MEASURING ENERGY EFFICIENCY OF OFFSHORE SUPPORT VESSELS IN UAE FOR DEVELOPING AN OPERATIONAL FRAMEWORK AND PERFORMANCE INDEX

A thesis submitted to the
University of Petroleum and Energy Studies

For the award of
Doctor of Philosophy
In
Management

By

Ajith P J
SAP ID No:500042712
October 2023

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DECLARATION

I Ajith PJ declare that the PhD thesis entitled "**Measuring Energy Efficiency Of Offshore Support Vessels In UAE for Developing An Operational Framework And Performance Index**" has been prepared by me under the guidance of Dr. T Bangar Raju, (Professor, School of Business, University of Petroleum and Energy Studies), Dr. B K Chaturvedi, (Professor, School of Business, University of Petroleum and Energy Studies) and Dr. P G Sunil Kumar (Managing Director, Aries Group). No part of this thesis has formed the basis for the award of any degree or fellowship previously.

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Date: 25th October 2023

CERTIFICATE

I certify that Ajith P J has prepared his thesis entitled "**Measuring Energy Efficiency of Offshore Support Vessels In UAE for Developing An Operational Framework And Performance Index**", for the award of PhD degree of the University of Petroleum & Energy Studies, under my guidance. He has carried out work at the School of Business, University of Petroleum & Energy Studies.

Supervisor:

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Bhartendu

Co-Guide:Dr B K Chaturvedi

Date: 14th July, 2023

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External Supervisor: Dr P G Sunil Kumar

Date: 14th July, 2023

ABSTRACT

The need to lower CO_2 emissions from ships has been raised by the International Maritime Organization. There have been numerous discussions in this regard, but there are no precise rules for tracking emissions from offshore support vessels. The goal of this thesis is to rank the various elements influencing these vessels' operational energy efficiency and to specify performance index parameters.

By ranking the factors and sub-factors based on input from various stakeholders, this thesis seeks to identify factors and develop a conceptual framework that describes the overall Operational structure for energy efficiency of offshore supply vessels in the United Arab Emirates. In order to measure all operational modes of an offshore supply vessel in the UAE, this thesis structures a framework and sets an Energy Efficiency Operational Performance Index. (EEOPI).

Three major factors—managerial, functional, and infrastructural—as well as each of their corresponding subfactors were revealed through an extensive literature review that was backed by expert verification. These three factors were taken into consideration for the research study. For the study, 37 stakeholders' opinions on a total of 17 sub-factors were gathered. To rank these factors based on feedback from various stakeholders, the Best Worst Method, a Multi-Criteria Decision Making (MCDM) approach, is used. Among the three key factors—managerial, functional and infrastructure—the results show that infrastructure factors take the lead. The study provides guidance for vessel operators to concentrate on infrastructure sub-factors for better energy efficiency in offshore vessels.

Progressive data-capturing devices are being used on ships to monitor performance, according to the findings of the Marine Environment Protection Committee's 76th session of the International Maritime Organization. By ranking vessel performance monitoring as the most crucial subfactor, this analysis supports that result finding. Trade and sailing area, the factor with the lowest ranking, demonstrates that this is an important factor that is relevant to

every region of the world, regardless of what influences demand in each area or where the business is situated.

In accordance with International Maritime Organization resolutions for SEEMP, the study's goal was to identify and prioritize energy-saving measures for offshore support vessels. The advantage of using a fuzzy approach like Fuzzy AHP, which accurately represents the fuzziness accompanying different operational modes of such a vessel, is the ability to assign the relative significance of attributes using fuzzy numbers rather than exact values. A good decision-making approach can be chosen for defining and creating the Energy efficiency Operational Performance Index (EEOPI) using Fuzzy AHP's weighting method and pair-wise comparisons.

The operational factors review for a specific offshore support vessel is required, according to research analysis ranked using the fuzzy AHP model, in order to enhance the procedure. The results of the research, which was analyzed for four different types of vessels, showed relative significance and a strategic approach in selecting the most important thing that could be done to improve operations. This was true because the research indicated that it was possible to prioritize the most crucial measure. The results of the analysis show that the highest importance and lowest importance vary depending on the type of ship for the following ship types: supply vessel/utility; anchor handling, towing, and escort vessel; PSV/OCV/ROV support; MPSV/DSV vessel; and safety standby/oil recovery/security vessel.

EEOPI, a tailored derivative of EEOI, is a solution that implements correctness to an acceptable level based on practical applicability for particular types of offshore support vessels. Despite this, EEOPI derived for specific vessel types cannot provide a generalized solution but rather an indicative metric suitable for a reasonably effective benchmarking mechanism for each type of offshore support vessel. As a result of the research, a specialized performance index was created with the goal of tracking the energy economy of offshore vessels.

ACKNOWLEDGEMENT

I would like to express my heartfelt gratitude to the individuals and institutions who played a pivotal role in supporting and guiding me throughout my Journey of Academic growth that fueled my PhD Research Thesis.

First and foremost, I would like to express my deepest gratitude to my research guide, Dr. T. Bangar Raju whose expertise and unwavering support have been invaluable. His vast experience with industry- blended academic outlook have significantly influenced my evolution as a researcher. I am truly grateful for him being my guide, pillar of strength and mentor throughout my life. I am thankful to my co-guide, Dr. B.K Chaturvedi for his insightful suggestions, and support. I am deeply grateful to my External Guide, Dr. Sunil Kumar for his mentorship in assisting me to bridge the gap between industry and academics. I also want to extend my gratitude to all eminent faculty members & Professors of the UPES School of Business who helped me at various stages of my research.

I would like to acknowledge my belated father whom I lost half-way during this journey. His unwavering belief in the power of education has always served as a guiding light. My mother deserves a special mention for her unfailing care and highlighting me the importance of perseverance. I also extend my appreciation to my parents-in-law, who belong to a research background, which nurtured my passion for research and who have always been a constant source of motivation.

I would also like to extend my sincere gratitude to my beloved CEO Sir. Sohan Roy, Aries Group for his unwavering support during my entire professional journey which has exceeded two decades now. His encouragement for upgrading my skills and provision of flexibility have been instrumental to my pursuit of PhD while maintaining a professional career. I express my gratitude to all my colleagues in Aries whose support and camaraderie have made the research process smoother and rewarding.My biggest strength has been my Professional network. Interacting with different stakeholders including ship management companies, regulatory authorities, seafarers, trade associations, and leading organizations in the OSV industry in the form of interviews and discussions where they shared their experiences, insights, and wisdom in the field of my study was vital. I would also like to specially thank Mr. Murali Kirshna (M.D, Allianz Marine), Mr. Manoj Kumar (Technical Manager, Stanford Marine), Mr. Unnikrishnan (ABS), Captain Rajan (Sharjah Port), Mr. Vivek Seth (ADNOC) for supporting me in sourcing information for data gathering required for my research.

Finally, I would also like to extend my heartfelt appreciation to my beloved wife Tharunima and my daughters Tamanna & Amartya. Their unwavering support, understanding, and sacrifice during this arduous journey and willingness to accommodate my research commitments selflessly, while managing their own lives have been crucial and deserve special mention.

Thanks again.

Ajith PJ

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

Abbreviation	Details
GHG	Greenhouse Gas
IMO	International Maritime Organisation
SEEMP	Ship Energy Efficiency Management Plan
EEOI	Energy Efficiency Operational Indicator
MARPOL	Marine Pollution Regulations
MEPC	Maritime Enviornmental Protection Committee
CII	Carbon intensity Indicator
KPI	Key Performance Indicators
GRT	Gross Rates Tonnage
FPSO	Floating Production Storage & Off-loading
OSV	Offshore Support Vessel
IMCA	International Marine Contractors Association
DP	Dynamic Positioning
SMS	Safety Management System
MCDM	Multiple criteria Decision Making
AHP	Analytic Hierarchy Process
BWM	Best Worse method
ROV	Remote Operated Vehicle
LR	Literature Review
PI	Performance Indicators
EEOPI	Energy Efficiency Operational Performance Index
MCDM	Multi Criteria Decision Methods

CHAPTER 1

INTRODUCTION

CHAPTER 1

INTRODUCTION

1.0 STATEMENT OF PROPOSAL

With technological and operational approaches, there was a great opportunity for reducing GHG emissions. If all of these changes are adopted, they might boost efficiency and cut emissions by less than twenty five percent to seventy five percent. Despite the strategies being cost-effective, non-financial barriers may prevent their use (IMO- GHG Study 2009).

1.1 BACKGROUND

Every operator's main priority is shipping efficiency because it directly affects the company's income and timetable dependability. As per ship performance metrics, regular journey planning from port to port or port to offshore sites must be simple. Yet, in a competitive market like the UAE, where owners heavily rely on operators, ship management firms, and charterers, the turnaround time for all offshore activities becomes the crucial component that still has many aspects that are not directly connected with a single ship journey plan.

Using IMO (2012b), SEEMP, and EEOI, IMO established standards for weighing energy efficiency throughout operating phases. The regulation was brought into effect in January 2013 subsequent revisions to MARPOL Annex VI IMO (2011), an innovative section introduced on rubrics on ships' energy efficiency. All boats, including non-transport vessels used for work, must have a SEEMP in place to enhance everyday operations, whereas the current EEOI approach only applies to traditional ships that carry goods.

MEPC 76 of the International Maritime Organization was held virtually from June 10 to June 17 of that year. Specific operational control monitoring measures to reduce CO2 emissions in international shipping will go into action in November 2022, with certification becoming mandatory the following

January. (2023). Revisions to CII grade using the appropriate infrastructure, as well as revisions to SEEMP plan with more realistic and superior goals, are among the processes planned. Due to factors requiring revision, IMO was inept to proclaim its concluding SEEMP regulations and CII grading system. A precise technique for managing the energy efficiency of ships between 400 and 5000 GRT, which includes a sizable global fleet of offshore support boats, has not yet been addressed by the aforementioned MEPC 76. The only option, then is to abide by MEPC.1/Circ.684(2009) requirements, that encourage the use of optional operational indicators for energy savings. (EEOI) for all ships, whether old and new. There are certain special vessels, like those used in research, transportation, and remote support, that are not involved in transit duties. The IMO revisions and standard guiding principles for SEEMP (MEPC.282(70) 2016), which entered into force on March 1, 2016, are now being used by shipping firms in connection to the data gathering system. According to 4th IMO GHG Study 2020, service & offshore boats primarily explain CO2 emissions. The fraction of the world's fleet that is made up of service & offshore vessels is 28.4 percent. The International Maritime Organization's stance on offshore assistance vessels voluntarily employing the EEOI coefficient is not workable since it is directly related to the volume or amount of labour done based on trip coverage. Platform Support Vessels (PSV), Anchor Handling Tug Vessels, Well Stimulation Vessels, and Diving Support Vessels are examples of offshore support boats. Seismic vessels are not covered by the legislation since their primary function is not to carry just cargo and their propulsion type, speed, and activities vary. EEOI is an optional advice tool for current ships that can aid in locating the optimal operating procedures for maximising fuel efficiency. The present EEOI cannot be used to offshore support boats due to the fact that it involves transportation labour (cargo moved per nautical mile per tonne of fuel).

1.1.1 CLIMATE CHANGE – ENERGY EFFICIENCY DRIVERS

Driving force for all-encompassing, cross-sector tariffs and restrictions to lessen carbon emissions everywhere, including in transportation as stated in table 1.1, is environmental change. But generally speaking, save from those required by law. There is a lack of concern for the ecosystem and, consequently, no drive to do anything about it. to adjust industrial practices to reduce carbon emissions. Understanding the scientific principles behind environmental change as well as the administrative framework developed to address environmental change is crucial, as seen in figure 1.1.

1.1.1 IMO's MEPC has started studies and actions to reduce the amount of greenhouse gases (GHG) that ships release on the basis of response towards reduction of carbon emission by the shipping industry. These deals are harmonized with Kyoto Protocol's obligations and UNFCCC constitution.

Table 1.1 International Maritime Organisation

(Source Second IMO- GHG Study, 2009**)**

	GHG emission reductions	Fuel cost savings	
	Million tonnes CO_2	*% reduction*	*Billion US$*
By 2020	***180***	***9 - 16%***	***34 - 60***
By 2030	***390***	***17 - 25%***	***85 - 150***

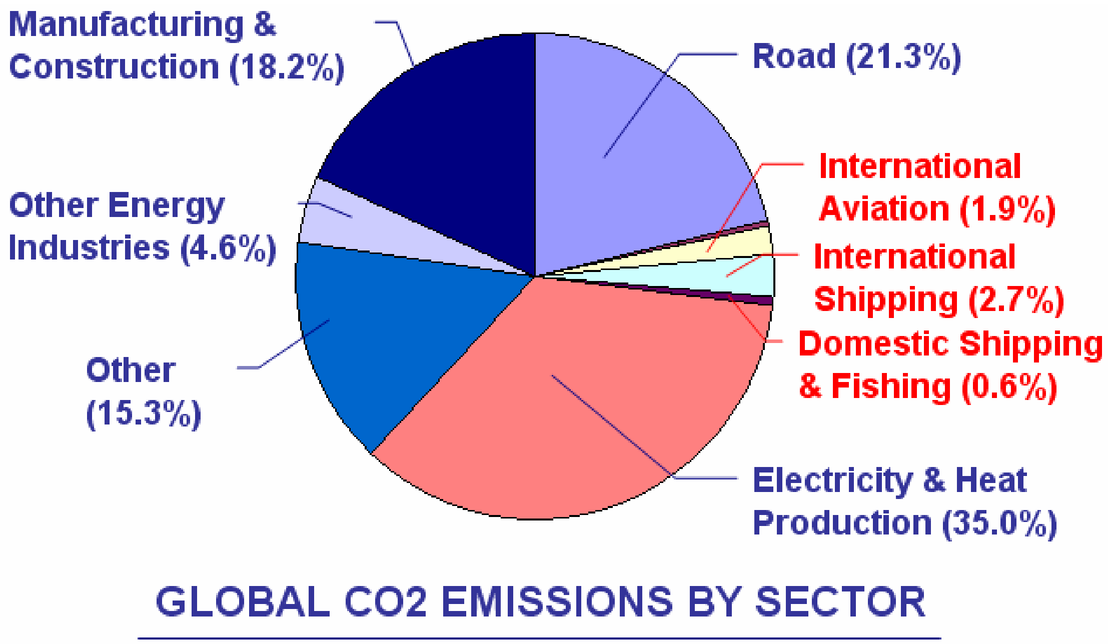


Fig 1.1 CO 2 releases (shipping) relative to global emissions (total)

(Source Second IMO- GHG Study, 2009**)**

Without controls, the increase in shipping might lead to a major increase in ship emissions. According to intermediate emissions scenarios, the increase in global commerce depicted in figure 1.2 by 2050 possible double- or triple-digit (relative to current levels) rise in ship emissions emissions in 2007).

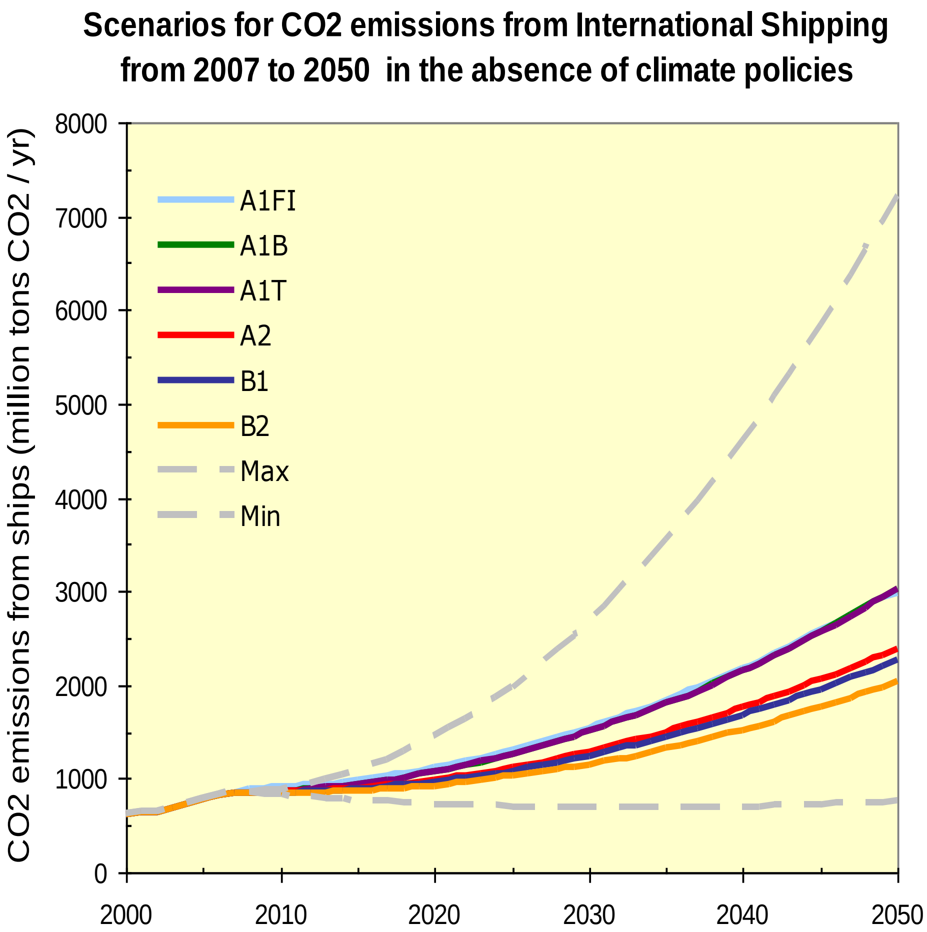


Fig. 1.2 Scenario for CO 2 Emissions from shipping 2007 -2050-Absence of Policies(Source : IMO MEPC 59/INF. 10 Circular,2009)

The findings of the study make it abundantly clear that Energy efficiency measures should be employed in the associated segment to diminish the usage of high-carbon fuels and CO2 emissions.

Oil pollution that was once the primary concern in the shipping industry has been joined by the air emission pollution as a more recent addition to the list of environmental concerns (Svensson and Andersson 2011). The idea of prioritising energy-efficient shipping in addition to the basic standards for the operation of the monetary system remains a relatively novel one that is largely unimplemented despite the passage of time. Energy saving standards set forth by the Maritime Organization of the United Nations (IMO), which went into effect in January 2013, are one of the primary efforts that have been made to address this issue.

The realisation that the shipping and transportation industry needs to become more energy efficient sparked discussions, improvements, and new product development across a variety of operational and planning domains. Partners who helped integrate these include: regulatory bodies; national governments; classification bodies; ship owners, ports, charterers, equipment suppliers, and research institutions. Short-term and long-term innovative solutions and operational procedures that, if implemented, could lead to considerable drops in the amount of cargo carbon emissions. Such a trend that has been observed recently. Nevertheless, this is giving execution takes place along with the progress of energy-generating technologies on energy efficient methods, and it continues to take place alongside these developments.

A vital thought with the establishment and usage of new plans, advances and operations on energy efficiency, is the prerequisite of human mediation at a wide range of echelons; from basic decision making to somatic execution. Also, variations and enhancements in vessel operational strategies call for efficient correspondence and collaboration amongst numerous partners. This opens up some human variable thought zones to adequately accomplish fully integrated fully integrated energy efficient ship operations while keeping safety and job role objectives.

Energy-efficient shipping requires parties to explore communication and decision-making networks. Identify the barriers and enablers to energy-efficient operational changes. Energy-efficient ship activities require identifying operational gaps and addressing them. Ship energy economy measurement solutions must be based on framework development. Developing a monitoring index that provides comprehensive energy efficiency measurement of ship performance to the various operating partners specifically identified with ship operation: the strategy includes examining existing working profiles and developing a ship operational performance model.

1.1.2 ENERGY EFFICIENCY IN SHIPPING & THE ENERGY EFFICIENCY OPERATIONAL INDICATOR, EEOI

ENERGY EFFICIENCY IN SHIPPING

Conferring with views given by environmental experts, a major problem today for international carriage is to limit or reduce the emissions of GHGs. Interestingly, CO2 is believed to cause the present-day crisis, the so called 'climate change'. As the global shipping industry is IMO (International maritime organization) controlled and regulated, reducing or capping greenhouse gas emissions is of interest to any related business. Reducing CO2 emissions is in fact directly related to reducing fuel oil consumption, which accounts for a sizable portion of the ship's running expenses. As the industry is growing in leap and bounds, ship CO2 emission indexing was established by IMO for the purpose of determining and developing methods and systems required to attain drop in release of carbon gases owing to intercontinental shipping. CO2 emission indexing expresses the amount of CO2 emissions that are produced for every tonne of actual net transport that is travelled. This emission indexing will be helpful in gauging fuel efficiency, as the extent of carbon dioxide released and volume of fuel used are proportionate.

IMO introduced guiding principles for the ship CO2 emission indexing requesting the shipping companies to report back their findings. It has also requested the operators to use the guidelines, for uniformity while calculating the index from the operational parameters. This index has been identified as **'index-operational'** as it mainly depends on the operational parameters of that ship, which also expresses the ships CO2 efficiency, IMO defines the ships energy efficiency is measured as CO2 emission indexing which acts as a potential tool for rating the ships. With this operational index a comparison of fuel efficiency across the fleet is possible for the operator or the owner and subsequently find a strategy to cut down on production of climate-altering gases.

Annex VI of MARPOL was revised to include chapter IV on ship energy efficiency after the IMO decided it was necessary to make the idea of "measuring energy efficiency" mandatory. As Carbon dioxide is the primary greenhouse gas released by ships, the concepts have become CO2 emission baseline, CO_2 efficiency of a ship and CO_2 emission indexing. As stated, an important element in this process of reducing GHGs from shipping sector is development of emission indexing for both existing ships and for new build ships to make the ships more energy efficient.

Objective and Importance of the Co_2 Operational Indexing for monitoring and measuring the IMO's "energy efficiency of a ship in operation," that can only be stated in terms of carbon dioxide released per component of transported effort and improvement of this index by best possible emission reduction measures. The purpose of this voluntary ship carbon dioxide emissions indexing is to use the data in environmental management systems of the companies.

Some practical advantages of this operational CO_2 indexing are described below:

- This index will be helpful in assessing ship performance in terms of fuel efficiency, as carbon dioxide releases and quantity of fuel used are proportionate.
- Implementing and monitoring operational CO_2 indexing on continuous basis is one good step to consistently reduce CO_2 emissions from global fleet.
- This index can be used by ship-owners as part of an environmental management system. In addition, it can potentially be used in policies to reduce or regulate CO_2 emissions.

EEOI, ENERGY EFFICIENCY OPERATIONAL INDICATOR

(Source: IMO @ for Scientific and Technical Advice (SBSTA 35) in Jan 2011, Agenda 9(a))

IMO recommends the Energy economy Operational Indicator (EEOI) for measuring ship energy economy. Calculation and publishing are voluntary. The EEOI calculates CO_2 emissions per tonne of cargo moved per nautical mile using operational data over time. In the guidelines (IMO 2009a), the average EEOI is calculated, but the rolling average time period is not stated. It's ambiguous. The EEOI is often used for fleet performance assessment, with a monthly or yearly average for cargo ships. Operational pace strongly affects the EEOI, which depends on ship supply and demand. The EEOI calculation (and baselines, if created) may unfairly favour certain ship types, sizes, and operational profiles while disadvantaging others. The EEOI of offshore support vessel parameters are not considered as part of the calculation Index derived by IMO.

Fleet management, voyage optimization, and energy management can reduce CO2 pollution by 10–50% per capacity mile. SEEMP addresses operational energy reserves, and EEOI can be employed to monitor and set yardsticks for diverse segments of ship, such as cargo ships. Operational pace strongly affects the EEOI, which depends on ship supply and demand. The EEOI calculation (and baselines, if created) may unfairly favour certain ship types, sizes, and operational profiles while disadvantaging others.

Shipowners, operators, and charterers should create ship-specific SEEMPs. The SEEMP improves ship energy efficiency through planning, development, control, implementation, self-evaluation and development. Such parts help enhance ship energy management in a continuous cycle. IMO best practises include vessel performance, optimised ship management, hull and propulsion system upkeep, waste heat recovery systems, fleet management, cargo handling, and energy management. It also covers fuel types, measure compatibility, ship age, practical service life, trade, and sailing area.

The IMO's voluntary ship EEOI guidelines provide a steady method for gauging ships' energy efficiency during a time period, helping ship owners and machinists evaluate their fleet's operational performance. The EEOI can also indicate a ship's fuel efficiency since bunker fuel oil usage directly affects CO2 emissions.

The input value along with emissions can be used by practically all ships irrespective of whether they are new or existing with passenger ships included, but not by crafts not used in transportation, such as tugboats, service and exploration vessels or FPSOs.

UAE's 2021 national motivation intends to accomplish a supportable environmental situation for nature of air pollution of water assets to increment clean vitality and execute green concept advancement.

For the foundation part the national plan intends to set up the UAE as the main nation internationally in setting nature of framework of air terminals seaports and road transport. UAE is positioned first regionally and third globally as far as nature of seaports infrastructure and is positioned 6th comprehensively as far as seaports structure as indicated by the Worldwide Records. This exhibits the vast exertion and accomplishments made in the seaports division in the current years. In terms of international and regional commerce across borders, the United Arab Emirates (UAE) has maintained a dominant position for several years running, ranking tenth globally and first in the region.

The harbours in the UAE are some of the largest in the world because they have some of the best infrastructure and facilities in the business. The United Arab Emirates features 12 thriving commercial ports outside of its hydrocarbon industry, totaling more than 310 berths, 45 kilometres in length, and a gross tonnage capacity of 80 million tonnes.

For servicing the local and global markets over 50 Ship owners, 180 shipping lines are operating in UAE and It is the major offshore transit facility, a gateway to the Arabian Gulf, and a strategic crossroads on the Indian Ocean's North-South-East-West trading routes.

1.2 Offshore Support Vessels (OSV) in UAE

UAE have a prominent presence in the Total number of offshore support vessels and stands 4th in the World OSV Fleet. 17% of OSV Fleet of the world is in UAE as shown in figure 1.3 and 1.4.

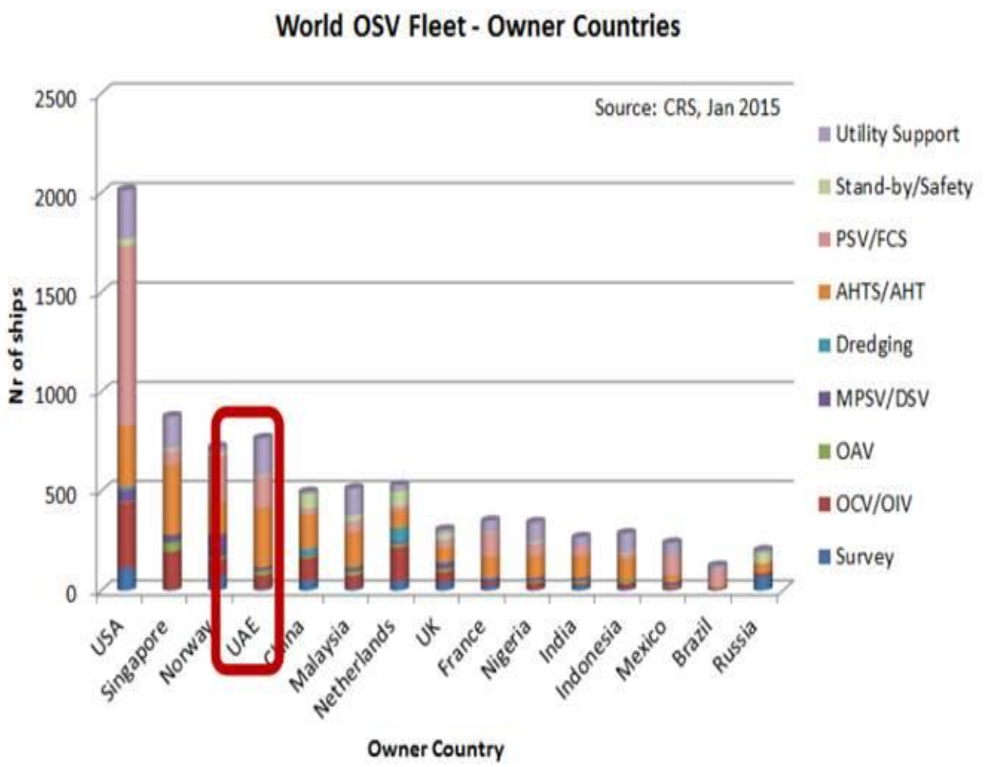


Figure 1.3 World Offshore Support Vessel Fleet Owners by Countries

(Source : Clarkson Research Services,2015**)**

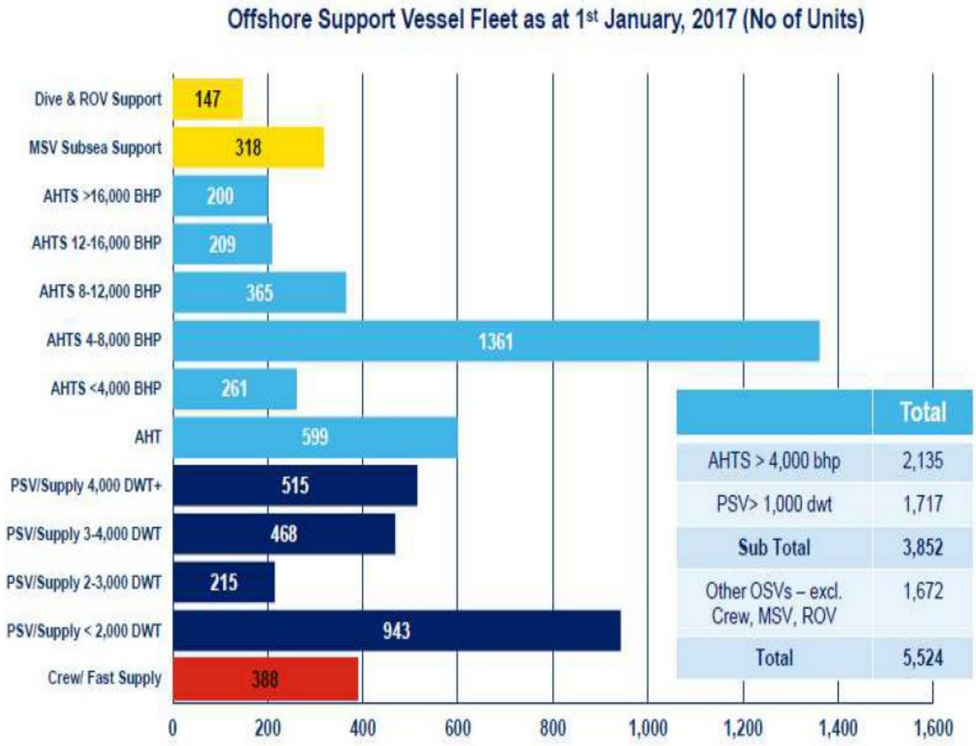


Figure 1.4 Offshore Support Vessel :Total Number of Units

(Source: Clarksons Research/Pareto ,2017)

The OECD (2015) predicts that between 2014 and 2025, energy demand will rise, which will affect the growing demand for offshore boats and the industry as a whole. The need for offshore support vessels used for installation supply is predicted to grow by fifty percent in coming years, while wind turbine installation vessels are predicted to see a 117% increase in demand. As of right now, the drop in oil prices presents a complication for the figures, but long-term studies indicate that demand will increase.

According to Smith et al., offshore and service boats account for about 6% of all maritime CO2 emissions. (2015). Therefore, it is important to pay particular attention to these ships and to develop tools for the personnel and the ship's owner to use in improving efficiency and cutting costs for various tyoes of Offshore support vessels segregated based on duties they perform as shown in figure 1.5.

