanced Driver Assistance Systems (ADAS), encompassing active safety systems like Automatic Emergency Braking and Lane Departure Warning, enhance safety. Passive safety features such as crumple zones and reinforced structures protect occupants during collisions. Vehicle-to-Everything (V2X) communication improves accident awareness and avoidance, contributing to continuous advancements in vehicle safety and adherence to regulations.

Method: the ARAS method stands out as the optimal approach for alternative selection. It simplifies the process effectively by employing suitable indicators, often using volume as a measure. This method facilitates replacement between alternatives, highlighting the variance in their effectiveness while neutralizing the influence of differing units of measurement [13]. The ARAS technique finds application in addressing a variety of Multi-Criteria Decision Making (MCDM) challenges, particularly those with a limited range of potential outcomes, such as project-related issues. It involves sorting through various options, each representing a distinct choice, and evaluating them against clearly defined criteria, in alignment with the ARAS methodology, to ascertain their suitability. This determination of attribute utility fees aids in gauging the potential opportunities and comparative efficiencies of the problem under consideration [14]. In the realm of transport companies, the ARAS approach serves as a comprehensive means of assessing performance. It encompasses the evaluation of 20 key performance indicators, enabling a holistic assessment of overall performance within the organization. This assessment unfolds in three phases, employing a sensitivity analysis method established during the evaluation process [15]. The ARAS approach simplifies complex international events by providing a structured framework for understanding and evaluating criteria. It emphasizes the importance of considering weighted quantities and casual descriptions of opportunities in the assessment of alternatives, particularly in the context of renewable energy systems such as Polysilicon Solar PV Energy, solid oxide fuel cells, Phosphoric acid fuel cells, and offshore wind energy systems.

Sustainability indicators play a crucial role in this evaluation, with input from energy experts shaping the ARAS hybrid method [16]. A novel approach, combining Advanced with the ARAS method, has been proposed to enhance the evaluation process. The technique, known for its cost-effectiveness and applicability across various domains including management, organization, production, planning, architecture, policy, and environmental sustainability, is integrated to introduce a subjective standards-weighting technique [17]. In geographical regions like the Arras Valley, characterized by moderate winter temperatures and conducive natural conditions, a diverse range of fruits belonging to the rosacea family, including apples, apricots, pears, peaches, plums, cherries, and various berries like strawberry and mulberry, thrive. While wild apricots, abundant in the valley under natural conditions, offer hundreds of fruits, human selection over the years has led to the cultivation of smaller-fruited varieties [18]. The ARAS (Additive Ratio Assessment with Gray Numbers) approach introduces a novel method for classical decision-making, particularly in troubleshooting Multi-Criteria Decision Making (MCDM) problems. Unlike traditional technical approaches, ARAS offers an optional technique that emphasizes values-based activities, involving the test producer from the outset. This method aims to identify superior alternatives compared to feature costs, relying on sound judgment despite inherent ambiguities. The incorporation of "gray" in ARAS signifies the acknowledgment of uncertainty in decision-making processes [19]. ARAS-G (Gray Additive Assessment) integrates principles into the ARAS system, emphasizing technical precision. While the literature on ARAS is relatively recent, it has found utility across various fields and industries, as evidenced by its application in numerous studies. In the context of flash-lamp photolysis experiments, ARAS measures a significant value of 1.9, followed by a rapid increase to one hundred and one after the onset of photosynthesis within the initial 150 PS test time [20]. the experiment encountered challenges due to circuit fluctuations caused by flash usage, rendering precise measurements unattainable. Prior experiments had addressed issues such as PMT intensity fluctuations resulting from excimer flashes, mitigated through monochromating, and electronic interference, addressed using optical isolators for signals. Furthermore, safety concerns associated with the excimer laser were resolved [21]. The ARAS method lacks the capability to handle ambiguity, subjective judgments, and coping with incomplete information. It relies on unbiased good judgment to address uncertainty, particularly in unknown and complex conditions, making it a valuable approach. The method provides options for sequencing and analysis based on facts and special cases, allowing selectors to express both optimistic and rational attitudes. While it appears numerical on paper, it offers the flexibility to create e-learning pathways tailored to individual needs, emphasizing the importance of mastery. The proposed integrated software for this method is both cost-effective and validated for suitability, ensuring its practical application [22].