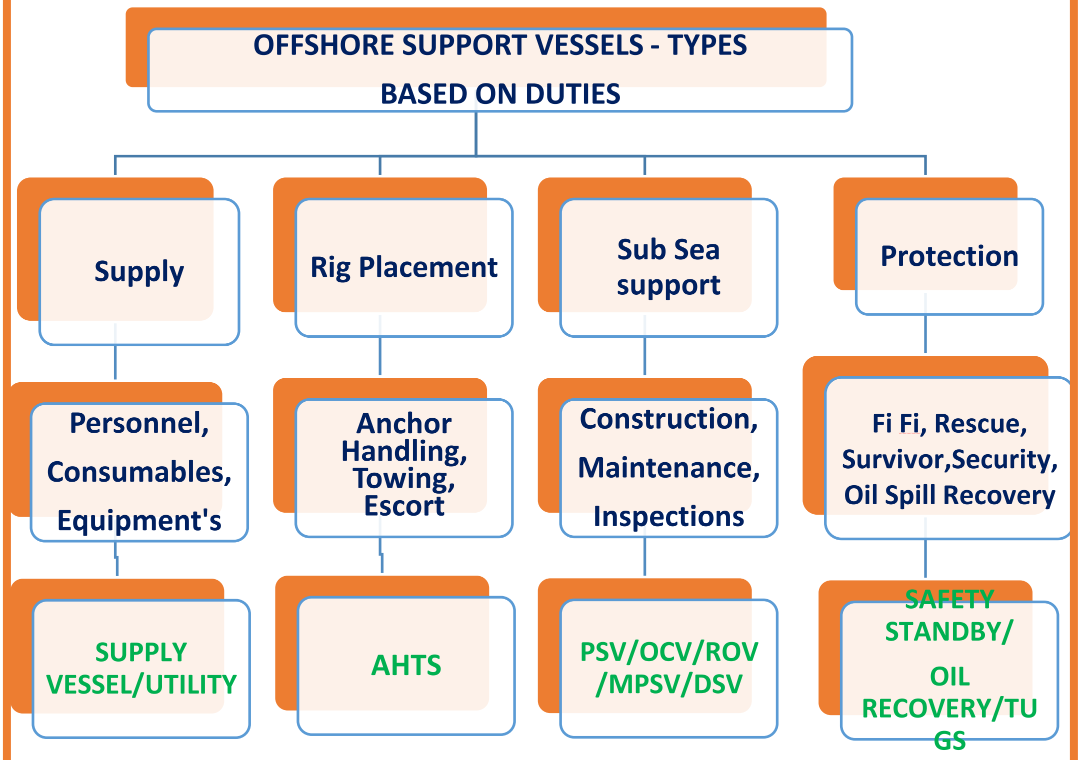


Figure 1.5: Offshore Support Vessel Types -Based on Duties

(Source: Author's own analysis**)**

Aim & Focus of Research: After amending MARPOL Annex VI IMO in January 2013, the IMO (International Maritime Organization) regulation became operational. (IMO 2011). — which was new chapter in ship energy efficiency rules. The Energy efficiency operational Index (EEOI) only applies to cargo-carrying conventional ships, but the SEEMP, which improves daily operations onboard, is required for all vessels, including non-transport working vessels. SEEMP is designed to enhance the day-to-day activities onboard by reducing waste, improving efficiency, and reducing emissions. The regulations do not apply to the offshore support vessels, as the primary function of these ships is not to transport cargo by itself. Since the current EEOI is calculated according to transport work (cargo transported per nautical mile per tonne of fuel), when it comes to offshore support vessels, it is impossible to use the same method that is used for other vessels.

In UAE, the offshore vessels work on a charter basis such that operational aspects and vessel investments where the owner is accountable for all expenses, including those that are connected to the vessel's capacity to conserve gasoline, while the charterer is accountable for disbursing costs linked to each trip, including the rate of fuel. Hence, the energy efficiency initiative is not monitored in UAE region for a specific operation. Since, regulations does not specify a method for monitoring energy efficiency and it is only a voluntary compliance aspects in a region like UAE with fuel cost in comparison with operational costs are less, Ship owners does not specifically attend to the Energy efficiency monitoring. Since the regional Operational Parameters and best practices followed vary for offshore operations, A UAE specific monitoring of the energy efficiency parameters have relevant impact.

It is clear that in the contemporary shipping situation, Due to unpredictability and flexibility of working vessels' operation profiles, performance monitoring systems were set up for long-distance sailing and can't be used on working ships.

Study's overarching goal is to map out the decision-making frameworks associated with offshore support boats' energy efficiency. To model a framework and create a performance index for it, extensive participation from a wide range of personnel and operational involvement is necessary.

FRAMEWORK OF OFFSHORE SUPPORT VESSEL OPERATION - FOCUS OF STUDY

In Jan 2013, IMO instituted regulations related to Maritime Energy Efficiency to set a yardstick towards energy efficiency and for new and existing ships for handling energy-efficient ship operations. Energy efficiency improvements must consider the vessel's operational profile, not just its design state. Ship designs generally optimise the exterior form for a restricted series of functional conditions, but with increasing computing power, ship design optimisation processes have improved. A vessel only works in its design conditions occasionally. Internal and external variables must be taken into account as part of the research into working profiles for offshore support vessel types in the United Arab Emirates. This includes the ship's owner, charter company, management company, final customer, and authorities in the area where the ship operates.

The UAE regions best Practices will be incorporated during working on the Framework which shall be based on mandatory guidelines such as IMCA - International Guidelines for The Safety Operation of DP Offshore Supply Vessels, Department of Transport -Maritime Sector Transport Regulations (General and Port Operations), OPCO Acceptance Standard
For Marine Vessels, OVID, the Offshore Vessel Inspection Database as well as regional operators, owners, Port authority guidelines.
In this analysis, we take into account the percentage of work spent in various operational work patterns of the vessel consisting of At Port, During Maneuvering, During Passage and At Offshore Operations with status as below:

- **At Port:** The ship is securely docked at the wharf or harbor, and its engines and propellers are turned off.
- **During Maneuvering**: The ship is making maneuvers in a port or other confined space. The motor, thrusters, and possibly dynamic positioning (DP) are all active and providing propulsion and maneuverability.
- **During Passage:** The ship is travelling between two fixed locations.
- **At Offshore Operations:** The ship's capabilities determine and the nature of work being done offshore, the vessel will engage in a variety of different kinds of offshore operations. This will be done in a variety of procedures that are carried out in the selected mode. Transporting goods, helping with anchors, tugging, connecting up, and standing by are all possible roles, some examples of possible operations as exhibited in figure 1.6

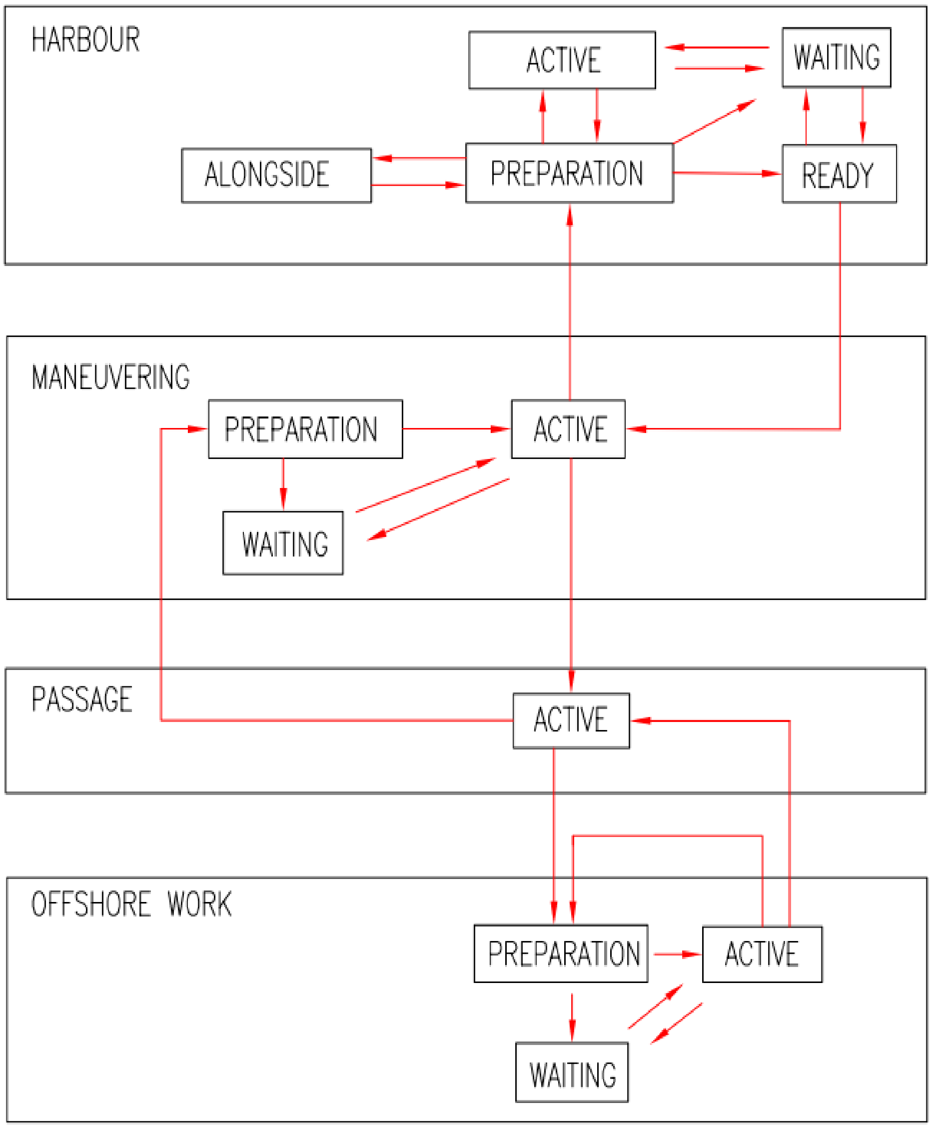


Fig 1.6 Operation Mode of Offshore Support Vessel:To be Analysed

(Source : Lützen, M., et al 2016)

The focus of this research in such context is, Since the measure to monitor will vary at different Operational conditions as stated above, The Performance index shall be derived based on permutations of Operational Modes versus different Work Patterns.

1.3 MOTIVATION FOR STUDY

1. The UAE's first unified energy strategy, "Energy Strategy 2050," launched in 2017 with the aims of boosting the stake of unpolluted energy out of the entire energy mix from twenty five percent to fifty percent by 2050 and reducing power generation's carbon footprint by seventy percent. The United Arab Emirates has helped execute the IMO's first strategy for cutting carbon dioxide emissions from ships, and it will keep lending a hand as the IMO works on its second action plan and its fourth greenhouse gas study for 2020. However, considering, the buoyant aspirations of Government of UAE, existence of performance index benchmarks in the maritime sector can alone help in enhance absolute energy efficiency levels by reducing carbon emissions. The current research, therefore, is an attempt to set a framework and derive a specific operational performance index benchmarks for the Offshore support vessel sector which currently does not have a specific criterion for the same that is evident from literatures.

2. To enrich my understanding on the conceptual and theoretical base of offshore support vessel operations and measures that could contributions on energy efficient performance of these vessels.

3. To contribute to the literature by integrating the available knowledge with my research to find some framework which could enhance the energy efficient performance of Offshore support vessels

4. IMO has not yet determined the technique to enhance regulations surrounding EEOI (MEPC.1/Circ.684). Although UAE runs one of the top five biggest offshore support vessel fleets in the world, the IMO committee MEPC 76 hasn’t hitherto addressed a precise procedure for

energy productivity management designed for vessels between four hundred and five thousand GRT.

5. The contribution of the research findings will be towards improving implementation of efficient energy parameters on offshore support vessels operating in UAE and develop and performance Index.

1.4 BUSINESS PROBLEM

1.4.1 BACKGROUND

1. Although there was a one-third increase in the energy efficiency of foreign ship operations between 2008 and 2018 (IMO, 2020), researchers still find insufficient efficient energy measures. The closing of these "energy efficiency gaps" (Jaffe and Stavins, 1994) is crucial to meeting the IMO's greenhouse gas reduction target. Rehmatulla (2020), Adland (2017), Smith (2015), et al. (2013), Jafarzadeh (2014), (2014), and Acciaro (2013) have assigned energy productivity disparities towards an extensive range of causes, with a focus on how principal-agent conflicts stand in the way of more efficient policymaking. Scholars in the field of conservation of energy draw a line between technological and operational approaches to reducing energy consumption (Rehmatulla and Smith, 2020).

2. Since 2013, the IMO introduced regulations that apply to commercial vessels of 400 GT and more required to adopt methodology to bring SEEMPs (Ship Energy saving Management Plans) outlining how they handle energy saving in voyage planning and execution (IMO, 2016) adopting methodologies like EEOI , EEDI.

3. EEOI is placed in the field of transportation (cargo transported per nautical mile per ton of fuel), that is also identified as gaps which makes it unusable for Offshore support vessels.

4. In UAE the market for offshore support vessels is in constant flux, and this has an effect on the number and quality of services provided by offshore supply vessels. Since this condition without proper methodology prevails for offshore vessel fleet, it will bring huge business loss to Offshore support vessel Operating Companies. The purpose of this research is to discover different approaches that could be taken to address this issue with the company.

1.4.2 BUSINESS PROBLEM

The Offshore Support Vessels operations in the UAE does not follow any specific methodology as it is not applicable as a regulatory aspect for offshore support vessels.

In the absence of methodology,

1. There is no proper measure to monitor energy efficiency parameters of offshore support vessels
2. Absence of measuring and monitoring can lead to direct losses since cost is incurred for operations of these vessels and indirect losses with increase in carbon emissions that have negative environmental impacts.

CHAPTER 2

LITERATURE REVIEW

CHAPTER 2

LITERATURE REVIEW

2.0 LITERATURE REVIEW

With intent to probe the existing literature on Energy efficiency, a summary of the previous literature will be presented here. Review is performed on a large number of research reports, publications, manuscripts and orders. The following table 2.1 depicts the details of the same:

Table 2.1: Sources of Literature Review

Key Words Used	Journals Explored	Databases
1. Maritime Energy Management 2. Optimize shipping 3. Energy efficiency in shipping 4. Monitoring effectiveness in vessel operations 5. Energy efficiency gaps 6. Energy efficiency barriers	1. Journal of Shipping and Ocean Engineering 2. Maritime Policy & Management 3. Publications of Abu Dhabi Chamber 4. Clarksons research 5. Danish Ship Finance 6. Drewry Maritime Research 7. Financial times 8. Koncept Analytics 9. International Energy Agency (IEA) 10. International Monetary Fund 11. World Bank – Data and Statistics	1. Taylor & Francis 2. Elsevier 3. Google-scholar 4. Palgrave 5. JSTOR 6. Scopus 7. Sciencedirect 8. IHS-World Fleet Statistics 9. IHS Fairplay

7. Energy efficiency indexes. 8. emission reduction technologies, 9. Environmental protection 10. Sustainability UAE 11. SSEMP 12. IMO resolution 13. IMO MEPC 14. Agency Theory	12. World Shipping Council 13. Maritime Policy 14. UNCTAD Reports 15. Transport Environment(Website) 16. IMO(Website) 17. Federal Transport Authority, UAE (Website) 18. UAE Shipping Association (Website)	

2.1 THEME: BASED LITERATURE REVIEW

Literature collected from the above sources is thematically collated as:

1. Regulations & Guidelines
2. Failures and Barriers: Energy Efficiency
3. Ship energy efficiency Management –Guidelines, Parameters, Factors
4. Offshore Support Vessels -Energy Efficiency
5. Energy Efficiency Measurement & Theory

2.1.1 THEME: REGULATIONS & GUIDELINES

According to (IMO 2011) Annex VI of the International Convention for the Prevention of Pollution from Ships (MARPOL) with addition of Chapter 4, the regulations regarding efficiency of energy were updated so that they comply with MARPOL, the Convention. Certification and issuance of IEE Certificate, which must be presented to demonstrate amenability with regulations, must be carried out by an organisation or authority that has been granted the necessary permissions. Even though some ship types and propulsion types are exempt and a waiver may be granted, all ships having a gross tonnage of more than 400 must comply with rules (IMO 2012a).

According to (IMO 2009), the guiding principles for the voluntary use of EEOI as established in the annexe, were decided and agreed to be circulated. In accordance with the same, Member Governments are requested to get the attention of everyone who is involved in this matter to the Guidelines and to endorse that they practice the Guidelines voluntarily. Future sessions of the Committee have extended an invitation to both member governments and observer organisations, soliciting feedback on their experiences thus far in putting the Guidelines into practise. Consistent monitoring and measuring methods should be documented. When designing monitoring procedures, the following factors should be considered: selection of operations/activities that will affect performance; selection of data sources and measurements, including format; selection of measurement frequency and personnel; and upkeep of verifying processes' quality assurance measures. This self-assessment can be used to evaluate the System's performance and find areas for improvement or correction.

According to (BIMCO 2011), legal considerations for slow steaming primarily focus on owner's duty to conform with the slow steaming directions with consideration towards the welfare of crew, ship and its cargo as owners are accountable for making sure the ship is in compliance with the slow steaming clause of the BIMCO slow steaming clause. However, if the parties agree to contain the clause, they should also be equipped to take on responsibilities; more specifically, should be "slow steaming ready" from the beginning of the process. Charterers may direct the Master in writing to slow the vessel's speediness or lower the RPM of primary engines in agreement with the BIMCO Slow Steaming Clause for Time Charter Parties. Owners must protect the vessel, cargo, crew along with the marine environment.

IMO GHG study (2012) the study's conclusion states that several strategies are feasible for cutting down on carbon gas releases from the vessels. The report examines various approaches pertinent to the discussion taking place within the IMO right now. According to the findings of the report, policy instruments based on the market combine high environmental effectiveness with a low cost per unit of effectiveness. These instruments are able to capture the greatest quantity of emissions within the bounds of the scope, allow for the implementation of technological and functioning stages in the shipping sector, and serve to offset emissions from other sectors. One low-cost way to encourage more energy-productive vessel design is to set lowest EEDI for new vessels. It is only applicable to brand-new vessels, and it provides incentives for design enhancements rather than operational ones, so the effect that it has on the environment is relatively minor.

Plans for optimising energy efficiency in ships may make reference to Company-specific steps to be put into effect in IMO MEPC Circular 683 from 2009. As stated, it is not up to individual ship management alone to increase energy efficiency in maritime operations. Possible participants include shipbuilders, ship proprietors, workforce, charterers, cargo owners, ports and traffic control services. JIT delivery, described in section 4.5, necessitates advanced coordination and planning amongst operators, docks, and traffic administration services. The more effective communication there is between these parties, the faster progress can be made. Ships aren't the best choice for tasks requiring coordination or overall management. If a company does not already have a plan in place for managing its fleet and coordinating with relevant parties, it is strongly advised that it develop one.

The effects of SEEMP are not completely understood, as (Bazari and longva 2011) point out. SEEMP will implement 30–60% of the most efficient operational measures, they predict. Compared to ISO 500001, the energy management standard, and ISM Code, (Johnson et al. 2013) conclude that SEEMP is lacking in several key areas that are essential for achievement of ISO 500001 and ISM Code like strategic management role and tackling with non-conformities. It is concluded that “these differences may be unfavorable for success of SEEMP”. In conclusion, the effects of SEEMP cannot be predicted with any degree of accuracy. It seems likely that only efficient improvements that are also cost effective will be implemented. Options for improving energy efficiency are put into action as soon as the marginal abatement cost models indicate that doing so will save money, so our model does not guarantee that the current energy-efficiency gap will be reduced (MACC). Assume that due to obstacles in implementing cost-effective measures and uncertainty about the benefits, only 75% of the potential will be realised. It is presumed that the number of features yet to be implemented will remain constant.

(IMO 2012b), the SEEMP Resolution MEPC 213(63) evidently outlines necessary framework and steps for planning for a designated vessel type. To begin with, it is important to determine which precise actions will increase the ship's energy efficiency, as these vary greatly depending on cargoes, vessel type, routes, and other aspects. An overview of necessary steps for the vessel can be obtained by listing all of these measures together as a package. Therefore, determining the current energy usage of the ship is crucial during this procedure. The SEEMP subsequently shows the energy-saving initiatives that have been taken and evaluates the efficacy of these measures. The SEEMP also determines what additional steps can be taken to boost vessel’s energy efficiency. However, it is important to remember that not all measures are suitable for that not all ships are created equal, and that the same ship can behave very differently depending on its working environment sometimes are even incompatible with one another. The SEEMP hopes that early actions will lead to not only energy but also cost savings to reinvest in the more complex and pricey productivity improvements.

(Perera 2016) offers overview of energy efficiency methods grounded on emission control that can be implemented during the ship's operational period to conserve energy. The first section of the research focuses on how the shipping sector can improve its energy efficiency in light of current laws governing emissions. That exemplifies the ideas of ECA, carbon dioxide cuts, SOx limits, and NOx Technical Codes for limiting emissions, and concepts of EEDI, EEOI, and SEEMP for maximising energy efficiency at sea. The second part is to figure out how energy could be saved during the operation phase of the vessel built on the preset energy flow pathway. The first investigation of navigation and performance factors for a designated vessel along energy flow route are shown to support the aforementioned circumstances. A big part of the SEEMP is figuring out where people use a lot of electricity and presenting possible ways to save energy in relation to the EEOI. Lastly, these findings are used to talk about the possibility of using the right navigation strategies in the chosen ECA to slash down on carbon dioxide, sulphurous and nitrous emissions.

(Canbulat et al. 2019) noted a sizable amount of power is used up each time a ship sails its course or a port operation is carried out. IMO has recently taken regulatory approaches with the aim of forcing the transport trade to make it more energy resourceful and sustainable. The literature on port and ship energy efficiency management is expanding. To get an Integrated Energy Efficiency framework for marine transport operations, however, not enough investigation has been done on the ship-port interface. This study creates a theoretical basis for evaluating comprehensive energy efficiency in the shipping business. With aim of improving energy efficiency while also cutting down on carbon dioxide emissions, shipping companies need to pinpoint specific port and harbour energy saving framework nodes. The overarching goal of study intends to optimise operational energy efficiency along with carbon dioxide emanations by means of a BBN application at the port-ship junction with respect to integrated operational energy efficiency interactions. The results suggest that factoring docks and vessel maneuver performances and basics into course scheduling and slow steaming decision-making could increase the likelihood of an energy productive and sustainable marine transport operation.

2.1.2 THEME: FAILURES AND BARRIERS - ENERGY EFFICIENCY

(Johnson et al.,2014) The results show that stricter energy efficiency standards will play a crucial role in cutting down on carbon dioxide released by ships. However, Numerous investigations have demonstrated that many of the commonly used to increase energy efficiency are also cost-effective. Market, institutional, and organisational barriers are frequently cited as the cause of this phenomenon in the literature. This is the initial of several articles that resulted from an industry-wide endeavour to analyse efficient energy management. The current article examines the challenges facing the shipping industry from the view of a small sea shipping company to adopt energy management system. Because of its potential to improve both research practise and knowledge, the action research approach was chosen. Findings highlight the complexity of energy efficiency initiatives and point to several trouble spots, such as inadequate project management skills, poor ship-shore contact, unclear accountability, a lack of useful performance metrics, and an absence of in-house energy efficiency experts. Action research and other interpretive research methods are proposed as potential sources of fresh insights into the long-standing barrier debate.

(Agnolucci et al. 2014) provides the first comprehensive study of the distribution of cost savings from travels with a low carbon footprint among ship owners and charterers. The incentives for ship operators to make investments in vessels that are more environmentally friendly are going to undergo revisions as a direct consequence of the allocation of financial savings, making this an important endeavour. The time charter market illustrates the principal-agent issue, like the real estate tenant-landlord problem. We found that between 2008 and 2012, ship owners only received 40% of the cost reserves from increased energy efficacy. The finding that vessel-owners only recoup a part of the savings may affect global and regional emission reduction policies.

(Brown 2001) demonstrates conclusively that customers in the United States are unable to acquire energy services at the lowest possible cost due to widespread market failures and barriers. Evaluations of various energy strategies and initiatives have that many of these market hurdles are surmountable with the help of public interventions. Both quantitative research and qualitative case studies attest to the pervasiveness of this chasm and the myriad of market barriers that contribute to it. Better policy interventions and public justifications could result from a deeper appreciation of these challenges. Successful policy initiatives in the past indicate that it is possible to at least partially narrow the energy efficiency gap.

(Faber et al. 2012) modelled ship emission predictions using saturation. Emission projections using such a model and transportation employment statistics are 6 percentage points higher than those obtained using more conservative assumptions. The largest cargo ships are getting bigger, which could reduce emissions by 3–7 percentage points by 2020 and 6–13 percentage points by 2050. The conclusions of this study propose that previous projections of emissions from maritime transport were too high. It also demonstrates that trade models should be used as the foundation for ship emission estimates, as projections of shipping activity are dependent on trade projections.

(Groot et al. 2001) Energy-saving technology investments help meet environmental aims. However, empirical data on policy success is scarce. This study analyses Dutch firms' investment behavior, energy policy attitudes, and environmental policy responses based on a survey. This study uses discrete choice models to examine how different types of businesses and industries influence the characteristics of important features.

(Hill 2010) draws attention to the analysis of obstacles to adoption, which can help guide policymakers and other interested parties. The results call for more in-depth policy action planning. Carbon reduction opportunities exist in the industry, but their success will require buy-in from many different parties. The OPS findings are particularly striking because they show how much of a role perception plays in preventing reductions in emissions. Most importantly, they show that the benefits of carbon abatement cannot be considered in isolation from the benefits of improving air quality, implying that multi-pollutant approaches should be used when constructing tools like abatement cost curves and damage cost functions.

(Rehmatulla et al. 2013) Moreover, the survey findings indicated that operational efficiency measures were more commonly put into place than in the other three simulated time charter situations when vessels were hired on time charter. It seems to infer that operative measures are less likely to be impacted by the principal agent issue than technical ones. As with credence goods, energy efficiency data is hard to watch and value during contracting, which may explain why the principal would put effective procedures in a time charter. Ship owner used operational measures in the setup with the lowest reserves transmitted suggesting it may be easy to do so.

(Johnson and Andersson 2014) demonstrates that there is room for improvement in the shipping industry's use of energy. While these operational and technical procedures fore reduction in costs of energy seem to be a good value for the money, shipping companies are slow in their adoption. This is recognized to be energy efficiency gap which affects the marine industry along with others. The deficit in energy efficiency is determined by a classification of monetary, administrative, and emotional hurdles that have been studied for decades in other fields using a number of different research frameworks. This article applies this research to shipping by speaking with experts in the field and examining related books and applications to help shipping managers. The article describes shipping blockades related to information disproportionateness and structures of authority in an organisation. Shipping company managers should look for the role of principal agent issues and organisational structures in explaining why their activities aren't more energy efficient and consider organisational change.

(Longarela-Ares et al. 2020) The rise in maritime traffic necessitates energy efficiency investments to reduce energy usage and emissions. Drivers must reduce or remove hurdles to encourage investment. This study examines how principal-agent issues in the shipowner-charterer relationship affect investment choices. The practice involves formulating a model and hypotheses, defining variables, utilising a state-of-the-art application to create a study based on sample and statistical analysis based on a descriptive analysis of variables and a binomial logistic regression model. The findings support the hypotheses and indicate that split incentives and principal-agent problems, particularly in time charter contracts, and a paucity of verified information discourage shipowners from investing in new vessels., which may be because of the problem in recuperating investment. These measures are more probable to be implemented in newer and broader vessels, as well as being encouraged by regulation to be implemented in older vessels. In addition, there is a higher probability of investment in ships that have their information verified and that have high activity and pollutant emission levels. The expansion of information in this area might make it easier for corporations and governments to behave in a more environmentally friendly manner, without having a negative impact on an industry that is innovative and competitive.

(Dewan et al. 2018), Total emissions in year 2012 were valued at 949 MT, or approximately two percent of the globe's carbon dioxide emanations come from transportation anticipated to escalate from 2012 to 2050 by around fifty to two fifty percent as reported in the Third Greenhouse Gas (GHG) Study 2014 of the International Maritime Organization (IMO). To achieve current and future global emission reduction targets, substantial changes are required across all industries through the implementation of energy efficiency design and operational measures. Some energy efficiency measures and new technologies have been around long enough to prove their effectiveness in reducing fuel costs, but shipping companies still don't seem eager to implement them. It has also been noted that stakeholders play a role, albeit indirect, in the shipping industry's efforts to implement energy efficiency measures. Thus, a qualitative survey among numerous stakeholders from all sectors of the shipping industry was designed to determine the obstacles to implementing operational measures to improve energy efficiency. Research has shown that almost all of the things that hinder cost-free operational measures from being used are the same. These include lack of awareness and information about the measure, lack of skills among ship workers and operation difficulties which are in form of technical and information barriers. However, owner's interest and financial issues are important barriers towards other operational measures which need investment for implementation and related to costing.

2.1.3 THEME: MANAGEMENT OF SHIP ENERGY EFFICIENCY – GUIDELINES, PARAMETERS, AND FACTORS

IMO's requirements for implementing the SEEMP and the aftermaths of using it were mentioned in the study by (Herdzik 2014). He did this to make some money off the plan's implementation. Under an IMO rule described in circular MEPC.213(63), shipowners had to make a plan for each ship and make sure that plan was carried out on every vessel over 400 GRT. The SEEMP gives ship owners more control over how their ships are used, how well marine power plants are used, how trash energy is recovered, etc. The main index is determined by dividing the volume of carbon dioxide released by how well a vessel moves for the marine power systems The goal of using SEEMP is to cut down on carbon dioxide emissions as a climate gas and make shipping more efficient.

(Notteboom 2006) says that controlling time is an important part of how modern liner services are made. Increased port traffic and limited facilities are two things that make it hard for shipping lines to give their customers the best liner services possible. Waiting times and delays make it harder to stick to a plan and could cost the customer in logistics. From the viewpoint of a transport line, the paper expresses upon the trade-offs that come with the time aspect in service plans. It not only looks at what makes schedules unreliable, but it also talks about the many measures and planning tools shipping lines use to make schedules as reliable as possible.

According to (Mihalis 2009), the berth scheduling problem is about putting ships in berths at a marine port. The goal is to make the ocean carriers happy (by dropping delays) and by keeping the terminal operator's costs as low as possible. In the prevailing literature, there are two chief assumptions related to vessel's position: All vessels to be assisted are in the seaport prior to onset of planning phase; or their arrival is delayed until after the planning phase has begun. In the second scenario, each ship's estimated arrival time is based on its exit stretch from preceding harbor, normal operating speed along with distance between two ports.

(Shubing 2009) There are many different ways that the maritime government could work better and be more efficient. Among these, quality shipping, openness, and partnerships may be seen as important if the Maritime Safety Administration wants to reach its goals in an efficient and effective way. Reforming public administration is never easy, and changes can't happen quickly. The fast pace of change in the workplace, especially when it comes to technology, will lead to more globalisation and interdependence in the new century. International events and causes will have more and more of an effect on domestic problems.

(Alvarez et al. 2010) remarked that under the terms of most contracts related to ocean shipping, a ship that was hired is required to set sail with "utmost despatch," regardless of whether or not there are available berths at the destination port. Many ports let ships dock based on who gets there first that further incentivizes the captain to keep the ship moving as quickly as possible. These legacy contracts and berthing practises hurt the economy, safety, and environment by making ports more crowded and increasing the amount of fuel used by ships. We suggest a framework for assessing the value of proposed changes to berthing regulations and maritime agreements. We have opted for a hybrid simulation-optimization approach owing to the impact of uncertainty on maritime transport system performance including requirement for simulation of efficient utilisation of finite assets. A discrete event simulation model is developed with the consideration of terminal's physical layout, the operation of land-based equipment, berthing policies, and penalties in addition to ships and their main economic and physical characteristics for breaking agreements. The terminal planner's reasoning can be summed up as an optimisation model, which is a significant generalisation of the classic berth assignment problem. The simulation programme represents the development of terminal planning by solving multiple instances of the optimisation model in sequence.