3. ANALYSIS AND DISCUSSION

TABLE 1. Efforts to improve ship Main Engine efficiency and Ensure its safety

	Fuel Efficiency Improvement	**Emissions Reduction**	**Reliability and Maintenance Costs**	**Safety Performance**
Advanced Engine Designs	250	56	189	78
Improved Monitoring and Maintenance	200	48	296	45
Enhanced Fuel Management	140	75	202	129
Innovative Propulsion Technologies	150	85	105	170
Automation and Remote Monitoring	240	145	120	150
Advanced Materials and Coatings	350	150	285	300

Table 1 shows the Efforts to improve ship Main Engine efficiency and Ensure its safety for Analysis using ARAS Method. Fuel Efficiency Improvement, Emissions Reduction, Reliability and Maintenance Costs and Safety Performance. Figure 1. shows Efforts to improve ship Main Engine efficiency and Ensure its safety in Advanced Engine Designs, Improved Monitoring and Maintenance, Enhanced Fuel Management, Innovative Propulsion Technologies, Automation and Remote Monitoring and Advanced Materials and Coatings. From the figure 1 and table 1 it is seen that Advanced Materials and Coatings is showing the Highest Value for Fuel Efficiency Improvement and Enhanced Fuel Management is showing the lowest value. Advanced Materials and Coatings is showing the Highest Value for Emissions Reduction and Improved Monitoring and Maintenance is showing the Lower value. Improved Monitoring and Maintenance is showing the Highest Value for Reliability and Maintenance Costs and Innovative Propulsion Technologies is showing the lowest value. Advanced Materials and Coatings is showing the Highest Value for Safety Performance and Improved Monitoring and Maintenance is showing the lowest value.

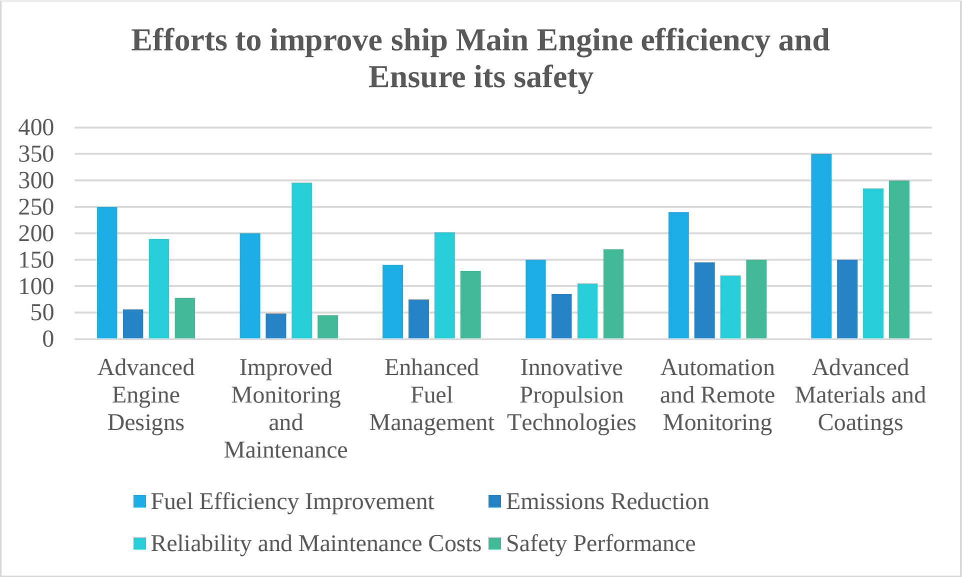

FIGURE 1. Efforts to improve ship Main Engine efficiency and Ensure its safety

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$$\boldsymbol{X_{max} = Max\ (X_1 \ldots\ldots X_n)} \quad \textbf{(1)}$$