(Chai and Yeo 2012) put forth a structure that stages the blockades to energy efficacy accordingly. Although many revisions have looked into the obstacles that prevent energy efficiency, we have only found a few that take into account the interplay between barriers when proposing policy measures to remove these obstacles. We used the problem-solving power of systems thinking, which finds system that explains why people behave in similar ways in different situations, to look for trends in the resistance to energy saving measures in industrial businesses. The proposed framework, which draws inspiration from systems thinking, consists of four phases: inspiration, capability, the process, the outcomes, and the feedback cycle. The context emphasises necessity for policymakers to take a comprehensive approach to overcoming the obstacles. We contend that the four-pronged approach to Strength of energy efficiency depends on its least efficient component. Most previous research has dealt with barriers independently, proposing solutions for each one without taking into account their interrelationship. Using our framework, you can learn more about the part that major stakeholders like governments and ESCOs play in promoting energy efficiency. This makes it possible to evaluate energy efficiency policies and pinpoint their weak spots.

(Streng 2013), When the time savings for carriers are weighed against the time costs for shippers and consignees, it becomes clear that slow steaming is rarely a viable option from a supply chain perspective. As a result, slow steaming has an even greater adverse impression on the container shipping industry as a whole and on the entire supply chains. Slowstreaming is an undesirable circumstance in terms of the logistics network.

(Banks et al. 2013) examined operating summaries of speed and time expended in dock, voyage type as a case study concluding that total time spent varies as per ship type. Data analysis reveals that the distribution of recorded operational speeds has broadened and shifted downwards over the past three years. Sailing draughts are relatively uniform in ballast, but when loaded, they span a wide operational range.

(Sun 2013) contrasts the ongoing vessels' efficiency to those used for inland river transport in terms of energy consumption and production of greenhouse gases. This investigation is grounded in a case study of cargo transport on China's Yangtze River. Calculations and examinations of energy efficiency operation metrics are carried out based on gathered data, which includes both smooth sea conditions and actual navigational conditions. In this manuscript, we investigate the outcome of navigational conditions upon matter of the energy effectiveness of inland river vessels in action and discover that it can vary significantly.

(Yuan et al. 2017), a remote collecting system was deliberated to enhance energy efficacy of maritime activities using a cruise ship. Ship's navigation environment factors were statistically analysed using collected data. The strength of the relationship Gray correlation study examined wind, water depth, water velocity, and ship energy efficiency. The Wuhan-Nanjing stretch of the Yangtze River (upstream and downstream) was picked to study how wind speed affects ship energy efficiency. Results of the data analysis show that optimising the main engine speed can significantly progress the ship's energy efficiency in a variety of navigational environments.

(Styhre 2010) the shipping business has high fixed costs and benefits from economies of scale because it is so large. Shipping firms typically run with a high quantity of unused vessel volume due to trade disproportions, demand disparities, market instabilities, and customers' claims for high frequency. The study's goal is to discover how physical vehicle capacity can be better utilised so that transportation costs can be cut. The study draws on quantitative and qualitative information from three different studies of diverse categories of vessels for utilization in shallow seas: Ferries, cargo ships, Roll-on/Roll-off ships. Knowledge acquired as of the study lead to a framework for small shipping companies aiming to augment their vessel capacity use. Four parts of the framework are the following: the choice of volume utilisation strategy, the specification of sailing schedule, the enhancement measures for vessel capacity, and the enhancement measures for variations in vessel capacity. A long-term, economically viable shipping service with a rational service level, reliability and flexibility towards customers is the primary purpose of implementing enhancement measures coupled with a thoughtful strategy. As a result, the improvement is useful for both shippers and transport firms. Short sea shipping is effective in terms of energy efficiency and environmental performance, and it can reduce traffic bottleneck on land, so it's a win-win for society.

2.1.4 THEME: OFFSHORE SUPPORT VESSELS-ENERGY EFFICIENCY

(IMO 2009) these Guidelines' overarching purpose is to aid users in developing a system for reducing or capping greenhouse gas pollution from ships in movement. These Guidelines introduce the idea of a ship-specific indicator for energy efficiency towards carbon dioxide releases per unit of transport effort. The guiding principles are meant to serve as an illustration of an estimation method that could be employed as an unbiased, performance-based approach to monitor a ship's operational efficiency. Such recommendations provide one possible application of an operational indicator and should be taken as such. However, ship owners, ship operators, and other interested parties are encouraged to incorporate these Guidelines or a comparable method into existing environmental management systems and to give serious thought to adopting the guidelines while formulating strategies for monitoring of performance. EEOI Principles and Practices Offshore support vessels are excluded from the parameters described.

(IMO GHG Study 2009), a required EEOI threshhold may be an economical way to encourage all transport ships to reduce emissions. It rewards technical and operational measures. However, setting operational efficiency baselines and targets is difficult, making this option technically difficult. The current EEOI applies to cargo ships (MEPC/Circ.471).

(Lützen et al. 2017) performance systems have been available for years to help vessels operate more efficiently. A number of such structures are for sailing over vast distances and are not suitable for use on operating vessels. The document presents a theoretical framework for energy-efficient working vessel operation decision structures. The framework's three models describe a vessel's operational modes and activity states, the conceptual dependency between actors in the operational context, and the conceptual solution model, which integrates the other two models. Around fifty interviews were conducted with experts and office staff related to procedural descriptions and observation on ships. A many layered decision-making structure will use the framework.

(Głowacki and Behrendt 2017) details the issues with creating an evaluation methodology for the energy efficiency of support vessels for oil rigs. This evaluation was conducted using data gathered during normal operations aboard an Anchor Handling Tug Supply vessel. The ship's intended use (providing technological assistance to oil rigs) was also taken into account. The Energy economy Operational Indicator has been used to evaluate the energy economy. The International Maritime Organization developed and adopted this metric, but the writers have tweaked it to fit the profile of the vessel under study. First time ever, the specifics of Offshore Support Vessels, of which the Anchor Handling Tug Supply craft is a part, have been laid out in such detail.

(Prill and Igielski 2018) The correct evaluation of carbon dioxide released by the vessel during action is complicated by using EEOI as a means to monitor the energy productivity of ships conducting tasks other than transport. After analysing data from 30 trips, the research-training vessel was found to have a better Energy Efficiency Operational Indicator than the world's transport vessels. In order to account for the unique operational parameters of these vessels, the authors propose revising the way in which the term "performed transport work" is calculated using the indicator technique endorsed by the International Maritime Organization.

2.1.5 THEME: THEORIES AND METHODS FOR EVALUATING ENERGY SAVINGS

According to a study by Ronen (2011), reducing the cruising speed may necessitate more ships operating a route in order to maintain liner service frequency and capacity. The authors create a cost model to examine the impact of slowing down versus adding ships to a container line's route, and they develop a straightforward method to determine the optimal sailing speed and fleet size for reducing the yearly running cost of the line. Using available data, he demonstrates how running at or near the minimal cost speed can result in significant savings. Any bunker fuel price can be calculated using the presented technique and procedure.

(James et al. 2009), There is a concerted effort to cut down ship-emitted CO2 around the world. Short-term simulations suggest that reducing speeds can substantially cut CO2 emissions; halving speeds across a variety of containership routes can reduce emissions by as much as 70%. Marginal costs are typically higher than stated in studies that ignore revenue lost due to service cuts. On most routes, CO2 emissions can be reduced even at lower speeds, albeit at a smaller reduction and at a higher expense, even when extra ships are added to keep scheduled frequency. Ship operators may still favour speed reduction to reduce CO 2 emissions when CO 2 trading is in place, depending on the route's cost-effectiveness and profitability maximisation factors.

Under the auspices of MEPC at IMO, technical, managerial, and market-related issues mitigation steps were being considered as of 2009. UNCTAD/DTL/TLB. There was still a need to better understand the relative comparison of alternatives based on their relative merits, and analysis of how suggested mitigation measures might affect global trade and market distortions, even though measure’s reduction potential and effectiveness had not yet been fully established. The United Nations Conference on Trade and Development was urged to put its knowledge to good use and carry out relevant work, particularly in the areas of trade and development for developing nations. The potential of these concepts to improve the energy economy of the world's fleets gains and their effects on global shipping had to be determined as well.

With only partial information about requests being shared between carriers (Junsong, 2015) propose a solution to the request selection and exchange issue. A plan of action for collaboration between a carrier and a supervisor is outlined. In this architecture, we design two request selection models for the shippers to use. Four methods of profit allocation are also addressed, and a request exchange method is suggested for the coordinator. Simulation results indicate that the proposed procedure is more productive and effective amongst four methods.

According to Guericke and Tierney (2015), the viability of a liner distribution network is largely reliant on on how well the cargo allocation issue is solved. In our innovative mixed-integer programming method, we add levels of service for transit time criteria and optimise the Each segment of a service's vessel speed. The realism and utility of the cargo allocation issue are significantly improved by these extensions.

(Zhiyuan et al. 2014) provides a comprehensive look at the issue of intermodal liner shipping network architecture. Current approaches to liner shipping network planning primarily focus on interport demand. However, the majority of demand is generated in and served by the interior. This means that you'll need to figure out how to handle OD pairs where the method of transportation changes from land-based to sea-based, which is the case for many ODs that originate in the interior of the United States. First, we suggest a method for transforming OD demand at landfall into OD demand at sea. Then, a strategy for planning the infrastructure of multimodal liners around the world is put forth. Finally, a large-scale network example is used to apply and numerically verify the suggested methodology.

(Sverre et al. 2010), as per the research, additional effort beyond the measures included in this research is required to implement if shipping is to follow the expected increase in carbon dioxide output over the next two decades. While there isn't a magic bullet, the sum of everyone's efforts adds up to something big. This will result in a business that uses less energy in its operations and recognises its responsibility to help lower global carbon emissions. From 2030 to 2050, we may find revolutionary non-carbon-based solutions that allow us to continue the absolute decrease in CO2 emissions since 2009.

At the IMO, it is widely accepted (according to Devanney, 2011) that Owners of ships are hesitant to implement changes that would improve petroleum efficiency, even when such measures are economically viable (i.e., should have been adopted even in the absence of regulation). DNV describes it as follows. Economic factors were not seen as a significant change agent, as shown by the findings of this research. This is a common misunderstanding. Term charterers and owners both have a keen understanding of the importance of petroleum efficiency. The market is not a flawless mechanism. And at least one imperfection in the market is presently having a major impact on owners' efforts to cut down on carbon dioxide emissions. That flaw is the sped-up nature of the ship Charter Party.

(EU 2015), the company is responsible for developing a strategy for tracking gasoline consumption and calculating costs for each vessel in its care and then consistently applying the methods: Onboard Bunker fuel reservoir monitoring; flowmeters for combustion processes; Measuring Carbon Dioxide Emissions Directly; Bunker Fuel Delivery Note (BDN) and fuel tanks are checked regularly; Measuring Carbon Dioxide Emissions Directly. After being evaluated by the verifier, any mix of these techniques can be used if it improves the reliability of the measurement as a whole.

Theoretical perspectives on EE barriers found by various sources are discussed by (Thollander et al. 2010). There is an in-depth explanation of the different elements that make up each type of barrier (financial, behavioral, and organisational). Several classification schemes for obstructions are explored. Based on the complexity of the underlying structures, the authors of paper tried to classify 15 theoretical blockades to EE into one of three groupings: (1) technological regime, (2) technical system, and (3) socio-technical regime. Heterogeneity, hidden costs, access to money and risk are all parts of the technical system. Imperfect intelligence, split incentives, adverse selection form information that feature in the system of technology. Values, Credibility, principal-agent relationship, authority, inertia, and the dominant viewpoint are all aspects of the socio-technological regime.

(Rehmatulla 2014) notes that discussions of energy efficiency barriers typically take place within the framework of economic models. Several mainstream or conventional economic theories, and some derivatives, can shed light on the causes of energy saving roadblocks. These ideas have been around since the turn of the century, while the debate of obstacles to energy efficiency dates back to the 1980s. Since neo-classical economics is the nesting ground for much of agency theory and its own principles to address energy efficiency barriers, it is essential to address the field.

(Vernon 2012) identified principal–agent problems characterised by split incentives as a significant category of extant flaws in the market that prevent clear pricing. These Principal Agent issues may obscure price cues, reducing incentives for fuel-efficient behaviour and hindering efforts to allocate resources effectively towards energy efficiency investments. The impetus for driver productivity behaviour and costffective apportionment of resources towards energy productivity reserves will be strengthened and modification will be accelerated when the structure of market transactions is altered to address the market failures.

(Elshenhadt 1989), Theory of Agency is pivotal, but it also has its detractors. This author looks at agency theory, what it adds to organisation theory, how much actual work has been done on it, and how it can be tested. The main conclusion is that agency theory gives us new ways to think about information networks, uncertain outcomes, incentives, and risk. It is a reasonable point of view, especially when combined with the other points of view. The main suggestion is to look at the many problems with cooperative organisation from the point of view of an agency.

(Rezaei 2015) It is suggested that we practice the best-worst method (BWM) to address MCDM issues. Multiple criteria decision making (MCDM) involves comparing potential solutions to an issue using a set of criteria to determine which one is the best.(s). The decision-maker begins the BWM process by determining the best and worst criteria. Both the best and worst are compared to the criteria in pairs. Relative importance of each criterion is then calculated by formulating and solving a maximin problem. The same method can be used to obtain the weights of the options with regard to various criteria. The best option is chosen based on a final number that is calculated by adding up the weights assigned to each criterion and each possible solution. For the BWM, we suggest using a consistency ratio to ensure reliable comparisons. We demonstrated this with some numbers and definite decision-making problem to demonstrate and assess the efficacy of the proposed approach. (mobile phone selection). We opted for AHP (analytic hierarchy process), another method founded on contrasting pairs of alternatives. The statistical findings for consistency ratio and evaluation criteria such as conformity, total deviation and minimum violation indicate that BWM does better as compared to AHP. Important features of the proposed method include (1) requiring less comparison data than existing MCDM methods and (2) leading to more consistent comparisons, which in turn leads to more trustworthy findings.

(Fan 2018) emphasised the significance of management of energy economy with regards to the current push to decarbonize and smarten up the ships of the future. In order to achieve credible evaluation of different energy efficiency strategies, it is crucial to establish a verified energy efficiency model. Modeling and verification of a ship's energy efficiency taking into account a variety of variables are performed using a 53,000-ton bulk carrier as the basis. The operational indicator of ship energy efficiency, fuel usage, resistance characteristics and main engine power are the four primary building blocks from which a ship energy efficiency model is created. According to the findings, the developed model is reliable enough to replicate the effect of factors like cargo load, ship speed, and the random impact of multiple natural environmental parameters on a ship's energy efficiency. In addition to aiding transport manager in assessing feasibility of the predicted energy efficacy, this research may also be used

Management and supervision of ship energy efficiency was cited by (Wang et al. 2016) as a method to boost the marine economy and cut down on CO2 emissions. In this paper, a wavelet neural network was used which allowed the established ship energy efficiency real-time optimisation model to then determine the best engine speed for the optimum energy efficiency under different conditions of work based on the predicted working condition before the cruise in relation to factors in the navigating environment. Experimental investigations corroborated the success of the proposed optimisation model in achieving energy savings and emission reduction, providing theoretical recommendations for achieving peak ship performance in operation. Our proposed method has greater practical importance for enhancing ships' energy efficiency than the conventional setting speed navigation method.

To fulfil the need for energy saving and emission reduction, more and more attention is being paid to Wang et al.'s (2018) optimisation of ship energy efficiency. The energy efficacy is significantly influenced by environmental variables, such as wind and water velocity and depth that have a major impact on the energy efficiency of ship operations. Here, we propose a new method for dynamic optimisation that borrows heavily from model predictive control (MPC), for optimising ships' energy efficiency while taking into consideration these dynamic environmental factors over time. In the first step, we set up a nonlinear system model of ship energy efficiency and a dynamic optimisation model that takes into account the effects of time-varying environmental variables. The results demonstrate that the dynamic optimisation method can be used to ascertain the optimum sailing velocities at different time steps. The energy efficacy of ships and their carbon footprints can both benefit from this technique.

Poulsen and Sornn-Friese (2015) stated that Partial adoption of effective techniques for reducing energy consumption in shipping can lead to energy efficiency gaps. This study identifies energy efficiency gaps in maritime activities and delves into the causes of those gaps. Factors such as a lack of time to develop and provide accurate information on energy efficiency, a lack of information on energy efficiency, and a lack of energy training at sea and onshore all contribute to energy efficiency gaps. varying ship management models have varying effects on energy efficiency at sea, and this article fills the void between the ship management and energy efficiency literatures. It is challenging to achieve energy efficiency in ship operations when third-party ship management is used. Implications for management within shipping companies that outsource ship administration are discussed at the end of the paper.

Ship releases of carbon dioxide gases and other atmospheric pollutants are a significant contributor to global warming, according to (Zhang et al. 2019). Since there is a robust association between fuel usage and releases, increasing ships' energy efficiency is a crucial step towards greener shipping and long-term prosperity. This paper, using semi-empirical analyses, proposes a new metric dubbed the EEPI to overcome these limitations. Instead of using confidential information, EEPI makes use of the estimation results from an unobserved effects model and quantile regressions to add a new proxy of "transport work." Due to its simplicity, practicality, objectivity, and adaptability to the existing policy framework, EEPI has the potential to be used as a benchmarking tool, alone or in conjunction with a rating mechanism, to create incentives for improved energy efficiency performance and cleaner operation. EEPI was originally developed for use with oil vessels, but it could be used with any vessel that follows a predictable routine, such as a bulk carrier or a ship transporting a liquid chemical. With some adjustments, it may also apply to other varieties of ships. However, EEPI can be seen as a prototype for further improvement given the difficulties of its implementation in practise.

(IM et al. 2019), In order to comply with IMO's policy on reducing carbon dioxide emissions, shipping firms are encouraged to employ energy-saving practises in their ship operations. In this research, we suggest an evaluation methodology for figuring out how well a ship follows through on its energy efficiency plan. Ship Energy Efficiency Management Plan (SEEMP) operational standards served as the basis for the selection of the measures used to create this technique. Using an analysis based on AHP, we were able to determine the comparative position of several factors that affect a ship's ability to run efficiently on its fuel supply. As a result, a new method of evaluation was suggested that takes these metrics and their weights into account. South Korean shipping firms were subjected to this evaluation methodology, and resulting operational energy effectiveness indices were compared. The government and shipping companies can benefit from using this evaluation technique to evaluate energy productivity of operations.

(Beşikçi et al. 2016) Concerns about the climate and the economy have increased the maritime industry's focus on reducing ships' fuel consumption. Using current technology and practices, as well as technical advances in the design of new ships, has the capability to lessen shipping consumption of fuel by 25%-75%. The possibility for energy savings through changes in operations has been discussed regardless of the availability of many design and technology based techniques. Within the framework of the IMOs SEEMP, operational metrics were analysed. (IMO). To assign relative importance to each metric, we exercised the MCDM FAHP method which is a deliberate technique to find energy-effective solutions. It does this by accurately reflecting the imprecision of human thought and showing comparative position of operational measures which is highly important information for decision-makers (operating companies and ship owners).

(Munim et al. 2020) examines how best to adopt green port management (GPM) practises by analysing different port governance models. We suggest a MCDM framework grounded on social systems engineering principles, with five major GPM practise indicators and four port governance models taken into account. Our study also shows that BWM, which needs fewer judgement comparison. In January 2019, respondents did not diagnose they would use a different model to solve the same MCDM issue, which is a experimental plan with repeated measurements. In both studies, port privatisation improves GPM implementation. ANP, is a more robust MCDM approach with broader utility.

Table 2.2: Summary of Literature Review

Theme	Author	Inference	Gaps
Regulations & Guidelines (18)	IMO -MEPC Committee(2011), BIMCO(2011), IMO -MEPC Committee 61(2010), IMO Circular Ref. T5/1.01 MEPC.1/Circ.684 (2009), BIMCO(1989), Buhaug, (2009), IMO -MEPC Committee SEEMP(2009),Smith, (2015), INTERTANKO(2012),OCIMF(2010), IMO GHG-WG 3/3/3(2011), IMO MEPC.203(62)(2011), IMO MEPC213(63)(2012b),IMO GHG Study (2014), Perera (2016), Canbulat(2019)	1.Measurement systems in the regulatory sector are directed towards compliance rather than service enhancement. 2.Performance metrics are not systematically collected. 3.Studies concentrate on volume of cargo output not applicable for OSVs	1. No holistic representation given, only broad parameters considered. 2.Many pointers of significance overlooked 3.Input factors on Operational features
Failures and Barriers: Energy Efficiency (13)	Hannes (2014),Paolo Agnolucci,Tristan Smith,Nishat Rehmatulla(2014), Brown(2001),Eide, M (2009), Faber, J, (2012),Gordon, S (2008), Hasanbeigi, A, (2009), De Groot, H, (2001),Jenny Hill (2010),Rehmatulla, N., (2013), Johnson (2014),Dewan (2018)	1.Most Studies relied on operational performance indicators 2.Commonly used Elements are not considered 3.External physical and operational factors	1. Inadequate use of Operative indicators affects factual depiction 2. Inadequate use of benchmark indicators results in partial measurement 3. Dearth of usage of peripheral factors compel the non-

		4.Selection of comparison is not based logical approach.	reflection of comprehensive performance.
Ship energy efficiency Management – Guidelines, Parameters, Factors (12)	Jerzy Herdzik (2014),Notteboom, T.E. (2006), Mihalis (2009),Shubing Li (2000), Pescetto, A. (2012), Alvarez, F (2010), Chai, K (2012), Streng Lloyds List (2013), Banks, C. (2013), Sun X, (2013), Yuan Y(2017), Styhre L(2010)	1. Limited number of publications 2. Majority of indicators considered are operational in character. 3. Resources indicators rarely considered.	1. Research is required to recognize efficiency enhancements 2. Responsibility to manage and method is seldom part of the management team 3. Monitoring cycle not clearly defined
Offshore Support Vessels -Energy efficiency (6)	J.Herdzik (2014), IMO MEPC.1/Circ.684,(2009),IMO GHG Study (2009), Lützen M, (2017), Bartosz GŁOWACKI (2017), Prill K (2018)	1. Results of reforms are mixed. 2. Usage defined by the interpretation of user and management 3. No short voyages, different mode of operations considered	1. Energy efficiency has not been studied in a holistic manner. 2. Impact of Energy efficiency of OSV have not studied 3. No applicable Index reflects Operation of OSVs

Energy Efficiency Measurement & Theory (36)	WEO Journal, (2009), D Ronen, (2011), James J. Corbett, (2009), UNCTAD/DTL/TLB,(2009), Junsong Li, (2015): ,Stefan Guericke (2015): ,Zhiyuan Liu, (2014): Sverre, (2010): DNV(2010), Chong, D (1993), Davis, L(2009),Devanney, J (2011), EU(2015), Regulation (EU) 2015/757, Soren T. (2004), Allcott H, (2012), Rohdin P, (2006), Bunse K, (2010), Apostolos F, (2013),Brown Marilyn (2001); William Stephens, (1999);Thollander P, (2010); Stich V, (2012);Blumberga D, (2015),Rehmatulla, ; (2014), David Vernon(2012) Kathleen (1989), Rezaei (2015), Ailong (2018),Wang (2016)(2018), Poulsen(2015), Zhang (2019), IM N, (2019), Beşikçi E (2016),Munim Z (2020)	1. Performance measurement need consider individual vessel capabilities 2. Operational Parameters play a significant determinant of vessel performance index 3. Onboard operations is neglected sector. 4. Consider biases in engg analyses for energy efficiency 5. Inference can be drawn to similar industries in other developed countries 6. Presents insights about future research areas in energy efficiency 7. Presents good description of market failures and barriers in with specific reference of energy eff gap	1. No study done to perceive if operational factors have impact on performance. 2. It needs to be confirmed if there is a relation between shore operations and performance. 3. Large industries are not covered. 4. Nothing is mentioned that how the barriers would be addressed 5. Research is generic to industry and can be applied to specific industry or sector 6. Discussion is focussed on clean energy policy formulation in line with market failures and barriers. 7. Talks about barriers to EE only.Not operational aspects 8. Significance of proportion of frame work on different

		8. Presents insights about various barriers to EE 9. Inference can be taken to apply similar approach for EE in production sector companies 10. Energy efficiency measures should be connected with energy management techniques 11. It is only a voluntary structure to measure energy efficiency on offshore vessels 12. Agency theory shall be applicable to the Principal agency problems 13. BWM, Fuzzy-AHP MCDM approaches can be employed for analysis.	operational modes of performance is yet to be checked. 9. Human factor involvement not considered 10. Agency theory need to be applicable based on each agent involved with principal

2.2 GAPS FROM THE LITERATURE REVIEW

From the review of above literature, 3 primary gaps crop up for further understanding and they are:

1. There is a dearth of research into the topic of quantifying and tracking the operational energy efficiency of offshore Support Vessels in the UAE.
2. IMO adopted SEEMP includes the use of efficiency measurement tools like the Energy Efficiency Opportunity Index (EEOI), but these tools were not designed to assess the operational efficiency of offshore support vessels as a whole.
3. An established method and framework, ideally an international standard, needs to be applied to quantitatively examine the energy efficiency of these Offshore support vessels.

2.3 THEORETICAL PREMISES OF THE STUDY

The approach of “Agency Theory” has been applied in this study for assessment of factors and setting up framework of the research as well as rating of performance index.

Various theories like Agency theory, Stakeholder Theory, Utility Theory, and Resource-Based Theory were studied to deliberate the theoretical premise for this study. After due deliberation, the the most applicable theory for the study is found to be Agency theory.

Review on Theories Considered

Stakeholder theory: It can identify internal and external stakeholders that impact factors and explain how they affect the eco-friendly policies of the company (Phillips, 2003, Frooman 1999, Freeman 1984). Primary participants are those with a formal relationship with shareholders, employees, suppliers, customers, and government bodies while media, authorities, local community and citizens are the secondary stakeholders (Clarkson 1995). Now, these factions are need to be considered more importantly in assessing business's ecological and social effects than managers used to think (Sharma and Henriques 2005). Stakeholders use direct or indirect influence tactics depending on their resource relationship. (Frooman 1999). Dependent or autonomous stakeholders. Therefore, there are four possible configurations in which companies and stakeholders share resources.

Utility Theory: The theory seeks to explain the situation observed behavior and choices (Anderson J.Brito, 2020) proposed a multicriteria model for assessing and classify its section into categories. The model was developed by integrating Utility theory and the Electre Tri method (Kaplinski, 2013) suggested method of analysis grounded on the claim of utility theory. The statistics used for evaluation is based on economic data (supply, seasonality, demand,), chronological data, restricted probability and utility function.

Resource-Based Theory: In this view, having access to strategic tools doesn't automatically give a company an edge over its competitors (Barney, 1991). It originates from economic disciplines and its application has been extended towards management, sociological, information management and knowledge management (F.J. Acedo, 2006). (K. Almarri, 2014) considered this theory as a fragment of strategic management theory and has been extensively employed by decision-makers in project management. (Paul Govan, 2016) proposed a resource-based approach.

Agency Theory: Both positivist research (Jensen 1983; Eisenhardt, 1989) have contributed to the development of agency theory. While both share the element of examination (contract) and the assumption described above, they diverge in three crucial extents: scientific rigor, dependent variables, and statistical significance (Eisenhardt, 1989). Researchers of the positivist school have concentrated on identifying situations where agency problems arise, resulting in agency costs (such as the costs of monitoring or incentivizing for goal alignment), and then while less mathematically rigorous, describes the solutions that put bounds on agency issues. Most studies of this kind have concentrated on the principal-agent dynamic between shareholders and corporate executives (organisational behaviour/economics) in large public companies (Eisenhardt 1989; Argawal & Mandelker 1987; Wolfson 1985; Walking & Long 1984; Ahimud & Lev 1981).

Agency Theory: Applications for measuring, monitoring & Framework setup

Agency theory is applied to operational energy efficiency measures (Rehmatulla, 2014). Blockades and failures in the market impact energy efficiency. (David Vernon, 2012) in their paper, used Agency Theory to identify and quantify principal–agent problems affecting energy efficiency investments.

This research will create a framework and measure UAE offshore support vessel operational energy efficiency. To realize the goal, identify the energy effectiveness gap in transportation by exploring the extent of employment of energy-effective operational procedures along with the blockades to their implementation. The study examined energy-efficient procedures by examining internal and external factors and barriers. The parties involved including the management of the company, owner, charter, operating region authorities and the end customer determine whether it is a principal-agent problem. In UAW, the energy-efficient operational measures in offshore support vessels have no baselines in the current research scenario. Agency theory will measure energy efficiency parameters through operational measures for primary and secondary data collection. The survey technique will be employed to comprehend and establish a reference point for operational measure application, how it varies across principal agent problem cases, and each party's perception. (Principal and various Agents). The survey outcomes are related to principal agent problem observations based on content analysis of each party (agent) and operational efficiency data. Ship owner is principal.

Agency theory can explain most operational aspects, especially efficiency implementation failures, making it the most relevant theory for this research. In explicit research, agency theory is valid in policy, organizational, and individual settings, resulting in its high applicability to socio-economic backgrounds. It proposes the best contract to reduce Principal agency problems. The theory's broad applicability would help explain principals and agents' operational measures in shipping's energy efficiency. The agency theory is testable and empirically valid because it has been widely used in organisational studies and supported by research employing a wide range of empirical methodologies. as shown in figure 2.1.

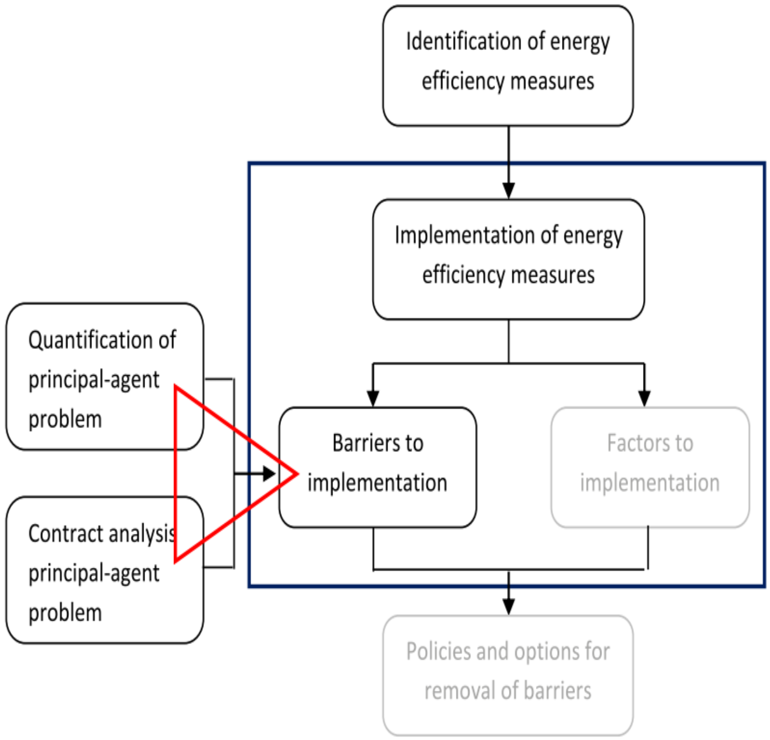


Figure 2.1 Agency Theory Process (Source: Rehmatulla, N, 2014)

The main benefit acknowledged by proponents of Agency Theory is its explanatory power. (Wright 2001, p. 414) states that "by narrowly focusing on the principal-agent relationship, and with a given set of assumptions, the contribution of this Theory is that it provides logical predictions about a relationship". As a consequence, "Agency Theory offers a fresh, practical, and empirically testable angle on questions of collaborative effort." (Eisenhardt, 1989, p. 72). Its competency is leveraged to calculate potential impact upon energy consumption in cases involving the Principle Agent. The central insight of Agency Theory is that interactions between principals and agents inevitably result in economic inefficiency. The focus of the Theory then shifts to how the dynamic between agents and leaders can be optimised. Under different conditions of outcome uncertainty, risk aversion, goal of Agency Theory is to figure out what conditions are optimal for taking any given course of action.

CHAPTER 3

RESEARCH METHODOLOGY

CHAPTER 3

RESEARCH METHODOLOGY

3.0 RESEARCH METHODOLOGY

3.1 OVERVIEW

In this chapter, we will examine the methodology that was used in order to accomplish the research goal to develop an operational frame work and performance Index o of offshore support vessels. The most effective strategies and procedures to rank the factors which act as barriers for improving energy efficient and possible strategies to overcome the identified factors are also explained in detail in this chapter. The various phases for identification of the aspects with various data collection methods and the sources of data from different stakeholders from specific industry is also argued in this chapter.

3.2 RESEARCH PROBLEM

An offshore-support vessel's operational parameters represent its energy efficiency. While there is a wealth of information and approaches for calculating functioning of commercial cargo ships, there have been very few attempts to quantify and track the energy efficiency of offshore support vessels. Current operational practises surveyed for such vessels in UAE do not allow for comprehensive monitoring of improvements in operational energy efficiency, a goal of environmental protection.

Therefore, the demand for Offshore Support Vessels and the number of orders for the services they provide will be correlated with the operational features of the services they offer and the range of technological procedures at their disposal for meeting the specifications. The cost of fuel accounts for between fifty and eighty percent of a ship's overall operating and maintenance costs, so any changes there will have significant repercussions. Therefore, only businesses and vessels with effective energy management strategies will survive. Improving energy efficiency in offshore support vessel operations not only affects cost effective service pricing, but above all needs to reduce the carbon emission issues caused by fuel combustion. Here the question has been raised by vessel operators of OSVs on how to implement the IMO, the Shipboard energy efficiency management plan for those vessels which are operating especially in dynamic functional modes of UAE.

So, it is necessary to identify and evaluates the factors which act as hurdles to contribute to energy efficacy. Monitoring the factors and setting up a framework for overcoming these barriers by identification of correct factors along with usage of advanced technologies, functional features and categorizing the operational modes will help to improve the performance of OSVs and contribute to energy efficiency operations to reduce Green House Gas emissions.

3.3 RESEARCH QUESTIONS

RQ1. What is the overall framework and factors to be followed for energy efficiency optimization of offshore supply vessels in UAE?

RQ2. What is the method to be adopted to measure performance index of offshore supply vessels in UAE on all the Operational Practice modes?

3.4 RESEARCH OBJECTIVES

The core objectives of Research study include:

1. To identify factors and develop a conceptual framework that describes the overall Operational structure for energy efficiency of offshore supply vessels in UAE. (RO1)

2. To develop an Energy Efficiency Operational Performance Index (EEOPI) to measure all operational modes of an offshore supply vessel in UAE(RO2)

3.5 SAMPLING

Appropriate and feasible sample selection is crucial for achieving research goals. Probability sampling and non-probability sampling are the two main buckets that sampling techniques fall into. There are many steps involved in developing samples, including choosing a sampling technique, outlining the sampling framework, zeroing in on the specific industry or sectors of interest, and determining an appropriate sample size. Whether or not the sample is industry-specific is the primary concern during the sampling process. The variables affecting the energy efficiency of OSVs were identified by conducting an analysis of the relevant publications and expert opinion, and were found to be universal across almost all industries. For this reason, it makes sense to focus on a category-level example; this will ensure that you receive useful, actionable feedback and close any knowledge gaps that exist regarding that category and any subcategories it may contain. Vessel varieties and their defining characteristics were also sampled. To correctly identify uncharted and problematic areas, it is important that the respondents chosen for the sample hold excellent knowledge and extensive experience. Respondents in this study are drawn from intermediate and upper-level maritime industry executives with hands-on experience in OSV operations.

For sampling purposes, a minimum of five years in OSV industry is considered a reasonable time frame to become an experienced maritime professional, which requires a multi-disciplinary approach that integrates insights from education, industry norms, and professional development. The maritime industry has established standards and requirements through organizations such as the IMO and industry associations that are generally met over a long period of time. This means that five years represents a reasonable time frame for the acquisition of skills and expertise where complex assignments and knowledge are learned. Safety, human factors and Training often focus on the time frame needed for individuals to adjust to complex working environments, which emphasizes the importance of learning and accumulating experience to become competent in high-stake industries, like the maritime and offshore field, within the first five years.Most professionals reach leadership or expert status after about five years of dedicated work within maritime industry to which reearch is focused.Since the certifications or licenses require at least five years of sea service to qualify as an officer's on ships. Therefore, the convergence of principles from multiple disciplines, industry standards and regulatory requirements supports the claim that a minimum of five years is sufficient for professionals to achieve a level of expertise has been taken into consideration for the research.

In terms of sampling units, elements and geographical extent, and measurement duration, the target sector has been determined. The target sectors for the present study are listed below:

Type of Universe: To develop a sample design, the researcher needs to define the set of the universe which could be finite or infinite. In our study, it is finite.

Elements – Middle / upper level Management personnel

Sampling units – experienced management personnel of the sectors in the Maritime as per mentioned criteria.

Time – May 2021 to July 2021.

Extent – UAE

Target Population size : The target population surveyed for this analysis is individuals working in relation with Offshore Support vessel Companies which is considered as 40 numbers in UAE.

Sample size: To ascertain sample size, (Yamane 1967) has given a simple formula which is:

$$\mathbf{n = N / [\ 1 + N\ (e)^2]}$$

with n being sample size, N as population size and e as precision level. Applying the above formula to the target population (95% confidence level),

the sample size obtained is,

$$n = 40/(1+40*(0.05)^2) = 36 \text{ respondents}$$

The elements of current research are management personnel of the various sectors in the Offshore support vessel (OSV) operations. During the process of data collection, an expert survey consisting of 37 respondent professionals was compiled. Professionals are selected using criteria such as industry experience of individuals, experience in the area of Managerial, Functional, and Infrastructure aspects of Offshore support vessels, experience in the area of Managerial, Functional, and Infrastructure aspects of Offshore support vessels, their standing in the pertinent industry, the educational credentials they possess, and the position they hold within the organisation etc. The experts who were selected for the purpose of this ongoing investigation are very knowledgeable about the maritime and OSV industries and have a great degree of specialised knowledge in their respective fields. In light of the fact that research has developed into a subject of increasing significance in the past 10 years, it was decided that one of the primary criteria for evaluating the data should be an individual's length of service in the pertinent industry of more than 10 years.

It is essential to investigate the level of experience that the respondents possess in the OSV business. It has been suggested that the data gathered on the respondents' employment experience, measured in years, is suggestive in Table 3.1 below with sector experience mentioned in Figure 3.1F.

Table 3.1 - Experience sector: (Source: Author)

Experience in sector (years)	**No.**	**Percentage**
0-5 years	0	0%
5-10 years	03	8%
Above 10 years	34	92%
Sum	**37**	**100%**

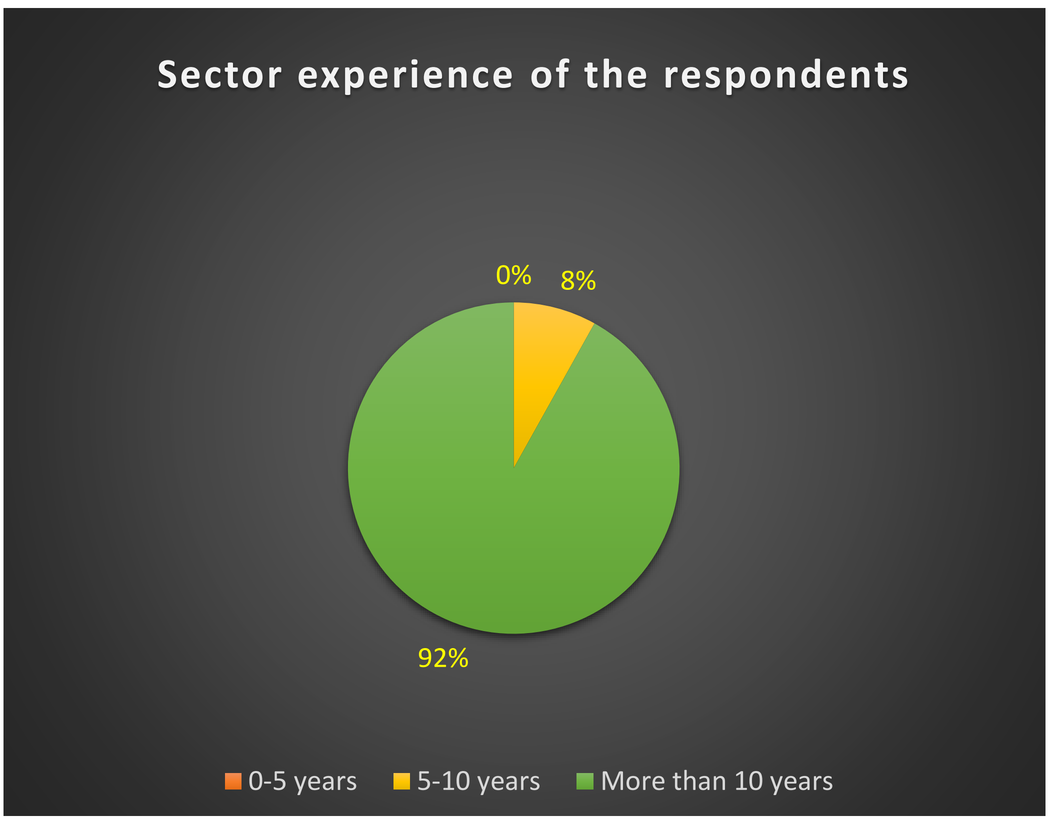


Fig 3.1: Percentage illustration of work experience in specific sector

(Source: Author's own analysis)

It is extremely vital to take into account the respondents' profiles, as Professionals with more experience and higher levels have access to a greater variety of information and resources, and there is a very good chance that they will offer constructive criticism. Demographics of respondents is provided below.

Table 3.2: Designation of respondents: (Source: Author's own anlaysis)

Respondents' Profile (In Numbers)	**No. of individuals**	**Percentage**
Top Management	05	13.5%
Middle Level Management	21	56.8%
Operational Level Management	07	18.9%
Strategists, policy makers and think tanks	04	10.8%
Total	**37**	**100%**

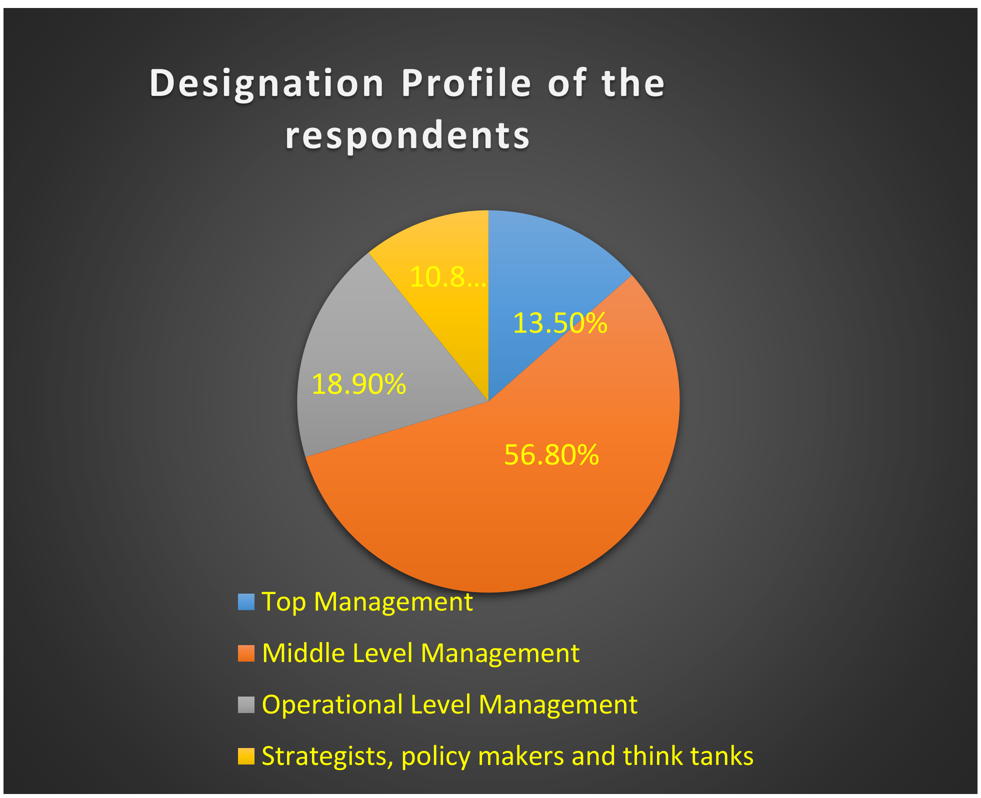


Figure 3.2: Individuals' percentage with different designations

(Source: Author's own analysis**)**

Experts in the maritime and pertinent OSV field should also be contacted and their feedback gathered, as each expert's viewpoint plays a distinct role in the overall valuation and the sampling would be incomplete without it. The types of respondents contacted for this study's comments are detailed in Table 3.3 below.

Table 3.3: Areas of domain expertise of respondents contacted(Source: Author)

Type of actors	**Number of respondents**	**In percent**
Ship Owners	6	16.2%
Ship Management Experts	5	13.5%
Technical Management Experts	9	24.3%
Operations Experts	6	16.2%
Regulatory (Consultants,QHSE,Class societies etc)	7	19.0%
Others(Seafarers,Shipping Agents etc)	4	10.8%
Total	**37**	**100%**

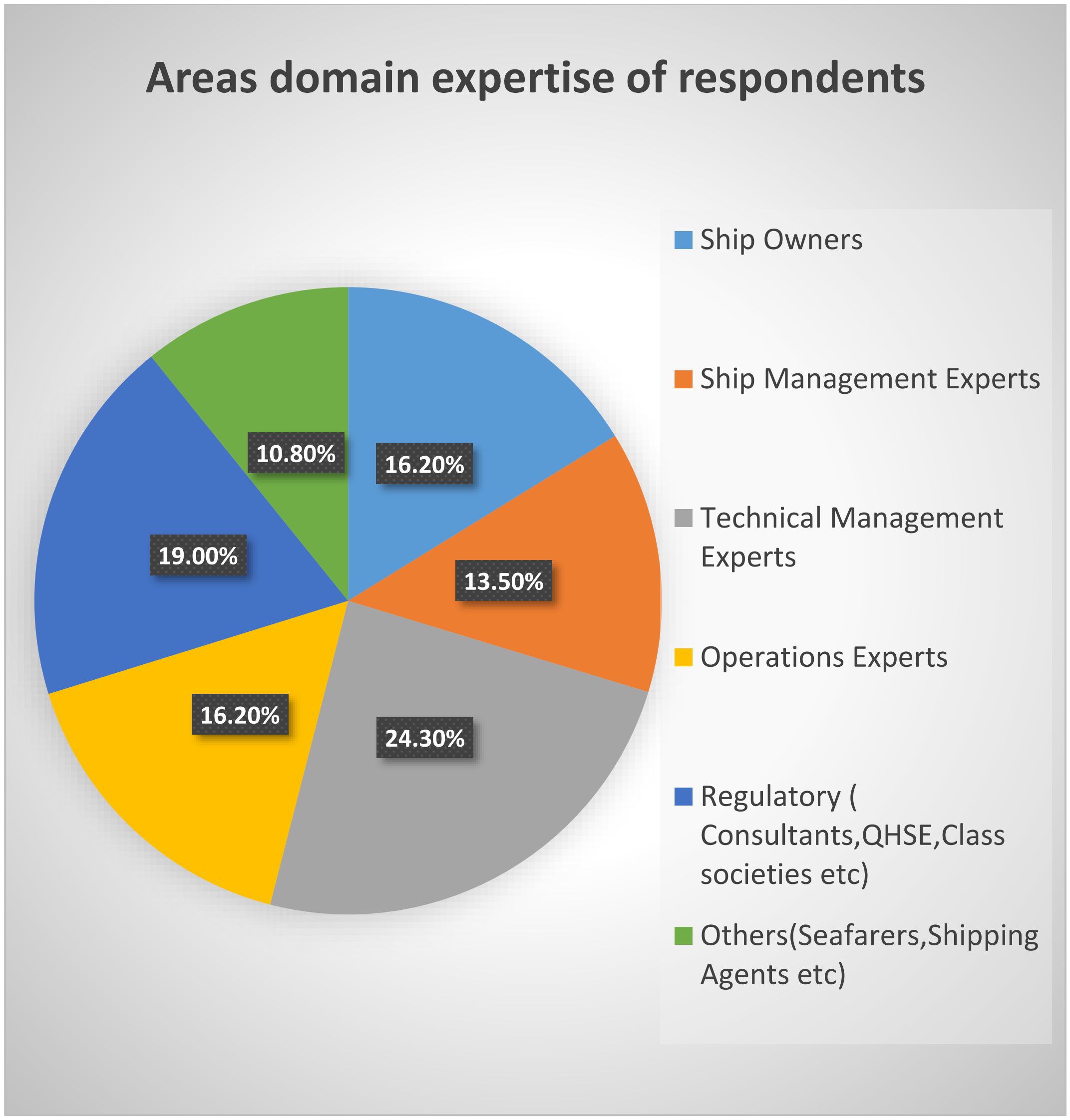


Figure 3.3: Percentage of domain experts survey taken.

(Source: Author's own analysis**)**

3.6 RESEARCH TECHNIQUES

The methods used for analysis of data to meet research objectives 1 and 2 are as given below (refer Table 3.4):

Table 3.4: Studies on Delphi Method, Modified Delphi Method, BWM, Fuzzy-AHP and EEOI

Technique	Authors
Delphi Method	(Duffield,1987; Cramer,1991; Rowe and Wright1999; Cuhls, 2001; van Zolingen and Klaassen,2003; Hsu and Sandford, 2007; Skulmoski,2007; Hsu and Sandford, 2007)
Modified Delphi Method	(Custer,1999; Hsu and Sandford, 2007; Keeney,2011b; Keeney, 2001; Pickard, 2012; Eisenhardt,1985; Ahimud and Lev, 1981)
BWM (Best Worst Method)	(Sahebi et al., 2017; Salimi & Rezaei, 2018; Gupta; 2018; Khan, 2019; Wen, 2019 ; Gupta 2020; Lau, 2021; Khan, 2022)
Fuzzy AHP (Analytical Hierarchical Process)	(Leung, 2000; Kahraman, 2003; Yang, 2004; Sun, 2010; Kutlu, 2012; Singh, Gunasekaran & Kumar, 2018; Raut, 2019; Liu,2020; Kashav, 2022; Ghosh, 2022)
EEOI	*(MEPC.1/Circ.684; MEPC.282(70) ;* (Sun, 2013; Johnson, 2014; Beşikçi, 2016; Bartosz, 2017; Yuan, 2017; Zhang, 2019)

Delphi Method: It is a structured process for consolidating opinions of an expert panel into a judgement on an issue. Multiple questionnaire cycles are used to collect expert data. (Hsu and Sandford, 2007). It collects and analyses data to reach consensus on an issue (Skulmoski et al., 2007). The technique was originally established in 1948 to address military and defense technology needs (Cramer, 1991; Hsu and Sandford, 2007; van Zolingen and Klaassen, 2003). It attracted more attention when it was applied to a large-scale national technology forecast in the 1960s (Cuhls,2001).Since then, it has become an extensively utilised instrument for developing, identifying, forecasting, and validating in a wide variety of research areas (Duffield, 1987, Rowe and Wright, 1999).

One of the many versions of the Delphi technique in use today is what we might call "traditional" Delphi. The following is a concise summary of the traditional Delphi technique, which requires paper and stylus. A team creates a questionnaire, sends it out to a larger group (the respondent group), receives it back, evaluates it, and then creates a new questionnaire that incorporates the input from the previous round. Groups of respondents are typically offered at least one chance to reconsider previously evaluated responses. According to Linstine and Turoff, this will enable a coordinated effort among a collection of people to address a difficult problem. (Linstone & Turoff, 1975). Interview questions were developed using the Delphi technique to ensure that they were based on the collective knowledge of a panel of specialists and not just the author's personal preferences.

For RO1 Modified Delphi Method is used as it fits the specific purpose better. The questions conscripted shall be grounded on the outcomes of the preliminary examination and distributed them to the selected panel of specialists for further evaluation.

Modified Delphi method: Modifications to the classic Delphi process have emerged since it became popular in the late 1960s. The Modified Delphi method was used since it proves to be an essential tool for conducting research on the topic as it was anticipated that both RO1 & RO2 will have numerous viewpoints where energy efficiency of offshore support vessels practices is of increasing importance in maritime industry currently. This methodology offers a structured and iterative approach as the current research need to facilitate the gathering of data from a diverse panel of experts that needs a holistic perspective. Modified Delphi method encourages the experts to provide open feedback, fostering a more open discussion especially on technical, operational practices, and regulatory measures to achieve Research objectives. Moreover, this method enables consensus building through multiple rounds of data collection, which is especially valuable for identifying and give flexibility in data analysis allows for the incorporation of both quantitative and qualitative data, enriching the depth and quality of research findings. The approach of the Modified Delphi method was adopted to enhances the credibility of research outcomes a comprehensive and reliable approach by an iterative process that allows the gathering and refining of expert opinions, and it can be used to identify research priorities, develop consensus from experts, and generate final feedback.

As a result of these adaptations, the core features and benefits of the Delphi method have been maintained in most instances. The most common modifications are:

1. including statements from the existing literature in the Round 1 questionnaire (Custer, 1999; Hsu, 2007, Keeney, 2011b);
2. Replacing Round 1 with focus groups or one-to-one interviews (Keeney et al., 2011b);
3. Reducing the number of rounds to two or three by replacing Round 1 with an extensive review of the literature (Keeney et al., 2001, Pickard, 2012).

In order to review the Research Objectives, The modified Delphi technique will be used in expert questionnaire, to prepare structured questions based on deep literature analysis. In the second stage each participant shall receive the first survey basis and will be asked to evaluate the information provided. In the third stage each participant shall receive an additional questionnaire, which included the results and summary of the preceding passes. These questions of discussions and analyses of questionnaires shall be divided in to various sections. From the result of the planned expert interviews and surveys, individual titles of the assessment criteria shall be clarified and ranking of significance will be made.

BWM method has been used first with the aim of understanding most preferred solution and the least preferred solution based on the expert inputs. The method does not require a complete pairwise comparison matrix as it evaluates the criteria considering the most preferred criteria and the least preferred criteria. It is also very simple for the decision-makers to reason and make judgements using this method. The steps applied in BWM are given as below (adapted from Salimi & Rezaei, 2018):

I: The criteria (or factors) displayed at different tiers are determined at this stage. The procedure for and specifics of deciding on parameters (factors and sub-factors) are covered (Salimi, 2018).

II: Here, given preference data is taken and each criterion ranked from best (B) (most significant) to worst (W) (least significant) (Salimi, 2018).

III: This step decides preference score (1 to 9) of best criterion (B) over others. 1 indicates equally essential to B, while 9 means B is more important. This yields A_B, best-to-others vector = $\left(a_{B1}, a_{B2}, ..., a_{Bn}\right)$. $a_{B1}, a_{B2}, ..., a_{Bn}$ signifies preference scores over criteria $1, 2, ..., n$ (Salimi, 2018).

IV Each element of the vector indicates a preference score for criterion B relative to criterion where the established requirements are present.

Stepping back from W, worst criterion, assign a preference number (1-9) to the remaining criteria using Fig 3.4 as a guide. With 1 as preference score, the criteria are just as essential as W, and with a score of 9, the criteria are more so. The procedure leads to the worst-to-best vector being derived (A_w).

$$A_w = (a_{1w}, a_{2w}, \dots a_{nw})T.$$

Vector elements signify corresponding preference scores over criteria W (Salimi, 2018).

V Each element of the vector indicates a preference score for criterion B relative to criterion where the established requirements are present (Salimi, 2018). This procedure involves determining the optimum weights by explaining the linear programming model. The optimisation model's goal is to reduce the largest possible differences between the various parameters. The optimal solution to the optimisation algorithm is as follows:

$$\begin{cases} Min \quad \underset{j}{Max} \left\{ \left| w_B - a_{Bj} w_j \right|, \left| w_j - a_{jW} w_W \right| \right\} \\ \text{Sub to;} \\ \sum_j w_j = 1 \\ w_j \geq 0, \ \forall j \end{cases} \qquad (1)$$

The equivalent linear programming model for (1) is as follows:

$$\begin{cases} Min \quad \xi^L \\ \text{Sub to;} \\ \left| w_B - a_{Bj} w_j \right| \le \xi^L \\ \left| w_j - a_{jW} w_W \right| \le \xi^L \\ \sum_j w_j = 1 \\ w_j \ge 0, \ \forall j \end{cases} \qquad (2)$$

By unravelling the linear programming model (2), the optimal weights $\left(w_1^*, w_2^*, \ldots, w_n^*\right)$ are estimated and the optimal objective function value ξ^{L*}.

ξ^{L*} Its value shows whether or not the comparisons given by decision-makers are reliable. Consistency is more likely when the value is closest to zero.

For multi-level decision-making situations (with criteria and sub-criteria for each level), the weights are determined using the BWM described above. The global weights can be calculated by multiplying the weights of the second-level criteria by those of the equivalent first-level criteria.

Linguistic Expression	Value	TFNs
Very Low	1	(1,1,3)
Low	3	(1,3,5)
Average	5	(3,5,7)
High	7	(5,7,9)
Very High	9	(7,9,9)

Table 3.5 Scale of relative preference (Source: Saaty, 1982)

Fuzzy AHP Technique: When making a choice that takes into account both quantitative and qualitative factors, (Satty 1980)'s AHP method can be a useful tool. Few disadvantages accompany AHP's use, including its usages in a hazy setting, the variability of evaluation scale, and the existence of imprecision and subjectivity (Raghuvanshi, 2018). This calls for incorporating fuzzy idea into it to lessen these drawbacks.

(Prakash and Barua, 2015; 2016a; 2016c). It is impossible to accurately evaluate linguistic factors using the fuzzy AHP method. This uncertainty can be mitigated through the use of a fuzzy strategy (Kashav, 2022).

(Zadeh 1975) developed the Fuzzy logic with the aim of tackling with ambiguity and vagueness in the decision-making methods. A fuzzy series allows for a real unit interval between the binary values of 0 and 1 and is a superset of a classical set. The degree of membership, which stands for continuous assessment, are the in-between numbers between 0 and 1. Fuzzy logic is founded on the idea that things cannot simply be classified as 1s or 0s, but also as in-between values. Numerous membership function types are utilized with fuzzy theory, including triangular, sigmoid, trapezoidal, and orthogonal ones; however, triangle membership functions are the most frequently used by academics (Hamzeh, 2019). TFN is acronym for triangular fuzzy number N with l as lower value; m as medium value; and u as higher value thus $l \leq m \leq u$.

TFNs used are presented in Table 3.6.

Intensity of Importance	Fuzzy Number	Linguistic Variable	Linguistic Variable Code	Triangular Fuzzy Number (TFNs)
1	$\tilde{1}$	Equal Importance	EI	(1,1,1)
2	$\tilde{2}$	Very Low Importance	VLI	(1,2,3)
3	$\tilde{3}$	Low Importance	LI	(2,3,4)
4	$\tilde{4}$	Average Importance	AI	(3,4,5)
5	$\tilde{5}$	High Importance	HI	(4,5,6)
6	$\tilde{6}$	Very High Importance	VHI	(5,6,7)
7	$\tilde{7}$	Extremely High Importance	EHI	(6,7,8)

Table 3.6 Scale used for intensity of importance

As per (Chang 1992**), Definition 1** If $\tilde{N}_1 = (p_1, q_1, r_1)$ and $\tilde{N}_2 = (p_2, q_2, r_2)$ are representative of two triangular fuzzy numbers then algebraic functions are as given below-

$\tilde{N}_1 \oplus \tilde{N}_2 = (p_1, q_1, r_1) \oplus (p_2, q_2, r_2) = (p_1 + p_2,\ q_1 + q_2, r_1 + r_2)$ ….. (1.1)

$\tilde{N}_1 \ominus \tilde{N}_2 = (p_1, q_1, r_1) \ominus (p_2, q_2, r_2) = (p_1 - p_2,\ q_1 - q_2, r_1 - r_2)$ ….. (1.2)

$\tilde{N}_1 \otimes \tilde{N}_2 = (p_1, q_1, r_1) \otimes (p_2, q_2, r_2) = (p_1 p_2,\ q_1 q_2, r_1 r_2)$ …… (1.3)

$\tilde{N}_1 \oslash \tilde{N}_2 = (p_1, q_1, r_1) \oslash (p_2, q_2, r_2) = (p_1/p_2,\ q_1/q_2, r_1/r_2)$ …… (1.4)

$\alpha \otimes \tilde{N}_1 = (\alpha p_1, \alpha q_1, \alpha r_1)$ where $\alpha > 0$ ……. (1.5)

$\tilde{N}_1^{-1} = (p_1, q_1, r_1)^{-1} = \left(\frac{1}{r_1}, \frac{1}{q_1}, \frac{1}{p_1}\right)$ …….. (1.6)

To employ the FAHP as per (Chang, 1992) method, extent analysis is used.

Following are the steps:

$M_{g_i}^1, M_{g_i}^2, M_{g_i}^3 \ldots \ldots, M_{g_i}^m$ Where g_i is the goal set (i = 1, 2, 3, 4, 5 …....n) and all the $M_{g_i}^j$ (j = 1, 2, 3, 4, 5 ...., m) are TFNs given in Table 10.

(Chang, 1992) Step 1: Determine S_i (fuzzy synthetic extent value) w.r.to the i[th] criterion

$$S_i = \sum_{j=1}^{m} M_{g_i}^j \times \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^j\right]^{-1} \qquad \ldots\ldots\ (1.7)$$

$$\sum_{j=1}^{m} M_{g_i}^j = \left(\sum_{j=1}^{m} p_{ij}, \sum_{j=1}^{m} q_{ij}, \sum_{j=1}^{m} r_{ij}\right)$$

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^j\right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{m} r_{ij}}, \frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{m} q_{ij}}, \frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{m} p_{ij}}\right)$$

with p being lower limit value, q being most promising value and r being upper limit value.

Step 2: The degree of possibility of

$S_2 = (p_2, q_2, r_2) \geq S_1 = (p_1, q_1, r_1)$ is defined as below

$V(S_2 \geq S_1) = \sup_{y \geq x} [\min(\mu_{S_1}(x), \mu_{S_2}(y))]$

Membership values are represented by x, y written as given below in equation 1.8:

$$V(S_2 \geq S_1) = \begin{cases} 1 & \text{if } b_2 \geq b_1 \\ 0 & \text{if } a_1 \geq c_2 \\ \dfrac{p_1 - r_2}{(q_2 - r_2) - (q_1 - p_1)} = \mu d, & \text{otherwise} \end{cases} \qquad \ldots\ldots\ldots\ (1.8)$$

Where µd is the maximum membership point μ_{S_1} and μ_{S_2} (fig 3.6)

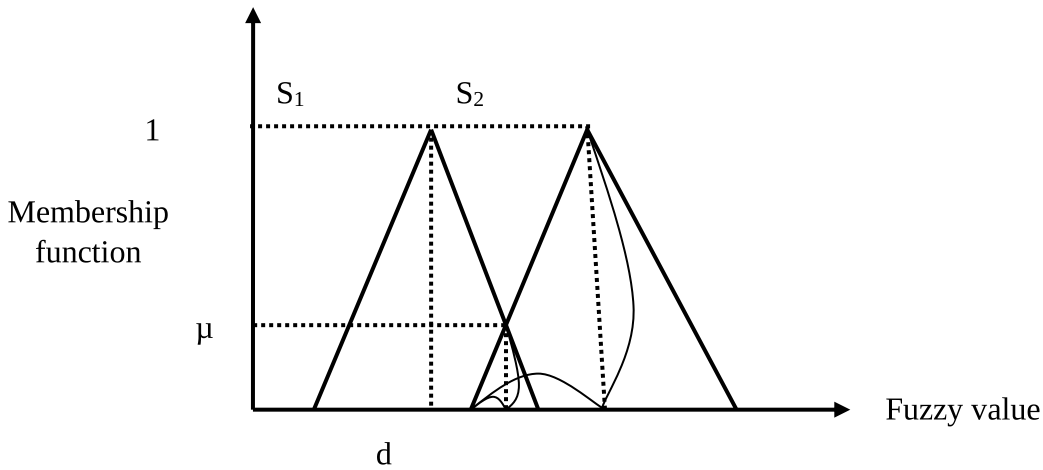


Fig 3.4: The intersection of fuzzy numbers

For comparing both S1, S2, V(S1 ≥ S2) and V(S2 ≥ S1) are required.