TABLE 2. Calculation of maximum value

	Fuel Efficiency Improvement	**Emissions Reduction**	**Reliability and Maintenance Costs**	**Safety Performance**
Max	**350**	**150**	**296**	**300**
Advanced Engine Designs	250	56	189	78
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Table 2 shows the Calculation of maximum value Efforts to improve ship Main Engine efficiency and Ensure its safety for Analysis using ARAS Method. Fuel Efficiency Improvement, Emissions Reduction, Reliability and Maintenance Costs and Safety Performance. Efforts to improve ship Main Engine efficiency and Ensure its safety in Advanced Engine Designs, Improved Monitoring and Maintenance, Enhanced Fuel Management, Innovative Propulsion Technologies, Automation and Remote Monitoring and Advanced Materials and Coatings.

$$X_{1nor} = \frac{X_1}{\sum(X_1 + X_2 \ldots\ldots X_n)} \qquad (2)$$

TABLE 3. Normalised Matrix

	Fuel Efficiency Improvement	**Emissions Reduction**	**Reliability and Maintenance Costs**	**Safety Performance**
Max	0.208333	0.211566	0.198259	0.255973
Advanced Engine Designs	0.14881	0.078984	0.126591	0.066553
Improved Monitoring and Maintenance	0.119048	0.067701	0.198259	0.038396
Enhanced Fuel Management	0.083333	0.105783	0.135298	0.110068
Innovative Propulsion Technologies	0.089286	0.119887	0.070328	0.145051
Automation and Remote Monitoring	0.142857	0.204513	0.080375	0.127986
Advanced Materials and Coatings	0.208333	0.211566	0.190891	0.255973

Table 3 shows the normalised matrix for Efforts to improve ship Main Engine efficiency and Ensure its safety for Analysis using ARAS Method. Fuel Efficiency Improvement, Emissions Reduction, Reliability and Maintenance Costs and Safety Performance. Efforts to improve ship Main Engine efficiency and Ensure its safety in Advanced Engine Designs, Improved Monitoring and Maintenance, Enhanced Fuel Management, Innovative Propulsion Technologies, Automation and Remote Monitoring and Advanced Materials and Coatings normalised matrix Value.

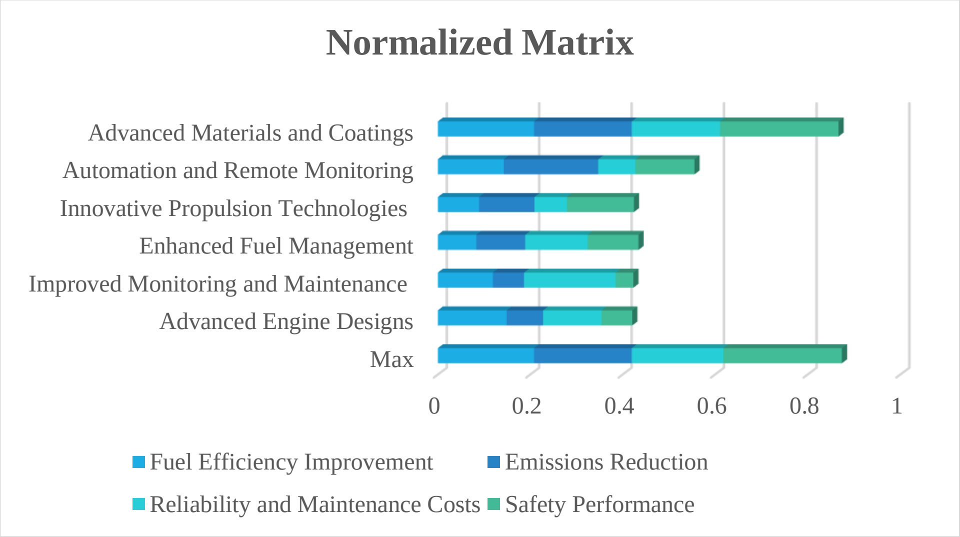

FIGURE 2. Normalised matrix

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$$X_{wnormal1} = X_{n1} \times w_1 \qquad (3)$$