Step 3: The degree of possibility for a convex fuzzy number S to be greater than k convex fuzzy numbers Si (i= 1,2,.....,k) can be defined by

V (S≥S1,S2,.......,Sk)

= V [(S≥S1) and (S≥S2) and ....and (S≥Sk)]

= minV (S≥Si), i= 1,2,.......,k

Assume that d′(Ai) = min V(Si≥ Sk) …………………...(1.9)

For k = 1, 2, …, n, k ≠ i, Than the weight vectors are given in equation 1.10 as,

W'= (d'(A1), d'(A2),.......,d'(Am))T ………….…….….(1.10)

Step 4: Finally, normalized weight vectors are known in equation as,

W= (d (A1), d (A2),.......,d (Am))T

According to recommendations of International Maritime Organization, EEOI is the procedure to be employed to quantify the energy productivity performance.

- Energy Efficiency Operational Indicator, EEOI is the fraction of carbon dioxide mass (M) released per unit of transport work: EEOI = M CO 2 /(transport work)
- EEOI Calculation: (MEPC, 2012) ; s (MEPC, 2014, UCL E.I., 2015))

The basic expression for EEOI for a voyage is defined as:

$$\text{EEOI} = \frac{\sum_j FC_j \times C_{Fj}}{m_{cargo} \times D} \qquad \text{Equation 1}$$

Where average of the indicator for a period or for a number of voyages is obtained, the Indicator is calculated as:

$$\text{Average EEOI} = \frac{\sum_i \sum_j (FC_{ij} \times C_{Fj})}{\sum_i (m_{cargo,i} \times D_i)} \qquad \text{Equation 2}$$

With type of fuel denoted by j; number of voyage by I; consumed fuel mass at a specific voyage by FC; conversion factor for fuel to CO2 by CF; m cargo indicates work done or cargo carried or gross tonnes for passenger ships; and D indicates distance conforming to work done or cargo passed (nautical miles). EEOI's unit is subject to the quantification of work done or cargo carried.

- **NOTE: m *cargo: IS NOT DEFINED FOR THE OFFSHORE SUPPORT VESSELS***

Considering the applicability issues of above EEOI formula stipulated for cargo ships as per International Maritime Organization as evident from Literature review, a modified version of the same shall be adopted for Offshore support vessels for generating results in real time scenario.

Hence, the applicability of the method for quantifying Energy Efficiency Performance Of Offshore support Vessels shall be defined as

$$EEOPI_{(Type\ 1,2,3,4)} = \frac{\sum_j FC_j \times C_{Fj}}{W_{Cargo} \times T}$$

$$Average\ EEOPI_{(Type\ n=1234)} = \frac{\sum_i \sum_j (FC_{ij} \times C_{Fj})}{\sum_{n\cdot} (W_n\ T_1) + (W_n\ T_2) + (W_n\ T_3) + (W_n\ T_4) + (W_n\ T_5) + (W_n\ T_6) + (W_n\ T_7) + (W_n\ T_8) + (W_n\ T_9) + (W_n\ T_{10}) + (W_n\ T_{11})}$$

With type of fuel denoted by j; number of voyage by I; consumed fuel mass at a specific voyage by FC; conversion factor for fuel to CO2 by CF; n as the Vessel Type as categorized from 1 to 4; W cargo is work done (derived via Preferential weightage for each type of offshore support vessel) ; and T as Time Spent in hours.

The unit of EEOPI is tonnes CO 2 /(Hour) and should be observed that equation 2 doesn't offer a simple average of EEOI amongst number of voyages, i.

3.7 RESEARCH DESIGN

Research planning is the first step in the research process, and it's where you decide how to put all the study's pieces together so they make sense and flow logically. The organised framework of a research plan guarantees that the study's aims will be met. According to (Yin 2009) and Akhtar (2016), a study is considered credible and reliable if and only if its findings can be drawn from an error-free research plan. Both exploratory and definitive study methods exist. The rationale of the present exploratory study is for improved understanding of the features and obstacles involved in evaluating a framework work and defining an energy efficiency performance index for offshore support vessels. This strategy is frequently employed to arrive at the goals of a research because of the rapid comprehension it provides. However, definitive studies can be broken down even further into observational and causal types. Whereas descriptive study seeks to characterise a population subset in detail. The focus on this research is more on "what" of research expanse rather than "why" of research domain. In simple terms, this research uncovers what is happening rather than why it is happening.

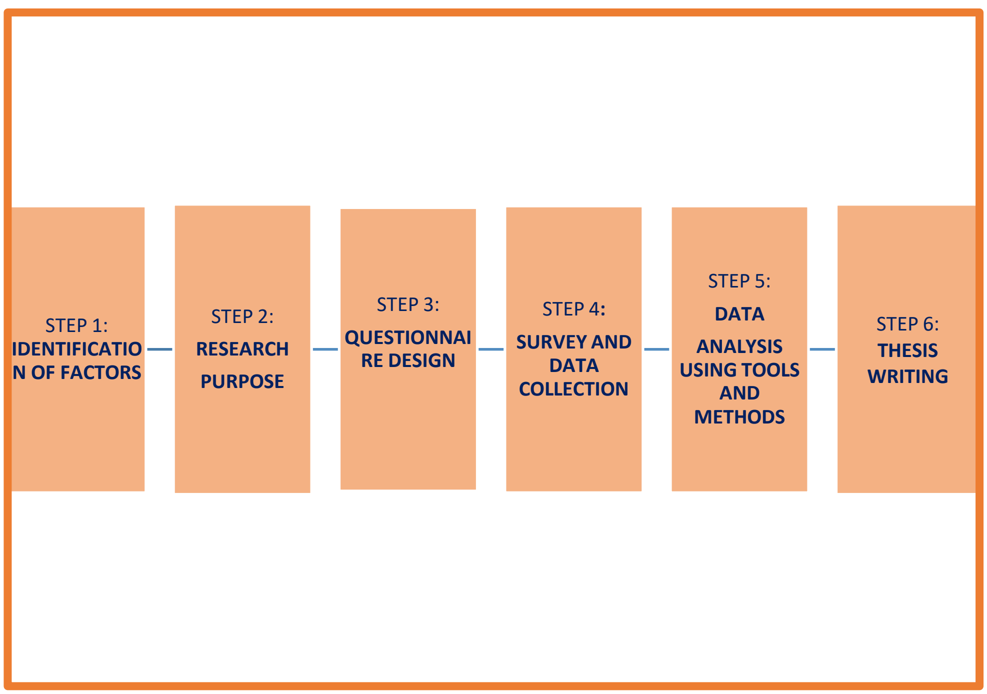


Figure 3.5 Step-wise detail of research design

The following is a detailed description of research design's steps:

Step 1: The research study helps to identify the factors effecting the measurement of Energy efficiency of Offshore Support Vessels in UAE with an intention to develop an Operational frame work and performance Index and identify issues existing from various sources. The secondary data was taken from journals, papers, printed reports and articles or sources including international Maritime Organization regulations/Guidelines / UNCTAD Reports/databases and many more.

Techniques such as Delphi Method, Modified Delphi Method, Survey reports, analysis of available literature, Questionnaire, and analysis of consultant's and researcher's reports and field visits were conducted to identify various factors, elements & barriers in the offshore support vessel functional aspects.

Step 2: BWM method were applied for analysing the identified factors and sub factors and thus a proposed framework developed. Further, the solutions/strategies suggested to overcome the factors which impact the energy efficient operations of the offshore service boats. In order to assess the functional, managerial, and infrastructure variables that have an effect on the performance indicator of such vessels' energy efficiency, the research team conducted a questionnaire survey.

Step 3: In this step, the types of vessels identified with 11 parameters for measuring all operational modes of an offshore support vessel in

UAE. Questionnaire is drafted for collecting the responses from 29 experts. Techniques such as Delphi Method, Modified Delphi Method were conducted to validate the parameters and further calculating the weights of cargo using Fuzzy AHP methods for each type of vessels. Further, customizing the formula in terms of weights and time (As refer to equation) for evaluating the operational efficiency of offshore support vessels in UAE.

3.8 RESEARCH METHODOLOGY FOR OBJECTIVES (RO1,RO2)

The research design methodology and requisite actions taken to complete Research objective 1 and 2 with Research methodology flow diagram have been shown below:

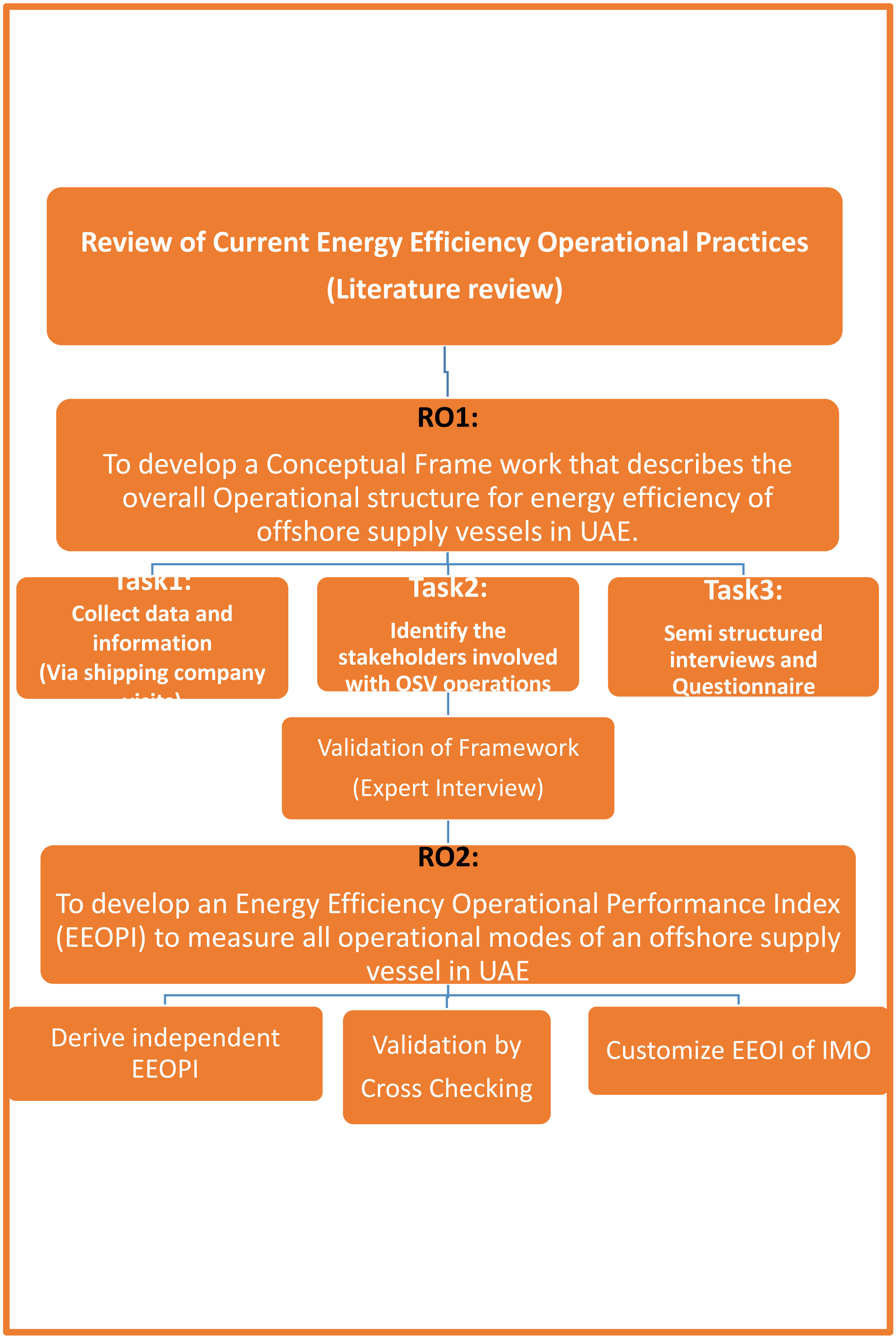


Figure 3.6 Research Methodology Flow Diagram

Research Methodology - To achieve RO1

The study proposes to start with identifying the different operational practices acquired from secondary data sources, Literature review, Publications and segregate them into input and output factors.

The gathered input and output factors are then to be tested for identifying the actual operational processes on the offshore support vessels.

1. Due to the complexity of the offshore supply ship's operation, the study necessitates heavy participation from those with working knowledge in the course of creating a model for the framework.
2. The UAE regions best Practices will be incorporated during working on the Framework which shall be based on mandatory guidelines
3. Shipping companies operating offshore supply vessels, to be involved. Information pertaining to particular companies, such as policies, operational instructions, and procedures taken from the Safety Management System (SMS) and various other internal documents and HSQE programs, etc., were investigated. The content of the ship's energy efficiency management plan (SEEMP) together with the use of the plan was also examined in greater detail.
4. Semi Structured interviews with Ship Owner, Ship Management firm, Technical Managers Port Operators, Regulatory bodies who represent both technical, management and HSQE departments from seaboard and interviews with the staff onboard the specific vessels were carried out. Questions were framed based on the initial input and output factors.
5. The knowledge obtained from interviews was defined and used to re-define and update the input and output factors.
6. A Judgement sampling with expert interviews with professionals was carried out for the validation of the framework.
7. A Delphi technique was used to ensure the validity of the interviews and ensure that the questions were as unbiased as feasible.

8. The questions for the research have been formulated in a way that includes both "what" and "why" questions. Descriptive and explanatory study describe and explain the phenomena (de Vaus 1995). However, Quantitative Data Analysis was done using Agency Theory, which asserts that principal agent barrier centers around the contract amongst the parties, and is involved with generating the most "efficient" contracts surpassing agency problems like informational problems, goal conflict between the principal and agent along with risk. Agency theory study uses questionnaires and meta-data analysis (Eisenhardt 1985; Lev 1981).

9. Solutions to overcome the operational factor barriers were arrived with weightage to each sub factor to define the framework

<u>Summarizing it further,</u>

- Exploratory Research conducted to identify the factors which act as barriers that describes the overall operational structure for energy efficiency of offshore supply vessels in UAE.
- Data collection through Expert Interviews, field visits, Survey Questionnaire and Literature Review
- Data Analysis done using Delphi Method and Modified Delphi Method
- Prioritization of barriers related to energy efficiency factors using BWM methods with the help of MS-EXCEL V 2019.
- Development of Model framework
- Suggestive solutions provided

<u>Research Methodology - To achieve RO2</u>

1. A questionnaire survey to be carried out in with various shipping firms based on Operational Practice parameters derived from literature review and discussions during stages of Step 1 including a wide range of quantitative data. Then a Likert Style questionnaire to enable

comparison of independent factors and to cross check results. Purpose of the questionnaire survey will be to provide figures to help pattern and weightage to be given to each factor based on frequency and usage.

2. An independent Method for Monitoring Energy Efficiency Operational Performance Index (EEOPI) shall be derived to measure all operational modes of an offshore supply vessel in UAE. The Operational modes shall be derived as the outcome of RO1 analysis.

3. The Performance index shall be derived based on permutations of Operational Modes versus different Work Patterns. Weightage will be given to each parameter based on the results and feedback in questionnaire surveys.

4. Based on result of questionnaire, Efficiency measurement tools such as Energy Efficiency Operational indicator adopted as part of SEEMP implemented by IMO to be customized for evaluating Operational efficiency of Offshore Support Vessels in UAE. Where as

The basic expression for EEOI for a voyage is defined as:

$$EEOI = \frac{\sum_j FC_j \times C_{Fj}}{m_{cargo} \times D} \qquad \text{Equation 1}$$

Where average of the indicator for a period or for a number of voyages is obtained, the Indicator is calculated as:

$$\text{Average EEOI} = \frac{\sum_i \sum_j (FC_{ij} \times C_{Fj})}{\sum_i (m_{cargo,i} \times D_i)} \qquad \text{Equation 2}$$

Such that **m cargo:** shall be derived for the offshore support vessels from the summary of result analysis from the variables encountered for operations modes in the Port, Maneuvering, passage, Offshore for each cases consisting of Active, waiting, ready, preparation alongside segregating ship characteristics such as Towing, hooking up, managing cargo, handling anchors, serving as a standby vessel, etc.

<u>Summarizing it further,</u>

- Descriptive Research conducted to analyses the types of vessels and their parameters
- Data collection through Expert Interviews, field visits and Survey Questionnaire
- Data Analysis done using FAHP using MS-Excel V 2019
- Deriving and developing EEOPI for offshore support vessels type in UAE

3.9 RESEARCH PHILOSOPHY

A philosophy of research is defined as "*a belief about the ways in which data about a phenomenon should be collected, analysed and used*". Quantitative versus qualitative analysis, as well as positivist versus interpretivist research philosophies, have long been sources of heated discussion. Accordingly, "interpretive researchers assume that access to reality (given or socially constructed) is only through social constructions such as language, consciousness, shared meanings, and instruments". The criticism of positivism in the social sciences served as the foundation for the development of interpretivism in philosophy. In accordance with this philosophy, qualitative analysis is prioritised over quantitative analysis. The interpretivist method relies on naturalistic methods of data acquisition, including interviews and observations. Secondary data research is also prevalent in the philosophy of interpretivism. In such a form of study, implications typically emerge at the inference of the investigation.

Quantitative data that can be analysed statistically are essential to positivism. It is generally accepted that "the empiricist view that knowledge originates from human experience is consistent with the positivist philosophy." It postulates that the cosmos is made up of separate, observable elements and events interacting in a manner that is deterministic, atomistic and orderly. As per study by (Crowther 2008), inductive research methods are more commonly linked with the phenomenology philosophical school of thought than with positivist studies. Where positivism is associated with the view that researchers should prioritise facts, phenomenology is concerned with meaning and provides for human interest. According to the pragmatist view, the research topic should be the central consideration when choosing a research methodology. Pragmatics can combine positivist and interpretivist approaches into a singular study depending on the type of research question. This study adopts Pragmatism in its emphasis on facts and its incorporation of professional interest in the research.

3.10 COLLECTION OF DATA

The research methodology applied in this research for collecting the data comprised of expert interviews and survey questionnaire. In the present study, the following methods were used for collecting the data with different offshore support vessel stakeholders as shown below:

a) Survey using semi structured & structured questionnaire- To obtain response from the key contributing players including Ship Management Experts, Ship Owners, Port Operations Experts, Technical Management Experts, and Regulatory (Consultants, QHSE,Class societies etc.) and the Others(Seafarers, Shipping Agents etc) stake holders involved in the specific ship sector.

b) Various survey, Guidelines, market and consulting reports by maritime associations, classification societies (DNV GL,BV,ABS etc) were referred.

c) Initial Inputs from the experts through structured and unstructured interviews.

3.11 PROPOSED FRAMEWORK

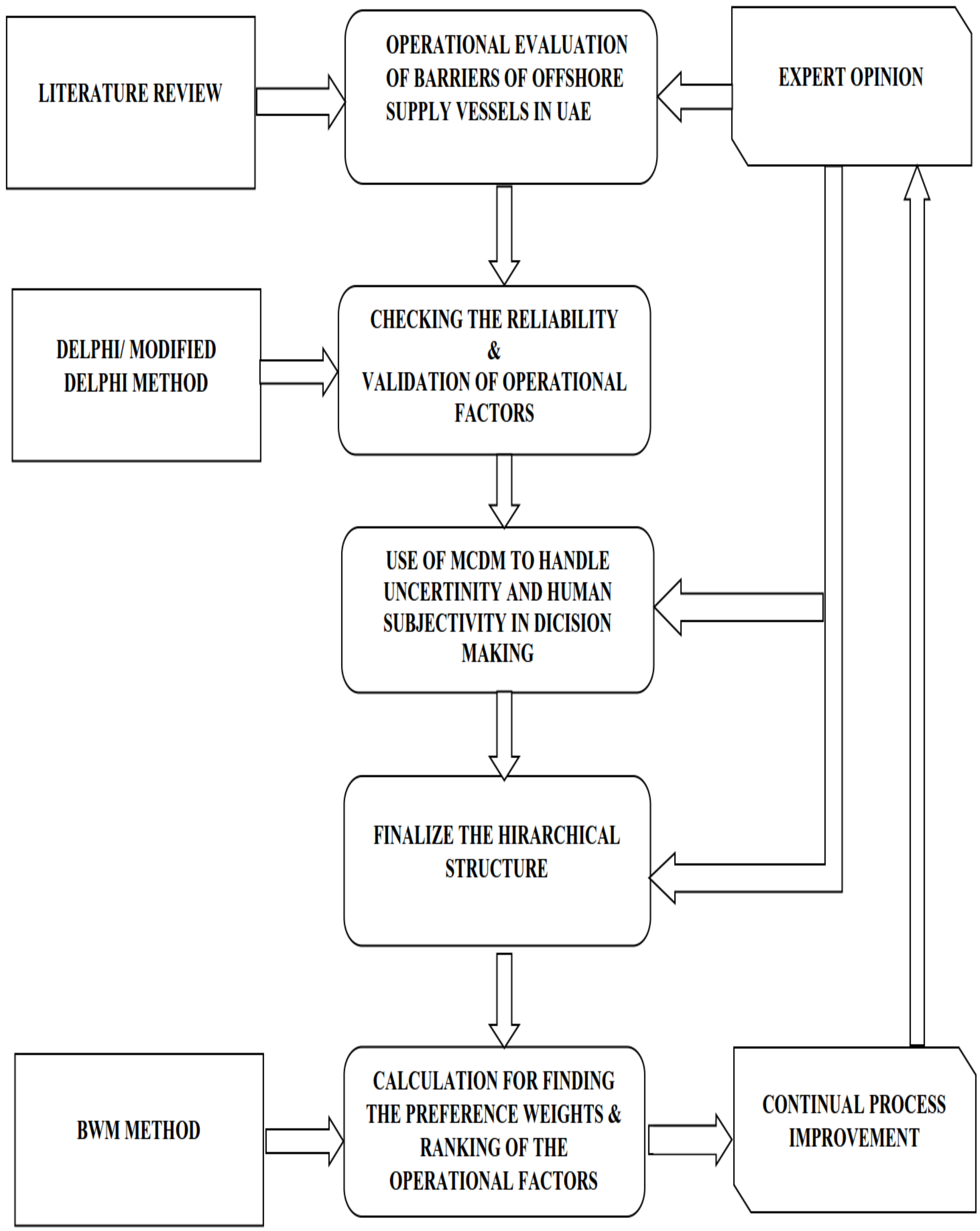


Figure 3.7 : Proposed Framework for the Research Objectives

(Source: Author's self generated diagram)

The Proposed research framework is highly appropriate for addressing the complexity of the research problem. It is structured into well-defined phases with an intention to facilitate a thorough review and robust findings. With identifying the research gaps as per literature review phase, it provides a strong underpinning by synthesizing existing scenarios. It ensures that the research is built upon a comprehensive understanding of the subject. The Operational Evaluation of barriers allows for the practical assessment of barriers in the real-time context. This hands-on approach ensures that research is grounded in the actual challenges faced by industry ensuring the reliability and validity of operational factors is crucial for the quality of the data. It enhances the credibility of the research findings and ensures that the data accurately represents the phenomenon under study. Given the complexity of factors involved, using a multi-criteria decision-making method is a choice that allows for a systematic and comprehensive analysis, which is particularly important when dealing with multiple, interrelated variables. Constructing a hierarchical structure for the research variables is a critical step in organizing the data and relationships. It aids in simplifying complex information, making it more manageable for research analysis. The assessment of preferential weightage and ranking based on survey data adds a quantitative dimension to the research. This step enables the prioritization of factors and helps in identifying the most critical elements of research. The inclusion of feedback from experts and a process for continual improvement and reevaluation demonstrates the research's commitment to validity and reliability. In summary, the proposed research design framework is well-structured, ensuring a systematic and rigorous investigation of the research problem that incorporates research methodology mechanisms, making it a comprehensive approach for addressing the complexities of the research objectives that need to be explained.

CHAPTER 4

DATA ANALYSIS AND FINDINGS

CHAPTER 4

DATA ANALYSIS AND FINDINGS

4.0 DATA ANALYSIS & FINDINGS

The analysis presented intends to evaluate the energy effectiveness of different types of Offshore support vessels during their service. Activity-based analytics data, measured and collected from various stakeholders involved in the OSV business. Ultimately, a solution to customize and apply the IMO established Energy efficiency operation index, specifically for the EEOI of different types of OSVs, which is used to determine the energy performance of these ships are derived. It also applies during SEEMP development stages.

With the aim to accomplish research objectives, this section discusses the analysis of collected data. The section purposes to provide answers to the research questions through identification and analysis of the factors that act as operational barriers for energy efficiency of offshore support vessels in UAE. Both primary and secondary sources are used to identify the major Factor categories and sub factor categories. To better comprehend the factors, their effect on offshore support vessels, and the situations of the operational premises, the current literature is analysed and interviews with specialists in the field are conducted. For that purpose, a model has been developed to suggest solutions for improving energy efficiency of OSVs with applicability based on administrative, functional and structural factors.

Thereafter, stages of BWM method, which lead to an analysis of the factors that need attention, are outlined to show why it is recommended. The section also identifies the different types of offshore support vessels with 11 parameters. With the aim of comprehending the recognised parameters in every form of vessel, the existing literature is reviewed meticulously and interviews with domain specialists are conducted. These all parameters will help in measuring all operational modes of an offshore supply vessel based on the formula adopted for the Energy efficient Operational Index/ Further, to develop an Energy Efficiency Operational Performance Index (EEOPI) for measuring the operational modes of an offshore supply vessel in UAE. Using the application of Fuzzy-AHP method, the weights are calculated to prioritize the operational modes and the suggested solutions.

4.1. PHASE I IDENTIFICATION OF OPERATIONAL BARRIERS: MAIN FACTOR CATEGORIES AND SUB-FACTOR CATEGORIES

Objective 1: *To identify factors and develop a conceptual framework that describes the overall Operational structure for energy efficiency of offshore supply vessels in UAE.*

Literature was reviewed exhaustively with the aim of comprehending the presence of operational barriers and thereafter identifying these barriers with factors impacting the same and also develop solutions to overcome them. After literature review was conducted, inputs were collected from the experts (using semi structured interviews, questionnaires as an instrument) from the related areas of offshore supply vessels industry involving Ship Owners, Ship Management Experts, Technical Management Experts, Port Operations Experts, Regulatory (Consultants, QHSE,Class societies etc.) and the Others(Seafarers, Shipping Agents etc)to obtain the required information. Thus, based on literature review as well as the expert professional inputs, 3 Main Factor Categories and 17 sub factor-categories were ascertained. The study consulted 37 experts with more than 5,10 years of experience in the relevant area. The identified issues and their sub-criteria have been presented in Table 4.1 along with a few selected relevant references.

4.1.1 Main Factor categories and Sub-Factor categories of barriers

Existing studies and feedback from domain experts were used to compile the Factor categories and sub-factor categories of operational barriers. The list of issue categories and subcategories is depicted in Table 4.1 along with a mention of selected few references. The energy efficiency factors have been grouped into three main categories: Managerial (M), Functional (O), and Infrastructure (I).

Table 4.1: Identified categories and sub-categories of the barriers for energy efficiency [Source: Author]

Energy Efficiency Factors (Criteria)	Criteria Code	Sub-Criteria	Sub-Criteria Code	References
Managerial	(M)	Regulatory compliance	M1	(M.Acciaro, 2013; Dewan, 2018)
		Capital constraints	M2	(M.Acciaro,2013; Dewan, 2018)
		current shipping practices	M3	(M.Acciaro, 2013; Lützen, 2017)
		owner-charter issues	M4	(Rehmatulla, N, 2014; Dewan, 2018)
		lack of incentives	M5	(M.Acciaro, 2013)
		change management issues	M6	(M.Acciaro, 2013; Dewan, 2018)
Functional	(O)	Crew awareness and training	O1	(Rehmatulla, N, 2014; M.Acciaro, 2013; Dewan, 2018)
		Additional operational cost	O2	(M.Acciaro, 2013; Dewan, 2018)
		mooring, maneuvering, transit, cargo operations	O3	(Lützen, 2017; IMO SEEMP, 2016)

		Age of the vessel and the operational function it provides	O4	(Dewan, 2018)
		Trade and sailing area	O5	(Dewan, 2018; Styhre, 2010)
		Turnaround time in ports	O6	(Rehmatulla, N, 2014)
Infrastructure	(I)	Vessel performance monitoring	I1	(Rehmatulla, N, 2014; Dewan, 2018; IMO SEEMP, 2016)
		Technological complexities	I2	(M.Acciaro, 2013)
		Safety and reliability risks	I3	(M.Acciaro,2013; Dewan, 2018)
		Digitized fleet management	I4	(M.Acciaro, 2013)
		Operational mode monitoring	I5	(Lützen, 2017; Styhre, 2010)

4.1.2 ANALYSIS OF OPERATIONAL BARRIERS USING BWM

The prioritization of the factors impacting operational barriers have been conducted by applying Best-Worst Method. This has been done to make it simple for decision-makers and vessel owners to compare and comprehend the barriers in order to apply them. As a result, this method is employed in the study since it produces data that are reliable and appropriate for this study's analysis. In order to determine the weights, the researchers collected comparison data required for the Best-Worst method from thirty seven experts who were stakeholders in the offshore support vessel industry consisting of Ship Owners, Ship Management Experts, Technical Management Experts, Port Operations Experts, Regulatory (Consultants, QHSE,Class societies etc.) and the Others(Seafarers, Shipping Agents etc). The BWM approach was then used to calculate weights based on their inputs. The global weights for each were then calculated. As per the requirements of BWM method the energy efficiency factors were grouped into three factorial clusters named as: Managerial, Functional and Infrastructure considering that each cluster has more than five sub-criteria. Managerial criteria are six; Functional has six; and Infrastructure has five sub factor-criteria's.

Experts' comments on various aspects of energy efficiency are broken down in depth in Table4.2. The most important consideration, by far, is infrastructure.

Table 4.2. Best and Worst Energy Efficiency Factors

Factors	Best	Worst
Managerial Factor	11	11
Functional Factor	5	19
Infrastructure Factor	21	7

Similarly, Table 4.3, 4.4 and 4.5 show the input from experts for each of the subfactors Functional, Managerial and Infrastructure.

Table 4.3. Best and Worst Managerial Factors

Sub Factors	Best	Worst
Regulatory Compliance (M1)	13	2
Capital Constraints (M2)	8	3
Current shipping Practices (M3)	7	5
Owner-charter issues (M4)	6	4
Lack of incentives (M5)	3	6
Change management issues (M6)	0	17

Table 4.4. Best and Worst Functional Factors

Sub Factors	Best	Worst
Crew awareness & training (O1)	16	2
Additional Operational cost (O2)	11	3
Berthing, Maneuvering, Passage, Cargo Operations (O3)	5	7
Vessel Age and operational service (O4)	1	7
Trade and sailing area (O5)	0	12
Turn-around time in ports (O6)	4	6

Table 4.5. Best and Worst Infrastructure Factors

Sub Factors	Best	Worst
Vessel performance monitoring (I1)	13	2
Technological complexities (I2)	7	9
Safety & Reliability risks (I3)	5	9
Digitized fleet management (I4)	9	7
Operational mode monitoring (I5)	3	10

In Table 4.6, ranks and weights of three key factors are presented. Infrastructure is at the top of the list considering the weights.

Table 4.6 Energy Efficiency Factors - Ranking and Weights

Factors	Optimal Weights	Rank
Managerial Factor	0.3155	2
Functional Factor	0.1924	3
Infrastructure Factor	0.4921	1

Tables 4.7, 4.8 and 4.9 present the weights and ranking of sub-factors of, Functional, Managerial, and Infrastructural factors.

Table 4.7. Managerial Factors - Ranking

Sub Categories	Weights (Optimal)	Rankings
Regulatory Compliance (M1)	0.3472	1
Capital Constraints (M2)	0.1861	2
Current shipping Practices (M3)	0.1657	3
Owner-charter issues (M4)	0.1634	4
Lack of incentives (M5)	0.0914	5
Change management issues (M6)	0.0462	6

Table 4.8. Functional Factors - Ranking

Sub Factors	Optimal Weights	Rank
Crew awareness & training (O1)	0.4324	1
Additional Operational cost (O2)	0.1951	2
Berthing, Manoeuvring, Passage, Cargo Operations (O3)	0.1107	4
Vessel Age and operational service (O4)	0.0964	5
Trade and sailing area (O5)	0.0216	6
Turn-around time in ports (O6)	0.1438	3

Table 4.9. Infrastructure Factors - Ranking

Sub Factors	Optimal Weights	Rank
Vessel performance monitoring (I1)	0.3921	1
Technological complexities (I2)	0.1316	3
Safety & Reliability risks (I3)	0.1234	4
Digitized fleet management (I4)	0.2517	2
Operational mode monitoring (I5)	0.1012	5

From the above Tables 4.1-4.9 describes in depth the factors and sub-factors that were chosen after careful consideration of the available literature and expert opinion. As exhibited in Table 4.10 in this study, amongst the primary factors, rank 1 is attributed to infrastructure factor. It is the most vital factor having 0.4921 as global weighted value, which shall have a bearing on the energy efficiency of offshore support vessels. Figure 4.1 displays this ordering, followed by management considerations (weight = 0.3155) and then practical considerations (weight = 0.1924). There were a total of 17 sub-factors analyzed, and the Global Rank number for vessel performance monitoring (I1) with weight (0.1930) was maximum. But the Global Rank's fifth criterion, which takes into account functional factor, commerce, and sailing area, had lowermost weight of any criterion (0.0042). This study backs up the findings of the 76th session of the Marine Environment Protection Committee of the International Maritime Organization (IMO), which discovered that performance monitoring using cutting-edge data capturing devices is already being implemented onboard the vessels, with vessel performance monitoring being ranked as the No. 1 subfactor. While demand in a particular nation or operating region is an essential consideration, the fact that the lowest trade and sailing area

(O5) was ranked as the most important subfactor demonstrates that according to experts, this applies worldwide.

Table 4.10. Factors and sub-factors - Relative importance

Factors	Weight of Factor	Sub Categories	Sub-factors Local weights	Sub-factors (Global weight)	Rank (Global)
Managerial Factor	0.3155	M1	0.3472	0.1095	**3**
		M2	0.1861	0.0587	**7**
		M3	0.1657	0.0523	**8**
		M4	0.1634	0.0516	**9**
		M5	0.0914	0.0288	**12**
		M6	0.0462	0.0146	**16**
Functional Factor	0.1924	O1	0.4324	0.0832	**4**
		O2	0.1951	0.0375	**11**
		O3	0.1107	0.0213	**14**
		O4	0.0964	0.0185	**15**
		O5	0.0216	0.0042	**17**
		O6	0.1438	0.0277	**13**
Infrastructure Factor	0.4921	I1	0.3921	0.1930	**1**
		I2	0.1316	0.0648	**5**
		I3	0.1234	0.0607	**6**
		I4	0.2517	0.1239	**2**
		I5	0.1012	0.0498	**10**

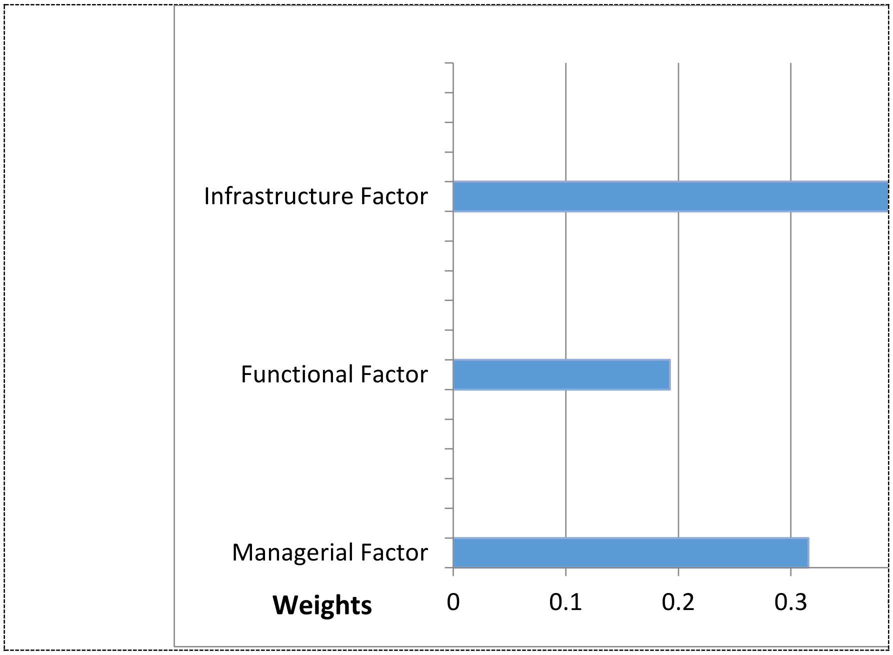


Figure 4.1. Main factors - Relative importance

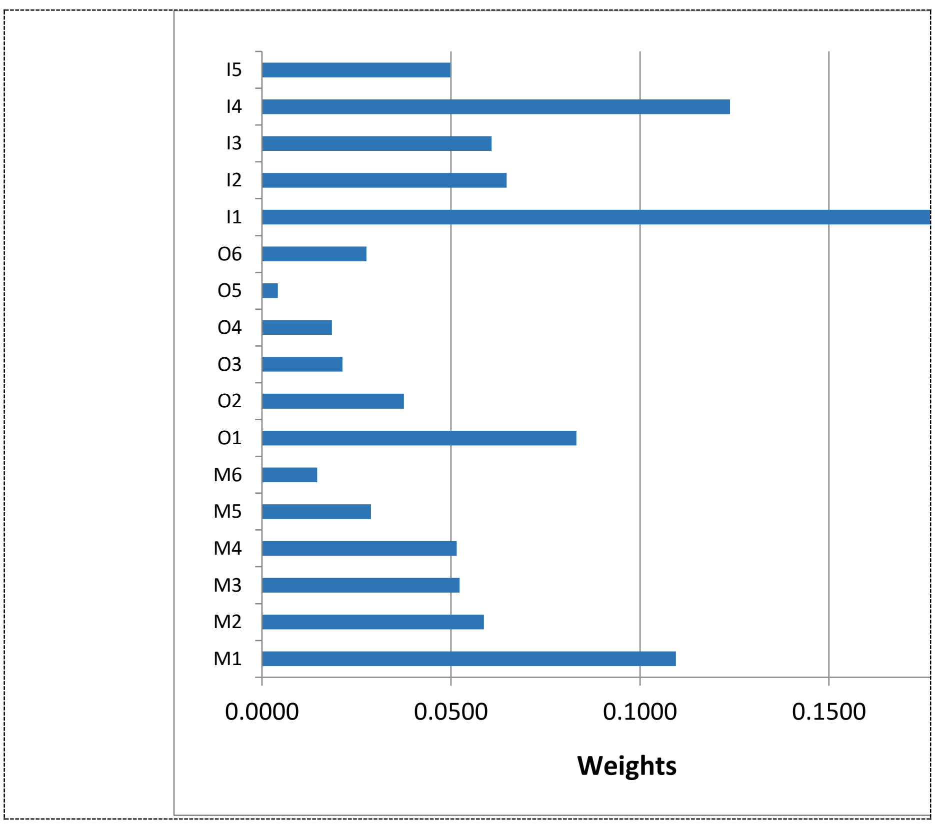


Figure 4.2. Sub factors - Relative importance

4.1.3 FINDINGS OF RO1

Figure 4.2 shows that four of the five sub-factors under the main factor infrastructure— digitalized fleet management (I4), safety and reliability risks (I3), technological complexities (I2), and vessel performance (I1) —have global ranking weights of 1, 2, and 6, respectively. Rather than placing too much emphasis on any one particular subfactor, this finding supports the importance of the primary factor of "infrastructure." Owners of offshore support vessels must, therefore, pay attention to performance evaluation, overpowering complexities in the technology, mitigating risk, digitalization, and operative controls, all are heavily influenced by technology. Currently there is little control to examine this movement thoroughly, so the fact that operational mode monitoring ranks so low in contrast to other sub-factors is expected. This may become an important component once other monitoring tools have been put in place.

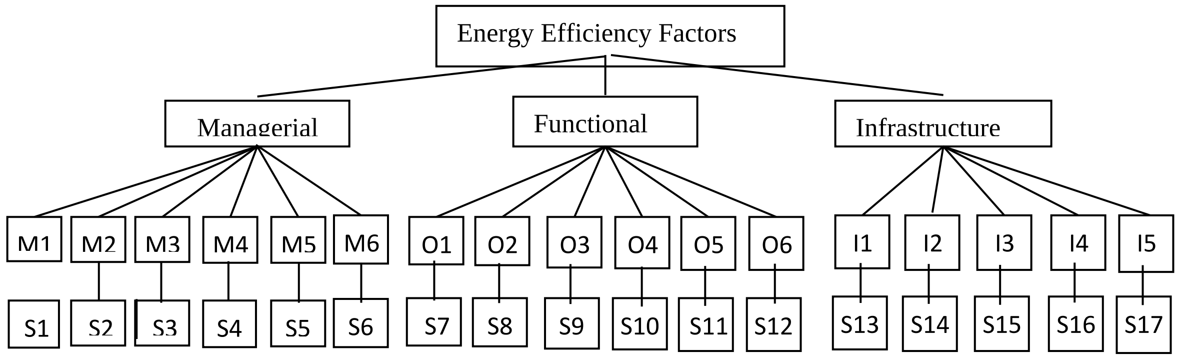
The regulation compliance (M1) subfactor of the managerial factor has the third-highest global weight. With the aim of achieving worldwide net-zero carbon emissions by the year 2050, recently, European Union and Maritime Environment Protection Committee adopted environmental protocols that mandate the implementation of procedures to diminish carbon emission and emphasize the need to increase surveillance in order to cut down on pollution. According to survey's key opinion leaders, this is because IMO member countries around the world will make an effort to execute energy-saving procedures for offshore support vessel groups they operate.

Crew awareness & instruction (O1) is a functional factor subfactor with a Global Weight Rank of 4. Maritime personnel can take part in IMO-style training programmes that focus on energy saving. Experts query the crew's dedication and practical awareness to improving energy efficiency on the offshore support vessel by investigating the process of putting into action, accepting, and making use of various energy management technologies and measures. There is a possibility that short-term crew contracts on support vessels could preclude crew members from fully committing to and becoming acquainted with the vessel’s energy productivity initiatives. The implementation of a mandatory monitoring system for crew efforts and the provision of adequate instruction are two potential solutions applicable to offshore support vessels. This will guarantee implementable ideas through the teaching of current skills and procedures.

The functional main factor and its subfactors received low scores because experts believe they are less essential in the current implementation, which prioritises putting the major factors into action during the first stage of implementation. That doesn't mean functional variables don't contribute to significant energy savings; it just suggests they aren't top considerations. Therefore, once the most essential factors have been implemented, it is crucial to take into account all of these others for the best possible outcome.

4.1.4 FINAL FRAMEWORK MODEL FOR RO1 AND SUGGESTION OF SOLUTIONS

This session presents the final model developed energy efficiency factors including the barriers identified. The model represents three energy efficiency factors with their respective barriers and solutions to them as shown in Figure 4.3



***Managerial*: M1,** Regulatory compliance**; M2,** Capital constraints**; M3,** current shipping practices[**; M4,** owner-charter issues**; M5,** lack of incentives**; M6,** change management issues**.**

***Functional*: O1:** Crew awareness and training**, O2:** Additional operational cost**, O3:** Berthing**,** maneuvering, passage, cargo operations**, O4:** Vessel age and operational service**, O5:** Trade and sailing area**, O6:** Turnaround time in ports.

***Infrastructure:* I1,** Vessel performance monitoring**; I2,** Technological complexities**; I3,** Safety and reliability risks**; I4,** Digitized fleet management**; I5,** Operational mode monitoring**.**

S1-S17 : Solutions

Figure 4.3 Final Framework Model and Solutions

4.1.5 INTERPRETATION OF THE MODEL

The model illustrates the factors which need to be resolved in order to overcome enhanced performance for energy efficient operations of offshore support vessels. The existence of these essential concerns causes a number of energy-efficiency performance-related challenges that ultimately result in significant CO2 release and fuel usage.

The issue of cutting down on carbon dioxide pollution from ships is raised by IMO. There have been many discussions on this topic, but no in-depth studies have been conducted to track emissions from distant supply boats. This study makes an effort to rank aspects of the vessels' activities that have an impact on their overall energy efficiency. The model accomplishes its goal by placing the factors and sub-factors in order constructed on input from a extensive range of interested parties. The model lays out the administrative, functional, and structural factors, as well as subfactors of each that were considered in the research.

The model employs Best worst technique, an MCDM strategy for ranking the elements based on input from different stakeholders. Among the three primary considerations, infrastructure emerged as the clear frontrunner, particularly with respect to the subfactors monitoring vessel efficiency, regulatory compliance and digital fleet management. To improve offshore vessels' energy efficiency, the model sheds light on and provides evidence for the importance of infrastructure sub-factors.

4.1.6 SUGGESTIONS OF SOLUTIONS TO OVERCOME THE BARRIERS

The suggested and prioritised strategies and solutions must be implemented at all levels of the Offshore Vessel Organisational and technical network that cover the assessed administrative, functional, and structural factors. The anticipated analysis enables offshore support transport operators help prioritise energy productivity solutions based on mode of operation. Moreover, stakeholders and affiliated organisations can implement the proposed solutions for their operations support vessel fleet. This will improve the vessel's performance and efficiency to a point where it can not only help reduce energy losses and fuel waste, but also take use of its advantageous position in order to comply with the IMO goal of reducing carbon emissions. With the intention of overcoming the factors which impact energy efficiency and reducing their negative influence on the vessel performance, various solutions are advocated in the outcome of the research in compliance utilising the guiding principles provided by IMO for progress of an energy efficiency management strategy for ships (SEEMP) is mentioned in Table 4.11 below. Although putting these solutions into practice is not an easy process, the decision-makers can do so depending on their importance and cost-effectiveness. Therefore, for the ease and convenience of decision-makers and policy makers, the solutions have been categorized and have been separately prioritized against each sub criteria factors. The prioritization on implementation has to be done using the rating obtained for the main factors and sub factors assessed using Best-Worst which compares the solutions considering both Best solution and Worst solution. Ranking of the sub factors is in the sequence

I1>I4> M1> O1> I2> I3> M2> M3> M4> I5> O2> M5> O6> O3> O4> M6> O5

It is crucial to apply and carry out these strategies if you want to obtain improved energy efficiency performance as well as reduce various losses in managerial, functional and infrastructure and wastage of vessel resources. Thus, with the help of the integrated approach, the priority list solutions are determined thus ensuring the robustness and reliability of proposed result. The stakeholders involved in the Offshore support vessel operations need to employ these solutions and strategies based on their ranks to overcome the issues developed due to various factors identified above.

The suggested solutions are derived from the most effective standards for operating ships in a manner that is economical with fuel. The pursuit for techniques to enhance energy productivity and intensity of carbon emissions across the complete supply chain of transportation is a responsibility that extends beyond what can be delivered by the company on its own. The list of all of the possible parties who have an interest in the effectiveness of a single journey is very extensive. The most obvious parties are manufacturers, shipyards, designers for different types of vessels along with charterers, ports, fuel suppliers, and traffic management services, for a certain voyage. Individually and collectively, each of the concerned parties ought to give some thought to the possibility of incorporating some forms of efficiency into their operations.

Implementation of solutions for Managerial Factors (Solutions: S1, S2, S3, S4, S5, S6) by Adopting Improved fleet management techniques, Maintenance, Improved voyage planning &Weather routing, Implement Speed optimization & Optimized shaft power

Shore and onboard Crew to be awareness and optimization techniques will surely show significant changes.

Functional aspects shall be improved by adopting Solutions driven by technology (Solutions: S7, S8, S9, S10, S11, S12) which involves the monitoring of training, the testing of alternative fuels, systematic examining for verifying and validating data consistency.

Checking Financial feasibility, Review Environmental conditions & proper voyage planning.

Infrastructure being ranked as No.1 will require effective implementation of digitalization and modernization of existing fleets which in turn mentioned in solutions (S13, S14, S15 & S17) consisting of Improved cargo handling, Energy management, Compatibility of measures, Data Driven Decarbonization & Voyage Planning

Table. 4.11 Solutions for overcoming Energy efficiency barriers(Source:Author)

Energy Efficiency Factors (Criteria)	**Sub-Criteria**	**Sub-Criteria Code**	**Solution Code**	**Suggested Solutions** (As per IMO 2022 Guidelines for development of SEEMP)
Managerial	Regulatory compliance	M1	S1	Adopt Improved fleet management techniques
	Capital constraints	M2	S2	Maintenance of Hull & Propulsion system
	Current shipping practices	M3	S3	Improved voyage planning &Weather routing
	Owner-charter issues	M4	S4	Implement Speed optimization & Optimized shaft power
	Lack of incentives	M5	S5	Shore and onboard Crew to be aware of Optimum ballast, Optimum propeller and propeller inflow and Optimum trim , considerations
	Change management issues	M6	S6	Clear terms on Chartering/Management

Functional	Crew awareness and training	O1	S7	Implement & Adopt Monitoring of training
	Additional operational cost	O2	S8	Emerging alternative fuels
	Berthing, maneuvering, passage, cargo operations	O3	S9	Establish checking at periodic intervals for verification and validation of consistency of data
	Vessel age and operational service	O4	S10	Check Financial feasibility
	Trade and sailing area	O5	S11	Review Environmental conditions
	Turnaround time in ports	O6	S12	Just in time
Infrastructure	Vessel performance monitoring	I1	S13	Improved cargo handling
	Technological complexities	I2	S14	Energy management

	Safety and reliability risks	I3	S15	Compatibility of measures
	Digitized fleet management	I4	S16	Data Driven Decarbonization
	Operational mode monitoring	I5	S17	Voyage Planning

4.2. PHASE II IDENTIFICATION OF OPERATIONAL MODES AND PARAMETERS

Research Objective 2: *To develop an Energy Efficiency Operational Performance Index (EEOPI) to measure all operational modes of an offshore supply vessel in UAE.*

The different types of vessels were identified using literature review, acceptable maritime criteria's and rules by regulatory bodies, secondary sources and inputs are collected from the experts using semi structured interviews as an instrument. Based on literature review and expert inputs, four types of vessels and eleven parameters were ascertained. The study consulted 29 experts with more than 10 years of experience in the relevant area. The types of vessels and their common parameters have been presented in Table 4.12 along with a few selected relevant references.

4.2.1 OPERATIONAL MODES AND PARAMETERS: CATEGORIES AND SUB-CATEGORIES

Information pertaining to types of vessels and their parameters of offshore support vessels in UAE have been procured from prevailing studies and pertinent feedback from domain experts. Table 4.12 illustrates the list of vessel types and their along with a mention of selected few references. The vessel types have been grouped into four main categories:

Supply Vessel/Utility Type *(Type 1)*; Anchor Handling, Towing, Escort Vessel Type *(Type 2)*; PSV (Platform Support Vessel)/OCV (Offshore

Construction Vessel)/ROV support/MPSV (Multipurpose Support Vessel)/DSV (Diving Support) Vessel Types etc., *(Type 3)*; and Safety Standby/Oil Recovery/Security Vessel Type *(Type 4)*.

The common parameters are grouped into eleven main sub-categories: Port or Harbour- Idle/Along Side (C1); Port or Harbour- Preparation (C2); Loading/Discharging (C3); Passage/Sailing (C4); Standby/Waiting (C5); Maneuvering (C6); Towing Operations (C7); Offshore work-Normal Support (C8); Offshore work-Dynamic Positioning (C9); Utility services (C10); and Anchor handling (C11).

Table 4.12: Identified categories & sub-categories of the operational modes for measuring EEOPI

<table>
<tr><th>S.No</th><th>Vessel Types (Categories)</th><th>Type Code</th><th>Parameters (Sub-Categories)</th><th>Sub-Category Code</th><th>References</th></tr>
<tr><td>1</td><td>Supply Vessel/Utility Type</td><td>(Type 1)</td><td rowspan="4">1 Port or Harbour-Idle/Along Side
2 Port or Harbour-Preparation
3 Loading/Discharging
4 Passage/Sailing
5 Standby/Waiting
6 Maneuvering
7 Towing Operations
8 Offshore work-Normal Support
9 Offshore work-Dynamic Positioning
10 Utility services
11 Anchor handling</td><td rowspan="4">C1
C2
C3
C4
C5
C6
C7
C8
C9
C10
C11</td><td rowspan="4">Głowacki (2017)

Lützen (2017)

IMO SEEMP (2016)</td></tr>
<tr><td>2</td><td>Anchor Handling, Towing, Escort Vessel Type</td><td>(Type 2)</td></tr>
<tr><td>3</td><td>PSV (Platform Support Vessel) /OCV (Offshore Construction Vessel) /ROV support/MPSV (Multipurpose Support Vessel) /DSV (Diving Support) Vessel Types etc.,</td><td>(Type 3)</td></tr>
<tr><td>4</td><td>Safety Standby/Oil Recovery/Security Vessel Type</td><td>(Type 4)</td></tr>
</table>

4.2.2 ANALYSIS OF PARAMETERS FOR EACH TYPE OF VESSELS USING FUZZY ANALYTIC HIERARCHY PROCESS (FAHP)

The above operational modes are further analyzed using Fuzzy-AHP approach for the purpose of calculating the weights of each parameter for each type of vessels to develop EEOPI.

The TFNS employed for evaluating the eleven criteria for the four types are exhibited in Table 4.13.

Preference Rating	TFNs
Equal Importance	(1,1,1)
Very Low Importance	(1,2,3)
Low Importance	(2,3,4)
Average Importance	(3,4,5)
High Importance	(4,5,6)
Very High Importance	(5,6,7)
Extremely High Importance	(6,7,7)

Table 4.13 Importance level (source: Saaty, 1982)

For Type 1

Fig 4.1 presents the corresponding TFNs for the various criteria of type 1 while Table 4.15 presents the fuzzy weights along with respective ranks.

λ max was estimated to be 11.2529, Consistency Index (CI) is 0.0252 and the Consistency Ratio (CR) for 11 criteria was calculated to be 0.0167. As the value of CR is less than 0.10, the suitability of data is indicated for application of Fuzzy AHP.

TABLE 4.14. TFNS (TYPE 1)

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
C1	(1,1,1)	**(1/5,1/4,1/3)**	**(1/5,1/4,1/3)**	**(1/3,1/2,1)**	**(1/3,1/2,1)**	(1,1,1)	(1,2,3)	(1,2,3)	(3,4,5)	**(1/4,1/3,1/2)**	(2,3,4)
C2	(3,4,5)	(1,1,1)	**(1/3,1/2,1)**	(1,2,3)	(1,2,3)	(2,3,4)	(4,5,6)	(3,4,5)	(6,7,7)	(1,1,1)	(5,6,7)
C3	(3,4,5)	(1,2,3)	(1,1,1)	(1,2,3)	(2,3,4)	(3,4,5)	(5,6,7)	(4,5,6)	(6,7,7)	(1,2,3)	(6,7,7)
C4	(1,2,3)	**(1/3,1/2,1)**	**(1/3,1/2,1)**	(1,1,1)	(1,2,3)	(1,2,3)	(3,4,5)	(2,3,4)	(5,6,7)	**(1/3,1/2,1)**	(4,5,6)
C5	(1,2,3)	**(1/3,1/2,1)**	**(1/4,1/3,1/2)**	**(1/3,1/2,1)**	(1,1,1)	(1,2,3)	(2,3,4)	(1,2,3)	(4,5,6)	**(1/3,1/2,1)**	(3,4,5)
C6	(1,1,1)	**(1/4,1/3,1/2)**	**(1/5,1/4,1/3)**	**(1/3,1/2,1)**	**(1/3,1/2,1)**	(1,1,1)	(1,2,3)	(1,2,3)	(3,4,5)	**(1/4,1/3,1/2)**	(2,3,4)
C7	**(1/3,1/2,1)**	**(1/6,1/5,1/4)**	**(1/7,1/6,1/5)**	**(1/5,1/4,1/3)**	**(1/4,1/3,1/2)**	**(1/3,1/2,1)**	(1,1,1)	**(1/3,1/2,1)**	(1,2,3)	**(1/6,1/5,1/4)**	(1,2,3)
C8	**(1/3,1/2,1)**	**(1/5,1/4,1/3)**	**(1/6,1/5,1/4)**	**(1/4,1/3,1/2)**	**(1/3,1/2,1)**	**(1/3,1/2,1)**	(1,2,3)	(1,1,1)	(2,3,4)	**(1/5,1/4,1/3)**	(1,2,3)
C9	**(1/5,1/4,1/3)**	**(1/7,1/7,1/6)**	**(1/7,1/7,1/6)**	**(1/7,1/6,1/5)**	**(1/6,1/5,1/4)**	**(1/5,1/4,1/3)**	**(1/3,1/2,1)**	**(1/4,1/3,1/2)**	(1,1,1)	**(1/7,1/7,1/6)**	**(1/3,1/2,1)**

C10	(2,3,4)	(1,1,1)	**(1/3,1/2,1)**	(1,2,3)	(1,2,3)	(2,3,4)	(4,5,6)	(3,4,5)	(6,7,7)	(1,1,1)	(5,6,7)
C11	**(1/4,1/3,1/2)**	**(1/7,1/6,1/5)**	**(1/7,1/7,1/6)**	**(1/6,1/5,1/4)**	**(1/5,1/4,1/3)**	**(1/4,1/3,1/2)**	**(1/3,1/2,1)**	**(1/3,1/2,1)**	(1,2,3)	**(1/7,1/6,1/5)**	(1,1,1)

Table 4.15. Fuzzy Weights of Geometric Means - w_l, w_m and w_u for Type 1

Category	w_l	w_m	w_u	M_i	N_i	**Rank**
C1	0.0321	0.0599	0.1172	0.0697	**0.0613**	**7**
C2	0.0921	0.1672	0.2958	0.1850	**0.1628**	**3**
C3	0.1198	0.2263	0.3901	0.2454	**0.2159**	**1**
C4	0.0580	0.1159	0.2366	0.1368	**0.1204**	**4**
C5	0.0442	0.0891	0.1861	0.1065	**0.0937**	**5**
C6	0.0328	0.0614	0.1216	0.0719	**0.0633**	**6**
C7	0.0173	0.0323	0.0662	0.0386	**0.0339**	**9**
C8	0.0223	0.0428	0.0893	0.0515	**0.0453**	**8**
C9	0.0114	0.0182	0.0342	0.0213	**0.0187**	**11**
C10	0.0888	0.1629	0.2934	0.1817	**0.1598**	**2**
C11	0.0139	0.0241	0.0469	0.0283	**0.0249**	**10**

Source: FAHP analysis

As per the results of the analysis done using Fuzzy AHP method, the ranks obtained for the eleven criteria for Type 1 are in the sequence: C3>C10>C2>C4>C5>C6>C1>C8>C7>C11>C10. Thus, the criteria C3 “Loading/discharging” is of highest importance while the criteria C10 “Utility Services” is of least importance.

Table 4.16 presents the idealised priorities of the parameters for Type 1.

Table 4.16 Final results on parameters presented as normalised priorities & idealised priorities

Parameters for Type 1	**Priorities (Normalised)**	**Priorities (Idealised)**
C1	0.0613	0.2839
C2	0.1628	0.7540
C3	0.2159	1.0000
C4	0.1204	0.5766
C5	0.0937	0.4339
C6	0.0633	0.2931
C7	0.0339	0.1570
C8	0.0453	0.2098
C9	0.0187	0.0866
C10	0.1598	0.7401
C11	0.0249	0.1153

According to (Saaty 2008), the normalised priorities are exhibited by dividing each priority weight by highest one, 0.2159 for C3 (Loading/Discharging) (refer above Table 4.16). This is done in order to generate the largest parameter as the ideal one with other parameter getting proportionate values. By doing this, following interpretations can be made: C1 is 28.4% as important as C3; C2 is 75.4% as important as C3; C4 is 57.66% as important as C3; C5 is 43.39% as important as C3; C6 is 29.31% as important as C3; C7 is 15.70% as important as C3; C8 is 20.98% as important as C3; C9 is 8.66% as important as C3; C10 is 74.01% as important as C3; and C11 is 11.53% as important as C3.

For Type 2

λ max was estimated to be 11.452, Consistency Index (CI) is 0.0452 and the Consistency Ratio (CR) for 11 criteria was calculated to be 0.0299. As the value of CR is less than 0.10, the suitability of data is indicated for application of Fuzzy AHP.

Table 4.17 presents the corresponding TFNs for the various criteria of type 2 while table 5 presents the fuzzy weights along with respective ranks.