TABLE 4. Weighted Normalized Matrix

	0.25	0.25	0.25	0.25
	Fuel Efficiency Improvement	**Emissions Reduction**	**Reliability and Maintenance Costs**	**Safety Performance**
Max	0.052083	0.052891	0.049565	0.063993
Advanced Engine Designs	0.037202	0.019746	0.031648	0.016638
Improved Monitoring and Maintenance	0.029762	0.016925	0.049565	0.009599
Enhanced Fuel Management	0.020833	0.026446	0.033825	0.027517
Innovative Propulsion Technologies	0.022321	0.029972	0.017582	0.036263
Automation and Remote Monitoring	0.035714	0.051128	0.020094	0.031997
Advanced Materials and Coatings	0.052083	0.052891	0.047723	0.063993

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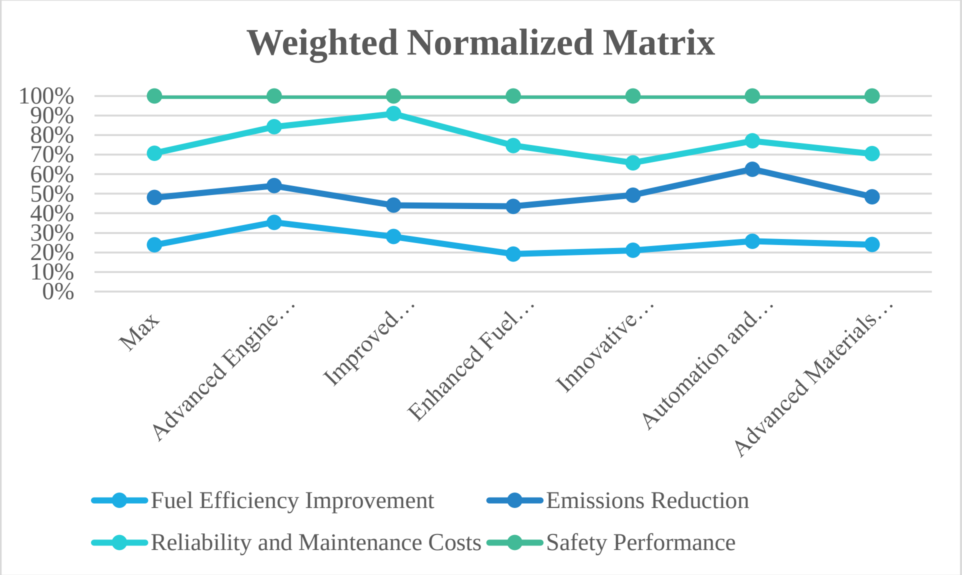

FIGURE 3. Weighted Normalised Matrix

Figure 3 shows the weighed normalized matrix for Efforts to improve ship Main Engine efficiency and Ensure its safety for Analysis using ARAS Method. Fuel Efficiency Improvement, Emissions Reduction, Reliability and Maintenance Costs and Safety Performance. Efforts to improve ship Main Engine efficiency and Ensure its safety in Advanced Engine Designs, Improved Monitoring and Maintenance, Enhanced Fuel Management, Innovative Propulsion Technologies, Automation and Remote Monitoring and Advanced Materials and Coatings it is also the weighed normalized matrix value.

$$Si = \sum(\boldsymbol{X_1} + \boldsymbol{Y_1} \ldots\ldots \boldsymbol{Z_n}) \ (4)$$

$$Ki = \frac{\boldsymbol{X_{wnor1}}}{\sum(\boldsymbol{X_{wnor1}} + \boldsymbol{X_{wnor2}} \ldots\ldots \boldsymbol{X_{wnorn}})} \ (5)$$

TABLE 5. Final Result

	Si	**Ki**	**Rank**
	0.218533	1	
Advanced Engine Designs	0.105234	0.48155	6
Improved Monitoring and Maintenance	0.105851	0.484371	5
Enhanced Fuel Management	0.108621	0.497045	3
Innovative Propulsion Technologies	0.106138	0.485685	4
Automation and Remote Monitoring	0.138933	0.635754	2
Advanced Materials and Coatings	0.216691	0.991571	1