Table 4.17. TFNs (Type 2)

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
C1	(1,1,1)	**(1/3,1/2,1)**	**(1/3,1/2,1)**	(1,1,1)	(1,2,3)	**(1/5,1/4,1/3)**	**(1/7,1/7,1/6)**	**(1/6,1/5,1/4)**	**(1/4,1/3,1/2)**	(1,2,3)	**(1/7,1/6,1/5)**
C2	(1,2,3)	(1,1,1)	(1,2,3)	(1,2,3)	(2,3,4)	(1,2,3)	**(1/6,1/5,1/4)**	**(1/4,1/3,1/2)**	**(1/3,1/2,1)**	(2,3,4)	**(1/5,1/4,1/3)**
C3	(1,2,3)	**(1/3,1/2,1)**	(1,1,1)	(1,2,3)	(1,2,3)	**(1/4,1/3,1/2)**	**(1/7,1/6,1/5)**	**(1/5,1/4,1/3)**	**(1/3,1/2,1)**	(1,2,3)	**(1/6,1/5,1/4)**
C4	(1,1,1)	**(1/3,1/2,1)**	**(1/3,1/2,1)**	(1,1,1)	(1,2,3)	**(1/5,1/4,1/3)**	**(1/7,1/7,1/6)**	**(1/6,1/5,1/4)**	**(1/4,1/3,1/2)**	(1,2,3)	**(1/7,1/6,1/5)**
C5	**(1/3,1/2,1)**	**(1/4,1/3,1/2)**	**(1/3,1/2,1)**	**(1/3,1/2,1)**	(1,1,1)	**(1/6,1/5,1/4)**	**(1/7,1/7,1/6)**	**(1/7,1/6,1/5)**	**(1/5,1/4,1/3)**	(1,2,3)	**(1/7,1/7,1/6)**
C6	(3,4,5)	**(1/3,1/2,1)**	(2,3,4)	(3,4,5)	(4,5,6)	(1,1,1)	**(1/4,1/3,1/2)**	**(1/3,1/2,1)**	(1,2,3)	(4,5,6)	**(1/3,1/2,1)**

C7	(6,7,7)	(4,5,6)	(5,6,7)	(6,7,7)	(6,7,7)	(2,3,4)	(1,1,1)	(1,2,3)	(3,4,5)	(6,7,7)	(1,2,3)
C8	(4,5,6)	(2,3,4)	(3,4,5)	(4,5,6)	(5,6,7)	(1,2,3)	**(1/3,1/2,1)**	(1,1,1)	(1,2,3)	(5,6,7)	**(1/3,1/2,1)**
C9	(2,3,4)	(1,2,3)	(1,2,3)	(2,3,4)	(3,4,5)	**(1/3,1/2,1)**	**(1/5,1/4,1/3)**	**(1/3,1/2,1)**	(1,1,1)	(3,4,5)	**(1/4,1/3,1/2)**
C10	**(1/3,1/2,1)**	**(1/4,1/3,1/2)**	**(1/3,1/2,1)**	**(1/3,1/2,1)**	**(1/3,1/2,1)**	**(1/6,1/5,1/4)**	**(1/7,1/7,1/6)**	**(1/7,1/6,1/5)**	**(1/5,1/4,1/3)**	(1,1,1)	**(1/7,1/7,1/6)**
C11	(5,6,7)	(3,4,5)	(4,5,6)	(5,6,7)	(6,7,7)	(1,2,3)	**(1/3,1/2,1)**	(1,2,3)	(2,3,4)	(6,7,7)	(1,1,1)

Table 4.18. Fuzzy Weights of Geometric Means - w_l, w_m and w_u for Type 2

Category	w_l	w_m	w_u	M_i	N_i	Rank
C1	0.0173	0.0288	0.0515	0.0325	**0.0291**	9
C2	0.0283	0.0543	0.1034	0.0620	**0.0555**	6
C3	0.0223	0.0438	0.0870	0.0510	**0.0456**	7
C4	0.0187	0.0323	0.0606	0.0372	**0.0333**	8
C5	0.0142	0.0239	0.0466	0.0282	**0.0252**	10
C6	0.0549	0.1001	0.1970	0.1173	**0.1050**	4
C7	0.1488	0.2589	0.4172	0.2750	**0.2460**	1
C8	0.0834	0.1533	0.2853	0.1740	**0.1556**	3
C9	0.0434	0.0826	0.1613	0.0958	**0.0857**	5
C10	0.0128	0.0211	0.0421	0.0253	**0.0227**	11
C11	0.1125	0.2009	0.3453	0.2196	**0.1964**	2

As per the results of the analysis done using Fuzzy AHP method, the ranks obtained for the eleven criteria for Type 2 are in the sequence: C7>C11>C8>C6>C9>C2>C3>C4>C1>C5>C10. Thus, the criteria C7 “Towing Operations” is of highest importance while the criteria C10 “Utility Services” is of least importance. Table 4.18 presents the idealised priorities of the parameters for Type 2.

Table 4.19 Final results on parameters presented as normalised priorities & idealised priorities

Parameters for Type 2	**Priorities (Normalised)**	**Priorities (Idealised)**
C1	0.0291	0.1182
C2	0.0555	0.2256
C3	0.0456	0.1853
C4	0.0333	0.1353
C5	0.0252	0.1024
C6	0.1050	0.4268
C7	0.2460	1.0000
C8	0.1556	0.6325
C9	0.0857	0.3483
C10	0.0227	0.0922
C11	0.1964	0.7983

According to (Saaty 2008), the normalised priorities are exhibited by dividing each priority weight by the largest one, 0.2460 for C7 (Towing Operations) (refer above Table 4.19). This is done in order to generate the largest parameter as the ideal one with other parameter getting proportionate values. By doing this, following interpretations can be made: C1 is 11.82% as important as C7; C2 is 22.56% as important as C7; C3 is 18.53% as important as C7; C4 is 13.53% as important as C7; C5 is 10.24% as important as C7; C6 is 42.68% as important as C7; C8 is 63.25% as important as C7; C9 is 34.83% as important as C7; C10 is 9.22% as important as C7; and C11 is 79.83% as important as C7.

For Type 3

λ max was estimated to be 11.241, Consistency Index (CI) is 0.0241 and the Consistency Ratio (CR) for 11 criteria was calculated to be 0.0160. As the value of CR is less than 0.10, the suitability of data is indicated for application of Fuzzy AHP.

Table 4.20 presents the corresponding TFNs for the various criteria for type 3 while table 4.21 presents the fuzzy weights along with respective ranks.

TABLE 4.20. TFNS (TYPE 3)

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
C1	(1,1,1)	(1,2,3)	(1,1,1)	**(1/4,1/3,1/2)**	(1,1,1)	**(1/3,1/2,1)**	(1,1,1)	**(1/3,1/2,1)**	**(1/5,1/4,1/3)**	(1,2,3)	(1,1,1)
C2	**(1/3,1/2,1)**	(1,1,1)	**(1/4,1/3,1/2)**	**(1/6,1/5,1/4)**	**(1/3,1/2,1)**	**(1/4,1/3,1/2)**	**(1/3,1/2,1)**	**(1/5,1/4,1/3)**	**(1/7,1/6,1/5)**	**(1/3,1/2,1)**	**(1/3,1/2,1)**
C3	(1,1,1)	(2,3,4)	(1,1,1)	**(1/3,1/2,1)**	(1,2,3)	(1,1,1)	(1,2,3)	**(1/3,1/2,1)**	**(1/4,1/3,1/2)**	(1,2,3)	(1,2,3)
C4	(2,3,4)	(4,5,6)	(1,2,3)	(1,1,1)	(2,3,4)	(1,2,3)	(2,3,4)	(2,3,4)	**(1/3,1/2,1)**	(3,4,5)	(2,3,4)
C5	(1,1,1)	(1,2,3)	**(1/3,1/2,1)**	**(1/4,1/3,1/2)**	(1,1,1)	**(1/3,1/2,1)**	(1,1,1)	**(1/3,1/2,1)**	**(1/5,1/4,1/3)**	(1,2,3)	(1,1,1)

C6	(1,2,3)	(2,3,4)	(1,1,1)	**(1/3,1/2,1)**	(1,2,3)	(1,1,1)	(1,2,3)	**(1/3,1/2,1)**	**(1/4,1/3,1/2)**	(1,2,3)	(1,2,3)
C7	(1,1,1)	(1,2,3)	**(1/3,1/2,1)**	**(1/4,1/3,1/2)**	(1,1,1)	**(1/3,1/2,1)**	(1,1,1)	**(1/3,1/2,1)**	**(1/5,1/4,1/3)**	(1,2,3)	(1,1,1)
C8	(1,2,3)	(3,4,5)	(1,2,3)	**(1/3,1/2,1)**	(1,2,3)	(1,2,3)	(1,2,3)	(1,1,1)	**(1/3,1/2,1)**	(2,3,4)	(1,2,3)
C9	(3,4,5)	(5,6,7)	(2,3,4)	(1,2,3)	(3,4,5)	(2,3,4)	(3,4,5)	(1,2,3)	(1,1,1)	(4,5,6)	(3,4,5)
C10	**(1/3,1/2,1)**	(1,2,3)	**(1/3,1/2,1)**	**(1/5,1/4,1/3)**	**(1/3,1/2,1)**	**(1/3,1/2,1)**	**(1/3,1/2,1)**	**(1/4,1/3,1/2)**	**(1/6,1/5,1/4)**	(1,1,1)	**(1/3,1/2,1)**
C11	(1,1,1)	(1,2,3)	**(1/3,1/2,1)**	**(1/4,1/3,1/2)**	(1,1,1)	**(1/3,1/2,1)**	(1,1,1)	**(1/3,1/2,1)**	**(1/5,1/4,1/3)**	(1,2,3)	(1,1,1)

Table 4.21. Fuzzy Weights of Geometric Means - w_l, w_m and w_u for Type 3

Category	w_l	w_m	w_u	M_i	N_i	Rank
C1	0.0337	0.0608	0.1120	0.0688	0.0590	**7**
C2	0.0157	0.0295	0.0656	0.0369	0.0316	**11**
C3	0.0415	0.0865	0.1714	0.0998	0.0856	**5**
C4	0.0840	0.1757	0.3371	0.1989	0.1706	**2**
C5	0.0305	0.0571	0.1120	0.0665	0.0570	**9**
C6	0.0415	0.0921	0.1894	0.1077	0.0923	**4**
C7	0.0319	0.0491	0.1237	0.0683	0.0585	**8**
C8	0.0521	0.0993	0.2580	0.1364	0.1170	**3**
C9	0.1199	0.2381	0.4276	0.2619	0.2246	**1**

C10	0.0192	0.0383	0.0893	0.0490	0.0420	**10**
C11	0.0305	0.0735	0.1120	0.0720	0.0617	**6**

As per the results of the analysis done using Fuzzy AHP method, the ranks obtained for the eleven criteria for Type 3 are in the sequence: C9>C4>C8>C6>C3>C11>C1>C7>C5>C10>C2. Thus, the criteria C9 “Offshore work- Dynamic Positioning” is of highest importance while the criteria C2 “Port or Harbour- Preparation” is of least importance. Table 4.21presents the idealised priorities of the parameters for Type 3.

Table 4.22 Final results on parameters presented as normalised priorities & idealised priorities

Parameters for Type 3	**Priorities (Normalised)**	**Priorities (Idealised)**
C1	0.0590	0.2626
C2	0.0316	0.1406
C3	0.0856	0.3811
C4	0.1706	0.7595
C5	0.0570	0.2537
C6	0.0923	0.4109
C7	0.0585	0.2604
C8	0.1170	0.5209
C9	0.2246	1.0000
C10	0.0420	0.1869
C11	0.0617	0.2747

According to (Saaty 2008), the normalised priorities are exhibited by dividing each priority weight by the largest one, 0.2246 for C9 (Offshore work-Dynamic Positioning) (refer above Table 4.22). This is done in order to generate the largest parameter as the ideal one with other parameter getting proportionate values. By doing this, following interpretations can be made: C1 is 26.26% as important as C9; C2 is

14.06% as important as C9; C3 is 38.11% as important as C9; C4 is 75.95% as important as C9; C5 is 25.37% as important as C9; C6 is 41.09% as important as C9; C7 is 26.04% as important as C9; C8 is 52.09% as important as C9; C10 is 18.69% as important as C9; and C11 is 27.47% as important as C9.

For Type 4

λ max was estimated to be 11.445, Consistency Index (CI) is 0.0445 and the Consistency Ratio (CR) for 11 criteria was calculated to be 0.0295. As the value of CR is less than 0.10, the suitability of data is indicated for application of Fuzzy AHP.

Table 4.23 presents the corresponding TFNs for the various criteria for type 4 while table 9 presents the fuzzy weights along with respective ranks.

Table 4.23. TFNs (Type 4)

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
C1	(1,1,1)	(1,2,3)	(2,3,4)	**(1/4,1/3,1/2)**	**(1/6,1/5,1/4)**	**(1/5,1/4,1/3)**	(3,4,5)	(1,2,3)	**(1/3,1/2,1)**	**(1/3,1/2,1)**	(4,5,6)
C2	**(1/3,1/2,1)**	(1,1,1)	(1,2,3)	**(1/6,1/5,1/4)**	**(1/7,1/7,1/6)**	**(1/7,1/6,1/5)**	(1,2,3)	**(1/3,1/2,1)**	**(1/4,1/3,1/2)**	**(1/5,1/4,1/3)**	(2,3,4)
C3	**(1/4,1/3,1/2)**	**(1/3,1/2,1)**	(1,1,1)	**(1/7,1/6,1/5)**	**(1/7,1/7,1/6)**	**(1/7,1/7,1/6)**	(1,2,3)	**(1/3,1/2,1)**	**(1/5,1/4,1/3)**	**(1/6,1/5,1/4)**	(1,2,3)
C4	(2,3,4)	(4,5,6)	(5,6,7)	(1,1,1)	**(1/3,1/2,1)**	**(1/3,1/2,1)**	(6,7,7)	(3,4,5)	(1,2,3)	(1,2,3)	(6,7,7)

C5	(4,5,6)	(6,7,7)	(6,7,7)	(1,2,3)	(1,1,1)	(1,2,3)	(6,7,7)	(3,4,5)	(3,4,5)	(2,3,4)	(6,7,7)
C6	(3,4,5)	(5,6,7)	(6,7,7)	(1,2,3)	**(1/3,1/2,1)**	(1,1,1)	(6,7,7)	(4,5,6)	(2,3,4)	(1,2,3)	(6,7,7)
C7	**(1/5,1/4,1/3)**	**(1/3,1/2,1)**	**(1/3,1/2,1)**	**(1/7,1/7,1/6)**	**(1/7,1/7,1/6)**	**(1/7,1/7,1/6)**	(1,1,1)	**(1/4,1/3,1/2)**	**(1/6,1/5,1/4)**	**(1/7,1/6,1/5)**	(1,2,3)
C8	**(1/3,1/2,1)**	(1,2,3)	(1,2,3)	**(1/5,1/4,1/3)**	**(1/5,1/4,1/3)**	**(1/6,1/5,1/4)**	(2,3,4)	(1,1,1)	**(1/3,1/2,1)**	**(1/4,1/3,1/2)**	(3,4,5)
C9	(1,2,3)	(2,3,4)	(3,4,5)	**(1/3,1/2,1)**	**(1/5,1/4,1/3)**	**(1/4,1/3,1/2)**	(4,5,6)	(1,2,3)	(1,1,1)	**(1/3,1/2,1)**	(5,6,7)
C10	(1,2,3)	(3,4,5)	(4,5,6)	**(1/3,1/2,1)**	**(1/4,1/3,1/2)**	**(1/3,1/2,1)**	(5,6,7)	(2,3,4)	(1,2,3)	(1,1,1)	(6,7,7)
C11	**(1/6,1/5,1/4)**	**(1/4,1/3,1/2)**	**(1/3,1/2,1)**	**(1/7,1/7,1/6)**	**(1/7,1/7,1/6)**	**(1/7,1/7,1/6)**	**(1/3,1/2,1)**	**(1/5,1/4,1/3)**	**(1/7,1/6,1/5)**	**(1/7,1/7,1/6)**	(1,1,1)

Table 4.24. Fuzzy Weights of Geometric Means - w_l, w_m and w_u for Type 4

Category	w_l	w_m	w_u	M_i	N_i	Rank
C1	0.0345	0.0632	0.1221	0.0733	0.0659	6
C2	0.0193	0.0343	0.0658	0.0398	0.0358	8
C3	0.0152	0.0260	0.0493	0.0302	0.0271	9
C4	0.0854	0.1538	0.2772	0.1722	0.1548	3
C5	0.1380	0.2396	0.3830	0.2535	0.2279	1
C6	0.1111	0.1955	0.3308	0.2125	0.1911	2

C7	0.0127	0.0205	0.0379	0.0237	0.0213	10
C8	0.0263	0.0482	0.0939	0.0561	0.0505	7
C9	0.0470	0.0862	0.1653	0.0995	0.0895	5
C10	0.0640	0.1166	0.2181	0.1329	0.1195	4
C11	0.0107	0.0161	0.0291	0.0186	0.0168	11

As per the results of the analysis done using Fuzzy AHP method, the ranks obtained for the eleven criteria for Type 4 are in the sequence: C5>C6>C4>C10>C9>C1>C8>C2>C3>C7>C11. Thus, the criteria C5 "Standby /Waiting" is of highest importance while the criteria C11 "Anchor handling" is of least importance. Table 4.24 presents the idealised priorities of the parameters for Type 4.

Table 4.25 Final results on parameters presented as normalised priorities & idealised priorities

Parameters for Type 4	**Priorities (Normalised)**	**Priorities (Idealised)**
C1	0.0659	0.2891
C2	0.0358	0.1570
C3	0.0271	0.1189
C4	0.1548	0.6792
C5	0.2279	1.0000
C6	0.1911	0.8385
C7	0.0213	0.0934
C8	0.0505	0.2215
C9	0.0895	0.3927
C10	0.1195	0.5243
C11	0.0168	0.0737

According to (Saaty 2008), the normalised priorities are exhibited by dividing each priority weight by the largest one, 0.2279 for C5

(Standy/Waiting) (refer above Table 4.25). This is done in order to generate the largest parameter as the ideal one with other parameter getting proportionate values. By doing this, following interpretations can be made: C1 is 28.91% as important as C5; C2 is 15.70% as important as C5; C3 is 11.89% as important as C5; C4 is 67.92% as important as C5; C6 is 83.85% as important as C5; C7 is 9.34% as important as C5; C8 is 22.15% as important as C5; C9 is 39.27% as important as C5; C10 is 52.43% as important as C5; and C11 is 7.37% as important as C5.

Further, summarizing the prioritization of parameters for each vessel types as shown in Table 4.26

Table 4.26 Ranking of sub-categories for each vessel type

Sub-Categories	**Preference Weight**	**Ranking**
Vessel Type 1		
C1	0.0613	7
C2	0.1628	3
C3	0.2159	1
C4	0.1204	4
C5	0.0937	5
C6	0.0633	6
C7	0.0339	9
C8	0.0453	8
C9	0.0187	11
C10	0.1598	2
C11	0.0249	10

Vessel Type 2		
C1	0.0291	9
C2	0.0555	6
C3	0.0456	7
C4	0.0333	8
C5	0.0252	10
C6	0.1050	4
C7	0.2460	1
C8	0.1556	3
C9	0.0857	5
C10	0.0227	11
C11	0.1964	2
Vessel Type 3		
C1	0.0590	7
C2	0.0316	11
C3	0.0856	5
C4	0.1706	2
C5	0.0570	9
C6	0.0923	4
C7	0.0585	8
C8	0.1170	3
C9	0.2246	1
C10	0.0420	10

C11	0.0617	6
Vessel Type 4		
C1	0.0659	6
C2	0.0358	8
C3	0.0271	9
C4	0.1548	3
C5	0.2279	1
C6	0.1911	2
C7	0.0213	10
C8	0.0505	7
C9	0.0895	5
C10	0.1195	4
C11	0.0168	11

4.3 DEVELOPMENT OF EEOPI (ENERGY EFFICIENCY OPERATIONAL PERFORMANCE INDEX)

Efficiency measurement tools such as EEOI adopted by IMO acts as a part of SEEMP. The customized formula suiting the actual operation mode of Offshore support vessels is proposed for evaluating operational efficiency of Offshore Support Vessels in UAE

i.e. Energy Efficiency Operational Performance Index (EEOPI) for Offshore Support Vessels.

$$EEOPI_{(Type\ 1,2,3,4)} = \frac{\sum_j FC_j \times C_{Fj}}{W_{Cargo} \times T}$$

$$Average\ EEOPI_{(Type\ n=1234)} = \frac{\sum_i \sum_j (FC_{ij} \times C_{Fj})}{\sum_{n\cdot} (W_n\ T_1) + (W_n\ T_2) + (W_n\ T_3) + (W_n\ T_4) + (W_n\ T_5) + (W_n\ T_6) + (W_n\ T_7) + (W_n\ T_8) + (W_n\ T_9) + (W_n\ T_{10}) + (W_n\ T_{11})}$$

With type of fuel denoted by j; number of voyage by I; consumed fuel mass at a specific voyage by FC; conversion factor for fuel to CO2 by CF; n as the Vessel Type as categorized from 1-4; W cargo is work done (derived via Preferential weightage for each type of offshore support vessel) ; and T as the Time Spend in hours corresponding to the work done.

The unit of EEOPI in such case on the measurement of work done shall be tonnes CO 2 /(Hour). It is to note that Equation 2 doesn't present a simple average of EEOI amongs voyage number i.

With the use of proposed formula, the EEOPI can be calculated for each type of offshore support vessels by considering the eleven parameters identified. The preference weights are calculated using Fuzzy AHP method which will be replace mass of cargo i.e. "m cargo" to Wcargo - which defines work done derived as per Preferential Weightage and Distance is replaced by "time". The calculation of EEOPI for all four types of vessels or operational modes are shown in Table 4.27.

Table 4.27 Calculation of EEOPI for all 4 Types of Vessels

Operational Modes/Vessel Types	Proposed Formula for Calculating EEOPI
Type 1	$$EEOPI_{(Type\ 1)} = \frac{\sum_j FC_j \times C_{Fj}}{W_{Cargo} \times T}$$ $$Average\ EEOPI_{(Type\ 1)} = \frac{\sum_i \sum_j (FC_{ij} \times C_{Fj})}{(0.0613\ T_1) + (0.1628\ T_2) + (0.2159\ T_3) + (0.1204\ T_4) + (0.0937\ T_5) + (0.0633\ T_6) + (0.0339\ T_7) + (0.0453\ T_8) + (0.0187\ T_9) + (0.1598\ T_{10}) + (0.0249\ T_{11})}$$
Type 2	$$EEOPI_{(Type\ 2)} = \frac{\sum_j FC_j \times C_{Fj}}{W_{Cargo} \times T}$$ $$Average\ EEOPI_{(Type\ 2)} = \frac{\sum_i \sum_j (FC_{ij} \times C_{Fj})}{(0.0291\ T_1) + (0.0555\ T_2) + (0.0456\ T_3) + (0.0333\ T_4) + (0.0252\ T_5) + (0.1050\ T_6) + (0.2460\ T_7) + (0.1556\ T_8) + (0.0857\ T_9) + (0.0227\ T_{10}) + (0.1964\ T_{11})}$$
Type 3	$$EEOPI_{(Type\ 3)} = \frac{\sum_j FC_j \times C_{Fj}}{W_{Cargo} \times T}$$ $$Average\ EEOPI_{(Type\ 3)} = \frac{\sum_i \sum_j (FC_{ij} \times C_{Fj})}{(0.0590\ T_1) + (0.0316\ T_2) + (0.0856\ T_3) + (0.1706\ T_4) + (0.0570\ T_5) + (0.0923\ T_6) + (0.0585\ T_7) + (0.1170\ T_8) + (0.2246\ T_9) + (0.0420\ T_{10}) + (0.0617\ T_{11})}$$
Type 4	$$EEOPI_{(Type\ 4)} = \frac{\sum_j FC_j \times C_{Fj}}{W_{Cargo} \times T}$$ $$Average\ EEOPI_{(Type\ 4)} = \frac{\sum_i \sum_j (FC_{ij} \times C_{Fj})}{(0.0659\ T_1) + (0.0358\ T_2) + (0.0271\ T_3) + (0.1548\ T_4) + (0.2279\ T_5) + (0.1911\ T_6) + (0.0213\ T_7) + (0.0505\ T_8) + (0.0895\ T_9) + (0.1195\ T_{10}) + (0.0168\ T_{11})}$$

4.4 DEVELOPMENT OF FINAL MODEL FOR RO2

This session presents the final model developed for all four types of offshore support vessels including the common parameters with different weightages. The model represents EEOPI for various operational modes for each offshore vessel types as shown in Figure 4.4

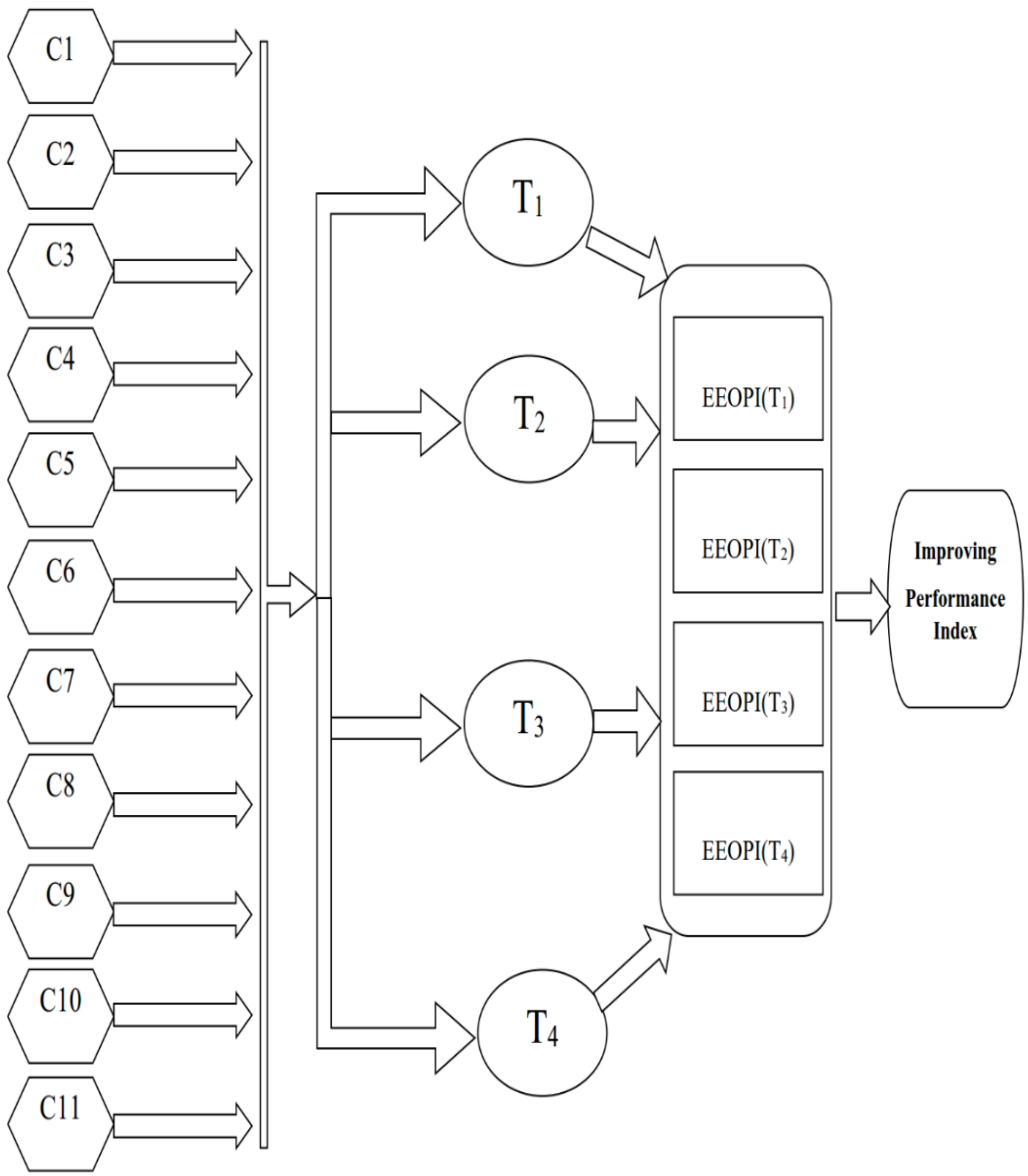


Fig 4.4 Development of Final Model for RO2

4.4.1 INTERPRETATION OF THE MODEL

The model illustrates the Sub categories which need to be determined in order to overcome enhanced performance of offshore support vessels categorized in to 4 Types based on their functionalities ultimately leading to improving the Performance of the vessel. Presence of critical assessment of these 11 parameters for each vessel type results directly in indexing the energy effectiveness performance in turn reflecting cost effectiveness & quality of specific ship activity. It is clearly evident that optimising the parameters based on ranking priority order that are grouped into eleven main sub-categories consisting of: Port or Harbour-Idle/Along Side (C1); Port or Harbour- Preparation (C2); Loading/Discharging (C3); Passage/Sailing (C4); Standby/Waiting (C5); Maneuvering (C6); Towing Operations (C7); Offshore work-Normal Support (C8); Offshore work-Dynamic Positioning (C9); Utility services (C10); and Anchor handling (C11) based on specific vessel type make sense that following a common pattern for all fleet types.This is due to the reason that each vessel types handle specific pattern of work done for which it is specifically facilitated for usage.

4.4.2 DISCUSSION ON RO2 RESULTS OF FUZZY AHP – RANKING OF PARAMETERS FOR VESSEL TYPES

Over the past decade, many investigations into ships' energy consumption and tactical effectiveness have been carried out. Several studies have looked at the challenges faced by the maritime industry when attempting to adopt energy effectiveness and operational effectiveness measures on ships. Research into the relationship between river vessels' efficiency and energy use and carbon gas releases was conducted (Sun X 2013). Considering that navigation is important, many studies have examined environmental factors and ship energy efficiency. (Yuan Y 2017),Ailong

(Fan 2018), (Wang K 2016), (Yan X 2018). (Hannes Johnson and Karin Andersson 2014) studied shipping energy efficiency hurdles to close the energy efficiency gap. The study examined low-carbon shipping barriers and the principal-agent problem. (Rehmatulla N 2015). (Poulsen R T 2015) examined how ship management models improve energy efficiency. (2015).Navigational strategies are key to reducing exhaust emissions. Perera (2016).A new energy performance gauge could improve cargo ship and bulk carrier benchmarking. (Zhang S, 2019). Energy efficiency of passenger ships can be improved by applying (El Geneidy's 2018) suggested novel energy conservation measures. Investment choices are derived to upsurge energy effectiveness after the effects of various technologies are measured. As per (Canbulat 2019) the effects of regular hull cleaning on energy use and fleet performance are presented in (Adland R 2018)]. (Dewan 2018) suggested that operational steps involving stakeholders could help ships use energy more efficiently. But it was found that the main deterrents for the same were the owners' interests and money problems.

4.4.3. Findings of RO2

This finding as per analysis demonstrates that for maximising the procedural effectiveness for a particular offshore support vessel, it is necessary to conduct an assessment of the operational variables involved. Beşikci prioritised measures for a ship's energy efficacy plan using (FAHP 2016). This exemplifies the significance of making a well-considered, strategic decision about which of several potential measures of operational success to prioritise, which was evident from the Results of research analysed for 4 Types of Vessels using Fuzzy AHP in which sub factors (11 numbers) were Ranked based on parameters for each vessel types applicable.

For the Supply Vessel/Utility Type *(Type 1),* As per the results of the analysis done using Fuzzy AHP method, the ranks obtained for the eleven criteria for Type 1 are in the sequence: C3>C10>C2>C4>C5>C6>C1>C8>C7>C11>C10. Thus, the criteria C3 “Loading/discharging” is of highest importance while the criteria C10 “Utility Services” is of least importance.

For Anchor Handling, Towing, Escort Vessel Type *(Type 2)*; As per the results of the analysis done using Fuzzy AHP method, the ranks obtained for the eleven criteria for Type 2 are in the sequence: C7>C11>C8>C6>C9>C2>C3>C4>C1>C5>C10. Thus, the criteria C7 “Towing Operations” is of highest importance while the criteria C10 “Utility Services” is of least importance.

For PSV (Platform Support Vessel)/OCV (Offshore Construction Vessel)/ROV support/MPSV (Multipurpose Support Vessel)/DSV (Diving Support) Vessel Types etc., *(Type 3)*; As per the results of the analysis done using Fuzzy AHP method, the ranks obtained for the eleven criteria for Type 3 are in the sequence: C9>C4>C8>C6>C3>C11>C1>C7>C5>C10>C2. Thus, the criteria C9 “Offshore work- Dynamic Positioning” is of highest importance while the criteria C2 “Port or Harbour- Preparation” is of least importance.

For Safety Standby/Oil Recovery/Security Vessel Type *(Type 4)*; As per the results of the analysis done using Fuzzy AHP method, the ranks obtained for the eleven criteria for Type 4 are in the sequence: C5>C6>C4>C10>C9>C1>C8>C2>C3>C7>C11. Thus, the criteria C5 “Standby /Waiting” is of highest importance while the criteria C11 “Anchor handling” is of least importance.

It is evident from the above analysis that 4 Types of Vessels have segregated weightage based on Operational specific mode in contributing to energy efficient operations which is directly proportionate to amount of work done in each scenario of 11 sub categorized factors consisting of Port or Harbour- Idle/Along Side, Port or Harbour- Preparation, Loading/Discharging, Passage/Sailing, Standby/Waiting,Maneuvering,Towing Operations, Offshore work-Normal Support, Offshore work-Dynamic Positioning, Utility services and Anchor handling.