Table 5 shows the final result and rank of the Efforts to improve ship Main Engine efficiency and Ensure its safety in Additive Ratio Assessment method. Fuel Efficiency Improvement, Emissions Reduction, Reliability and Maintenance Costs and Safety Performance. Efforts to improve ship Main Engine efficiency and Ensure its safety in Advanced Engine Designs, Improved Monitoring and Maintenance, Enhanced Fuel Management, Innovative

Propulsion Technologies, Automation and Remote Monitoring and Advanced Materials and Coatings and it shows the SI , KI, Rank. SI values are derived by using the formula(4), And KI values.

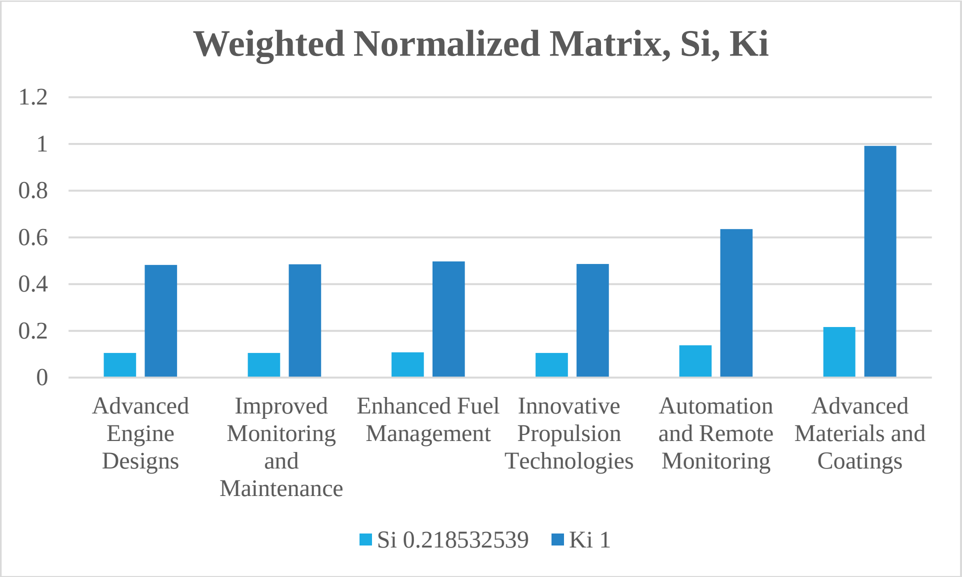

FIGURE 4. Weighted Normalized Matrix, Si, Ki

Figure 4 shows the weighted normalised matrix in Efforts to improve ship Main Engine efficiency and Ensure its safety in Additive Ratio Assessment method. Fuel Efficiency Improvement, Emissions Reduction, Reliability and Maintenance Costs and Safety Performance. Efforts to improve ship Main Engine efficiency and Ensure its safety in Advanced Engine Designs, Improved Monitoring and Maintenance, Enhanced Fuel Management, Innovative Propulsion Technologies, Automation and Remote Monitoring and Advanced Materials and Coatings. In SI method Advanced Materials and Coatings is showing the highest value and Advanced Engine Designs is showing the lowest value for KI method Advanced Materials and Coatings is showing the highest value and Advanced Engine Designs is showing the lowest value of weighted normalised data.

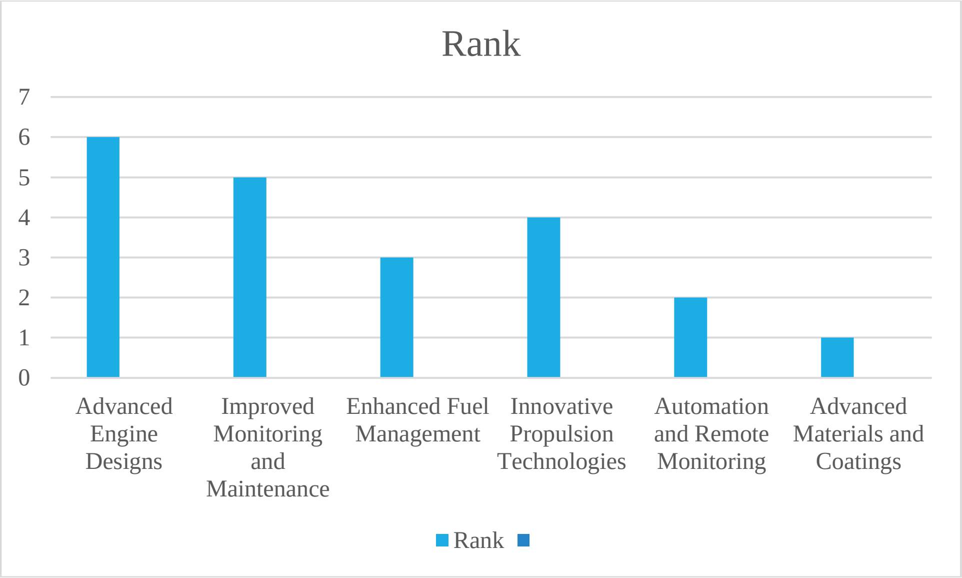

FIGURE 5. Shows the Rank

Figure 5 shows the Rank Efforts to improve ship Main Engine efficiency and Ensure its safety for Additive Ratio Assessment method. Advanced Materials and Coatings is showing the highest rank and Advanced Engine Designs is showing the lowest rank.

4. CONCLUSION

The main engine of a ship serves as its heart, propelling it through the vast expanses of the world's oceans while consuming significant quantities of fuel. Therefore, enhancing its efficiency directly impacts operational costs and reduces the environmental footprint associated with maritime transport. One primary focus of improving main engine efficiency lies in the advancement of engine design and technology. Over the years, there has been a concerted effort to develop engines that offer higher power output while consuming less fuel. This has led to the emergence of more efficient engine designs, such as slow-speed two-stroke engines and high-pressure, common-rail fuel injection systems. These innovations optimize fuel combustion, minimize energy losses, and enhance overall propulsion efficiency. Moreover, ongoing research and development efforts are aimed at harnessing alternative fuels and propulsion technologies to further enhance efficiency and reduce environmental impact. The Ship Energy Efficiency Management Program (SEEMP) stands out as the sole global regulatory framework aimed at enhancing energy efficiency in shipping. Predicted rises in CO2 emissions from maritime activities are anticipated to impact emissions in the near term. This article delves into the current SEEMP guidelines, comparing them with internationally recognized standards like ISO 50001 for Energy Management Systems (EMS) and the International Safety Management (ISM) Code, which outlines safety management prerequisites for shipping companies. While SEEMP lacks significant elements found in EMS and ISM, such as comprehensive policy requirements and administrative reviews, it does address best practices like monitoring, energy audits, and procurement procedures. Nevertheless, SEEMP could benefit from incorporating more detailed protocols akin to those in ISO 50001 for a more robust energy efficiency management system. The ARAS method lacks the capability to handle ambiguity, subjective judgments, and coping with incomplete information. It relies on unbiased good judgment to address uncertainty, particularly in unknown and complex conditions, making it a valuable approach. The method provides options for sequencing and analysis based on facts and special cases, allowing selectors to express both optimistic and rational attitudes. While it appears numerical on paper, it offers the flexibility to create e-learning pathways tailored to individual needs, emphasizing the importance of mastery. The proposed integrated software for this method is both cost-effective and validated for suitability, ensuring its practical application. Advanced Engine Designs, Improved Monitoring and Maintenance, Enhanced Fuel Management, Innovative Propulsion Technologies, Automation and Remote Monitoring and Advanced Materials and Coatings. the Rank Efforts to improve ship Main Engine efficiency and Ensure its safety for Additive Ratio Assessment method. Advanced Materials and Coatings is showing the highest rank and Advanced Engine Designs is showing the lowest rank. Fuel Efficiency Improvement, Emissions Reduction, Reliability and Maintenance Costs and Safety Performance.

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