4.5 MANAGERIAL AND STRATEGIC IMPLICATIONS

The various stakeholders and players in the Offshore support vessel industry contribute to decision-making related to energy efficient performance of the vessel, depending upon the type of stakeholder and their role like managerial, functional, Infrastructure levels. This study is meant for all the stakeholders of the offshore support vessel sector and hence will benefit all in effective decision-making in implementing the framework especially to offshore support vessels operating in UAE region. Hence, it will be highly truthful to mention that the study has significant practical implications for the different players in OSV industry consisting of regulatory authorities, vessel owners, vessel operators, technical managers, onshore/onboard crew and charters. The research determines and separates out facets into categories and sub-categories factors relevant to offshore support vessels which make it evident the applicability of Agency theory approach, which purports the principal agent problems. 3 Major Factors and 17 sub-factors of aspects prevalent in the Offshore support vessel framework have been identified which were approved by the experts along with the usefulness and preference of solutions for resolving the issues related to these factors. The results of the analysis will also help in understanding how important the issues are, helping to prioritize them for attention. As already discussed, FAHP method is used to assessment of the ranks obtained for the eleven criteria for 4 different Types of vessels where the weightage of parameters can be sequentially defined from the most prominent followed by others till least importance. Post analysis of these sub factors, the study helps in acknowledging and prioritizing strategies and solutions,

4.5.1 RELIABILITY OF CUSTOMIZED PERFORMANCE INDEX (EEOPI)

The IMO-proposed formula for EEOI includes the amount of cargo transported as one of the factors. Offshore support boats, on the other hand, are not designed to carry cargo but rather to perform highly specialised tasks associated with offshore activities. As a result, operations-determining factors are open and dependent on stakeholder objectives. The gasoline efficiency of each individual process, rather than type of shipped goods, will determine outcome. The paper by (Lützen, M. 2017) describes the procedure of establishing the framework, including the people who were involved, conducts analyses of operations in the form of a flowchart, and then concludes by describing potential obstacles (factors) to energy efficiency with regards to the working vessels' structure. However, the weight or priority of these considerations was not taken into account. The process of applying different weights to a variety of variables using an analytical hierarchy across the various operations of a shipping business, (Nam-kyun 2019) tried to create an metric for evaluating ship operation energy efficiency. We did not rate operational KPIs that dealt with principal-agent conflicts. In their article, (Bartosz Glowacki and Cezary Behrendt 2017) discuss the inaccuracies that arise when a standard index is applied to the problem of determining the energy efficacy of offshore support vessels. Using a modified version of the IMO formula, we analysed EEOI data gathered from an AHTS-type support vessel, taking into account the vessel's functionality. According to the author's research, the composition and layout of the analysed AHTS vessels play a role in evaluating offshore support vessels' energy effectiveness. The study found that a universal formula tied to the amount of cargo shipped was not optimal, and instead suggested deriving a unique formula for each ship class based on how it operates. This also means that it will be necessary to rank and grade various parameters in order to ascertain the OSV's EEOI. Similar observations were made by (Prill 2018) made in his analysis to compute the operative indicators, and they came to the same conclusion post its application to a dedicated vessel: it is imperative that specific criteria for transport work that is carried out be indicated, as these would be suitable for a given style of vessel. Present research session presents the final model developed for all four types of offshore support vessels including the common parameters with different weightages. The model represents Energy Efficiency Operational Performance Index for various operational modes for each offshore vessel types(segregated to 4 types). Since there was no existing such methodology to assess energy efficiency for supply vessels, this study holds dominant implications in managerial, functional and infrastructure usage for all the stakeholders in understanding, evaluating and monitoring the issues, their influence on the entire operational modes and the vessels performance monitoring along with suggestion of solutions to resolve the issues or reduce their impact considerably and thus contribute towards the sustainable development in reducing the carbon emissions and achieving the global goal of International maritime organization in creating energy efficient ships by performance monitoring. An apt performance indicator can provide another approach to GHG reduction through benchmarking for offshore support vessels.

Reliability of EEOPI: Since EEOPI shares the "*same unit of measure*" as EEOI and EEDI and benchmarking criteria is "*performed work done*" during a specific time, inclusion in the existing IMO policy framework is simple and intuitively understandable by industry. As an indicator, EEOPI is better suited to a relatively specific mechanism that is more of an incentive than a punitive measure for offshore support vessels. One potential scenario is that owners or operators of individual support vessels set purported annual EEOPI targets in the SEEMP. These vessels can be prompted to find places for growth and make adjustments through self-monitoring, administrative or third-party validation and disclosure. Offshore vessel owners could use a scoring mechanism based on the EEOPI to evaluate their energy efficiency performance and, in turn, their ability to compete with the market. It can also be used by port operators to create and execute incentive strategies, and by charterers to locate energy-efficient vessels. These vessels can be prompted to find places for growth and make adjustments through self-monitoring, administrative or third-party validation and disclosure. Offshore vessel owners could use a scoring mechanism based on the EEOPI to evaluate their energy efficiency performance and, in turn, their ability to compete with the market. It can also be used by port operators to create and execute incentive strategies, and by charterers to locate energy-efficient vessels.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

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The current goal industry-wide within the realm of offshore support vessels is to implement effective energy-efficient measures, identify contributing factors, and create a vessel-specific SEEMP. For reduction of GHG emissions, it is imperative to pinpoint the precise causes of those emissions so that energy-saving steps can be put into place. Grounded on the conclusions, it is proposed to apply a rating criterion to the set of factors that add to offshore support vessels' energy efficiency and lead to a technique to calculate EEOI for that factor set. Utilizing techniques for making decisions based on numerous criteria while incorporating the knowledgeable input of all decision-makers was found to be the most effective way for identifying the most promising energy-efficient enhancements. At the assessment levels including global and major, data were broken down by subfactor weight by application of BWM method. Furthermore, the outcomes demonstrate the necessity of analysis for assessing key performance indicators, which shall be fundamental, simple, and trustworthy aspects covering managerial, functional, and infrastructure considerations. Offshore support vessel companies can evaluate their energy efficiency efforts on a mode-by-mode basis using the component analysis that has been suggested through BWM method. In addition, this technique can be used by stakeholders and affiliated institutions to assess the efficiency of their operational fleet. With the help of the weighted index acquired by using the BWM, an MCDM technique as well as additional studies, an assessment method for the energy efficiency of ship operations that are used for offshore support vessels could be developed.

According to the outcomes of analysis, the sub-factors of infrastructure—including risks associated with technological complexity, safety, dependability, and vessel performance —carry the most weight in worldwide rankings. Therefore, weights are assigned to define the importance of infrastructure's primary factor in relation to the cumulative importance of the subfactors. It directs the owners of offshore support vessels towards a set of priorities including All of these are highly influenced by technology: performance review, figuring out how to deal with complicated technology, reducing risks, digitizing, and operational controls. The 76th session of the IMO's Marine Environment Protection Committee in 2021 found that progressive data-capturing devices are being used on ships to monitor performance. This analysis backs up that finding by ranking vessel performance monitoring as the most important subfactor. As lowest ranked subfactor, trade and sailing area demonstrates that this is a significant aspect that applies to all parts of the world, no matter what drives demand in a particular place or where the business is located..

The purpose of the study was to recognize and prioritise energy saving measures for Offshore support vessels within the purview of International Maritime Organization resolutions for SEEMP. Assigning the relative significance of attributes applying fuzzy numbers rather than exact is a benefit of using a fuzzy approach like Fuzzy AHP which accurately represents fuzziness accompanying different operational modes of such a vessel. Using Fuzzy AHP's weighting method and pair-wise comparisons, a best decision-making strategy can be selected for defining and formulating the Energy efficiency Operational Performance Index. (EEOPI).During a given operational mode of a voyage, an Offshore support vessel's EEOPI is calculated by dividing its total CO_2 emissions by its minimum transport labour for that mode. Fuzzy AHP analyses provide the foundation for this type of transportation work proxy, which has practical, reasonable consequences.

Research analysis ranked utilising the fuzzy AHP model clearly shows that an operational factors review needs to be done for a certain offshore support vessel in order to improve the process. Relative significance and a strategic approach in choosing the most vital thing that could be done to make operations run better. was apparent from the findings of research that was analysed for four different types of vessels. This was the case because the research showed that the most important measure could be prioritised. For the Supply Vessel/Utility Type *(Type 1),* the ranks obtained shows that "Loading/discharging" is of highest importance and "Utility Services" is of least importance. In case of Anchor Handling, Towing, Escort Vessel Type *(Type 2)*; the ranks obtained shows "Towing Operations" is of highest importance and "Utility Services" is of least importance. For PSV (Platform Support Vessel)/OCV (Offshore Construction Vessel)/ROV support/MPSV /DSV Vessel Types etc., *(Type 3)*; the criteria "Offshore work- Dynamic Positioning" is of highest importance while the criteria "Port or Harbour- Preparation" is of least importance. For 4tht type, Safety Standby/Oil Recovery/Security Vessel Type *(Type 4)*; the results of the analysis shows "Standby /Waiting" is of highest importance "Anchor handling" is of least importance.

This final model developed after the analysis for all four types of offshore support vessels includes the common parameters with different weightages which is specific for offshore support vessel. The model represents EEOPI for various operational modes for each offshore vessel types to improve performance index. With the use of proposed customized formula, the EEOPI (Energy Efficiency Operational Performance Index) can be calculated for each type of offshore support vessels by due weightage to the eleven parameters identified. The preference weights have been estimated using Fuzzy AHP method that will define Wcargo – work done derived as per Preferential Weightage for specific time duration is then related with amount of fuel consumed to give outcome of Performance Index of Offshore support vessels as an outcome of research.

As a customized derivative to EEOI, EEOPI is a solution, where correctness to an acceptable extent as per practical applicability is implemented for specific types of offshore support vessels. EEOPI's ability to generate less skewed metric findings without relying on commercially sensitive data is its greatest strength when compared to competing approaches. With the goal of encouraging and enhancing energy effectiveness and reducing carbon gas emissions in marine operation, this metric represents a promising metric for strategic purposes. In spite of this, EEOPI derived for particular vessel types cannot offer a one-size-fits-all solution, but rather an indicative metric appropriate for a reasonably effective benchmarking mechanism for each type of offshore support vessel.

5.1 LIMITATIONS AND FUTURE RESEARCH

In conclusion, the study accomplished its goals and obtained proof to support the research hypotheses, but it was not without its share of limitations. First, this study only included operators and stakeholders in the UAE offshore support vessel industry because that is where the research was done. The study would have had to include other regions with the possibility of various operational modes due to differences in regulators' guidelines in order to generalise the result. This investigation needs to be replicated in future to see if results are consistent across countries. Possible areas for future study in this field.

In addition, it would be beneficial to gain a deeper understanding of how one's internal information and competence on energy issues can be improved through collaboration with a variety of stakeholders involved in offshore support vessel operations, as this information could be used to improve the existing framework derived from RO1 analysis. For example, Lack of transparency regarding utilisation of energy, top industry standards, operational protocols, and governing mandates are few chief barriers to energy effectiveness for the vessels aboard. Suggested framework aims to serve as the groundwork for forthcoming multi-layered decision support system that will fill this void through methodical management of energy efficiency. Hence, subsequent studies may tackle more crucial success factors for managerial, functional and infrastructural variation associated with energy effectiveness, role of various organizational framework and the effect of predetermined measures with stakeholders.

In order to ensure effectiveness, the same research objectives of RO2 analysis can be extended through application of various criteria-deciding techniques like TOPSIS. For further research study, Considering the implementations happening in the new offshore support vessels for real time data monitoring of many factors, an upgrade on the operational energy efficacy measures within offshore shipping sector shall be designed using real ship operating data consequent of ships using decision support systems installed onboard the OSVs.

From this research analysis, another particular area may be of interest to study further since the factors identified in current survey by the experts was based on feedback in highly volatile market scenario which was prevailing highly depended on offshore oil prices. Given the prominence that commercial effects the role of selecting factors which impact performance vis-à-vis operational scenario, comprehending the role and usage of monitoring of energy usage in diverse forms of framework in real-time operations in a futuristic environment and applicability for other ship types may be a thought-provoking subject for further investigation.

5.2 RESEARCH CONTRIBUTION

This research has made an attempt to make useful contribution in the area of analysis and ranking of categories and sub-categories factors relevant to offshore support vessels. 3 Major Factors and 17 sub-factors of aspects prevalent in the Offshore support vessel framework have been identified along with the usefulness and preference of solutions for resolving the problems related to these factors.

The results from the research will also contribute in assessment of the ranks obtained for the eleven operational criteria's of 4 different types of offshore support vessels where the weightage of parameters can be sequentially defined from the most prominent followed by others till least importance. A customised performance Index specifically for monitoring offshore vessels' energy economy was derived as outcome of research.

CHAPTER 6

BIBLIOGRAPHY

CHAPTER 6

BIBLIOGRAPHY

6.0 BIBLIOGRAPHY-References

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Appendix A - Section of Research Questionnaire for Round 1

<u>RESEARCH QUESTIONNAIRE FOR ROUND 1</u>

Name of the Person: ………………………………………………………………………

Designation : ………………………………………………………………………

Company : ………………………………………………………………………

Activity : ………………………………………………………………………

Email : ………………………………………………………………………

Phone : ………………………………………………………………………

Dear Sir,

I request your assistance for gathering below Technical data as part of my **Doctorate (Phd)** Program I am currently engaged with Dept of Port & Shipping, University of Petroleum Studies, India.

The Topic of my research is "**Measuring Energy Efficiency of Offshore Support Vessels in UAE "**

The details I would be requiring shall be the data related to Ship Energy Efficiency Management planning followed for Offshore support vessels as part of sample collection.

Core details that will be required shall be to various Operation modes and to know on the general practice followed in operating the Offshore Support vessels in UAE.

The data that are collected will only be used in accordance with the purpose of the study as described above and outcome will be shared with you. Participation in the study is voluntary and usage of any data sourced will be done only with the Prior consent from your side.

The questionnaire shall be followed by few rounds of queries consisting of following:

<u>PART A :</u> Barriers affecting energy efficient operations in Offshore Supply Vessels

<u>PART B:</u> Factors affecting the energy efficiency operations of Offshore Supply Vessels

Your expertise also will be required in ROUND 2, 3 & 4(If required) towards bringing the consensus in Understanding the PART A & B as explained above.

Note:

Barrier means: What are the barriers during the Operations for the offshore support vessel connected between the Principal & Agent.

Principal shall be ship owner. Agent shall be all parties linked with Principal for vessel operations like Ship Management Company, Shipping agent, charter, Port Authority, Suppliers, end use, offshore contractors, class societies and operating region authorities.

Factors means : Any aspects(other than barriers) which will contribute to energy efficiency

QUESTIONS ROUND 1:

1. In your Opinion what are the various barriers between Principal and Agent which may affect the energy efficiency Operations in Offshore Supply Vessels?

2. In your Opinion what are the Factors (Other than barriers) which may affect the energy efficiency Operations in Offshore Supply Vessels?

Signature: ………………………………………………………………..

Appendix B: Survey Form for RO1

Dear Sir

Request your assistance for gathering Survey data required as part of writing an article on Topic on Measuring Energy Efficiency of Offshore Support Vessels(OSV).

Appreciate if you can spare few minutes to fill the below google survey form in order to assess & rate the general practices followed in operating the OSVs in the region.

Will be grateful if you can quickly fill your feedback in below link.

https://forms.gle/zMRYwv5vsNDDoZFo9

While filling survey form -In column, Areas of expertise in Industry, Kindly opt from below category:

OSV Owner

Ship Management

Technical Management

Port-OSV operations

Consultant

Regulatory(For flag/class/surveyors etc.)

QHSE

Others

Participation in the survey is basis on your personal expertise only and usage of any data sourced will be done only for this academic research purpose only.

Thanks for your support.

Survey form

Energy Efficiency Factors in Shipping Industry

Preference values on factors

Gender

- Male
- Female
- Prefer not to say

Area of expertise in shipping industry

Your answer

Experience in the field of shipping *

- Less than 5 years
- 5 to 10 years
- More than 10 years

Untitled Section

Which of the following ship management factor is the "most important" for improving the overall efficiency of the vessel. *

Choose

How much more important is the "most important" factor compared to other factors on a scale of 1-9? (1 refers to equally important and 9 refers to absolutely more important). *

	1	2	3	4	5	6	7	8	9
Vessel performance monitoring									
Crew awareness & training									

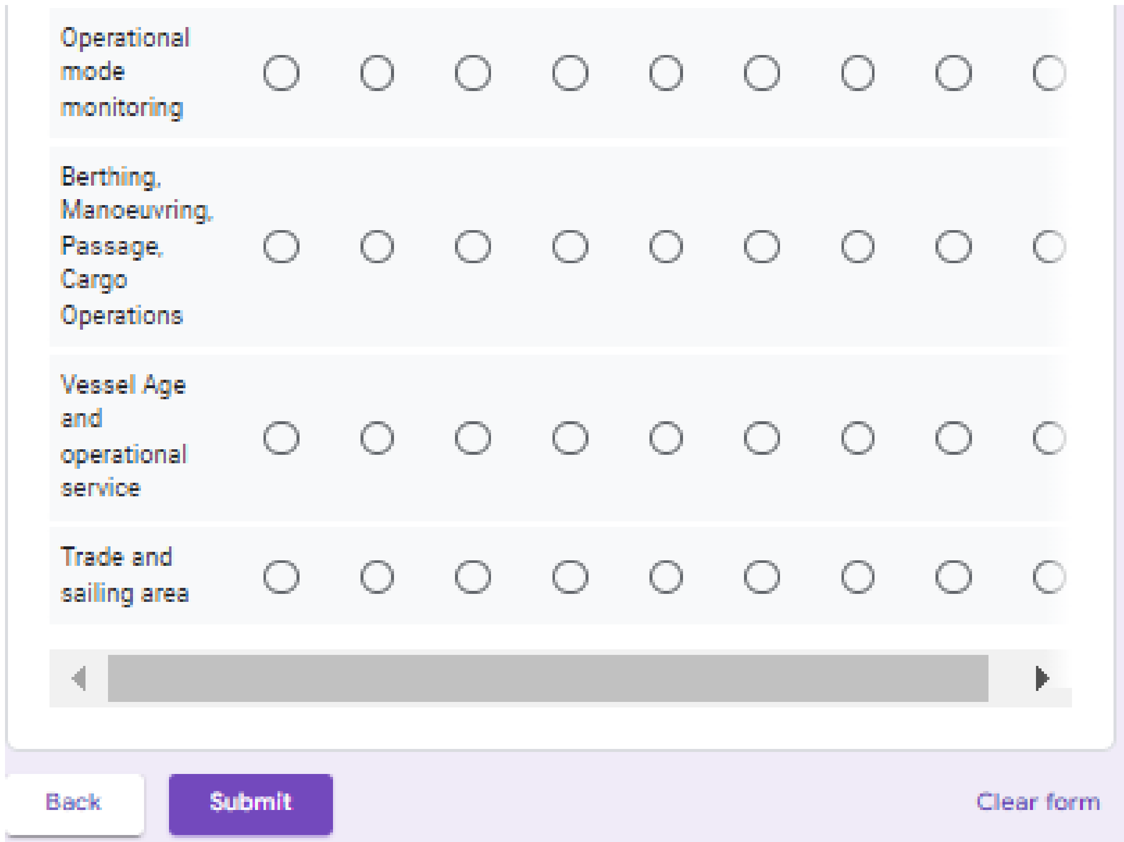
Crew awareness & training	○	○	○	○	○	○	○	○	○
Turn-around time in ports	○	○	○	○	○	○	○	○	○
Regulatory Compliance	○	○	○	○	○	○	○	○	○
Capital Constraints	○	○	○	○	○	○	○	○	○
Current shipping Practices	○	○	○	○	○	○	○	○	○
Owner-charter issues	○	○	○	○	○	○	○	○	○
Technological complexities	○	○	○	○	○	○	○	○	○
Lack of incentives	○	○	○	○	○	○	○	○	○
Safety & Reliability risks	○	○	○	○	○	○	○	○	○
Additional Operational cost	○	○	○	○	○	○	○	○	○
Digitized fleet management	○	○	○	○	○	○	○	○	○
Change management issues	○	○	○	○	○	○	○	○	○
Operational mode monitoring	○	○	○	○	○	○	○	○	○
Berthing, Manoeuvring, Passage, Cargo Operations	○	○	○	○	○	○	○	○	○
Vessel Age and operational service	○	○	○	○	○	○	○	○	○
Trade and sailing area	○	○	○	○	○	○	○	○	○

Which of the following ship management factor is the "least important" for improving the overall efficiency of the vessel. *

Choose

How much more important are the other factors compared to the "least important" factor on a scale of 1-9? (1 refers to equally important and 9 refers to absolutely more important). *

	1	2	3	4	5	6	7	8	9
Vessel performance monitoring	○	○	○	○	○	○	○	○	○
Crew awareness & training	○	○	○	○	○	○	○	○	○
Turn-around time in ports	○	○	○	○	○	○	○	○	○
Regulatory Compliance	○	○	○	○	○	○	○	○	○
Capital Constraints	○	○	○	○	○	○	○	○	○
Current shipping Practices	○	○	○	○	○	○	○	○	○
Owner-charter issues	○	○	○	○	○	○	○	○	○
Technological complexities	○	○	○	○	○	○	○	○	○
Lack of incentives	○	○	○	○	○	○	○	○	○
Safety & Reliability risks	○	○	○	○	○	○	○	○	○
Additional Operational cost	○	○	○	○	○	○	○	○	○
Digitized fleet management	○	○	○	○	○	○	○	○	○
Change management issues	○	○	○	○	○	○	○	○	○
Operational mode monitoring	○	○	○	○	○	○	○	○	○



Operational mode monitoring									
Berthing, Manoeuvring, Passage, Cargo Operations									
Vessel Age and operational service									
Trade and sailing area									

Back Submit Clear form

Appendix C: Survey Form for RO2

Dear Sir,

Request your assistance for gathering Survey data required as part of my Ph.d Academic research program on Topic Measuring Energy Efficiency of Offshore Support Vessels(OSV)

Appreciate if you can spare few minutes to fill the below google survey form in order to assess & rate the practices followed in operating the OSVs in the region.

Will be grateful if you can quickly fill your feedback in below link.

https://docs.google.com/forms/d/e/1FAIpQLScmkGMSfzIHPA8vQA7xayq8xKnm02x8XsXxla_ZX-UdF7Z9JA/viewform?vc=0&c=0&w=1&flr=0

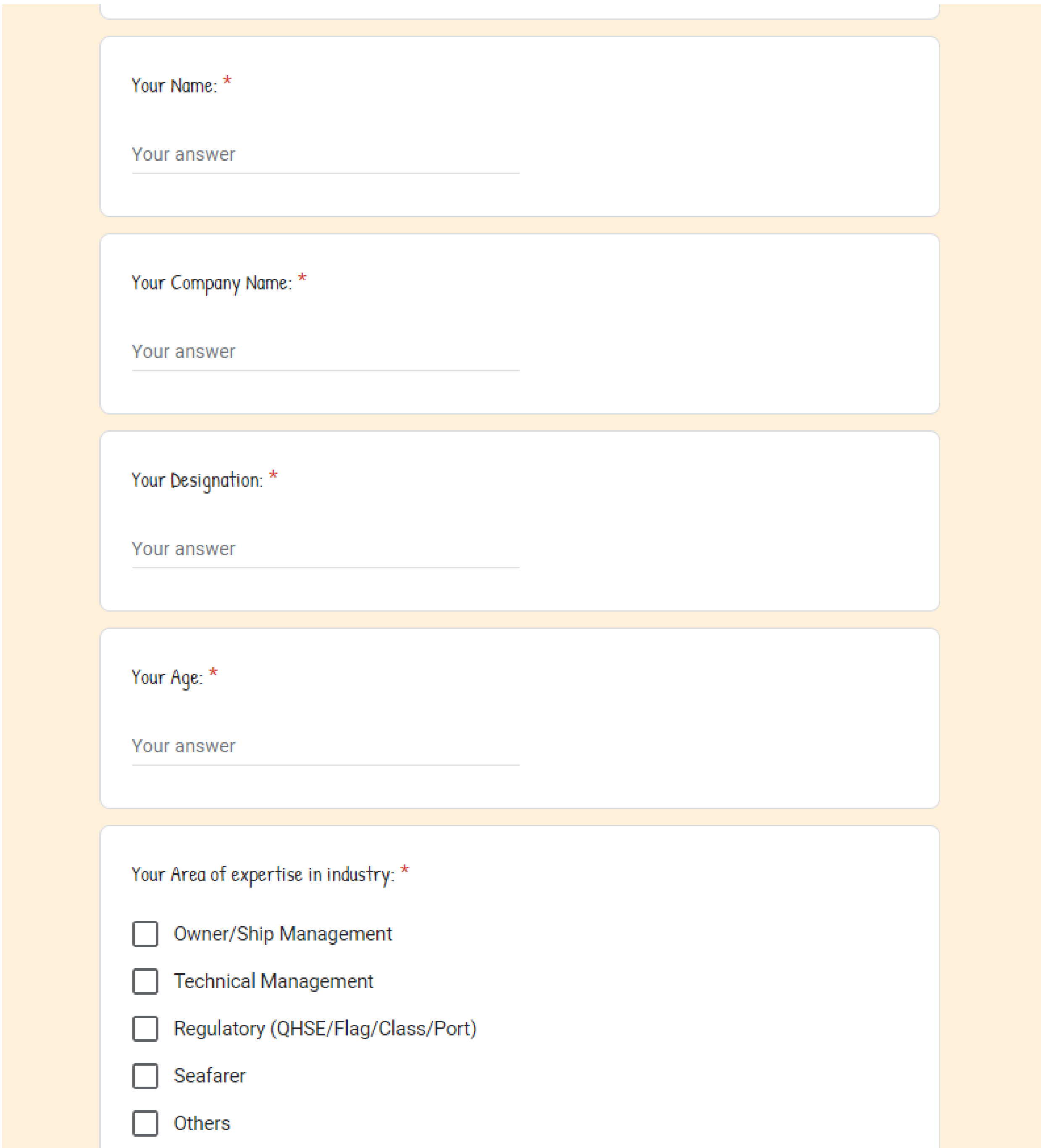
The survey is to assess the criticality and Time spend for each type of operational factors performed by different types of offshore support vessels.If you rate some parameter is Not Applicable or irrelevant for a specific ship type, Please mention it under “weak “category.

Participation in the survey is basis on your personal expertise only and usage of any data sourced will be done only for this academic research purpose only.

Thanks for your support.

Survey form 1

Your response is required as per Weightage and Time spend for each type of operational factors performed by different types of offshore support vessels categorized as below:



Your Name: *

Your answer

Your Company Name: *

Your answer

Your Designation: *

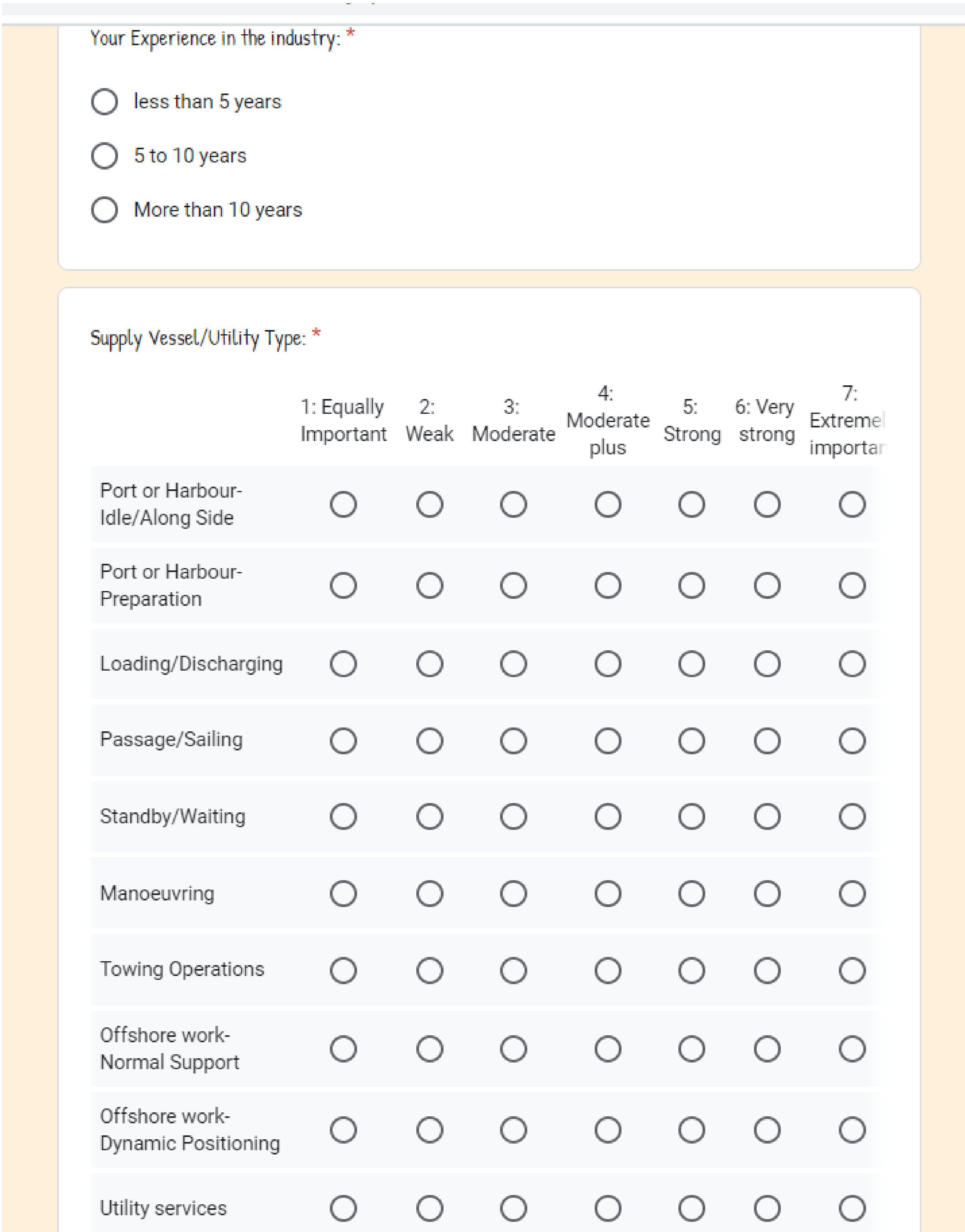
Your answer

Your Age: *

Your answer

Your Area of expertise in industry: *

- [ ] Owner/Ship Management
- [ ] Technical Management
- [ ] Regulatory (QHSE/Flag/Class/Port)
- [ ] Seafarer
- [ ] Others


Your Experience in the industry: *

- less than 5 years
- 5 to 10 years
- More than 10 years

Supply Vessel/Utility Type: *

	1: Equally Important	2: Weak	3: Moderate	4: Moderate plus	5: Strong	6: Very strong	7: Extremel importar
Port or Harbour-Idle/Along Side	○	○	○	○	○	○	○
Port or Harbour-Preparation	○	○	○	○	○	○	○
Loading/Discharging	○	○	○	○	○	○	○
Passage/Sailing	○	○	○	○	○	○	○
Standby/Waiting	○	○	○	○	○	○	○
Manoeuvring	○	○	○	○	○	○	○
Towing Operations	○	○	○	○	○	○	○
Offshore work-Normal Support	○	○	○	○	○	○	○
Offshore work-Dynamic Positioning	○	○	○	○	○	○	○
Utility services	○	○	○	○	○	○	○

Anchor Handling, Towing, Escort Vessel Type: *

	1: Equally Important	2: Weak	3: Moderate	4: Moderate plus	5: Strong	6: Very strong	7: Extremel importar
Port or Harbour-Idle/Along Side	○	○	○	○	○	○	○
Port or Harbour-Preparation	○	○	○	○	○	○	○
Loading/Discharging	○	○	○	○	○	○	○
Passage/Sailing	○	○	○	○	○	○	○
Standby/Waiting	○	○	○	○	○	○	○
Manoeuvring	○	○	○	○	○	○	○
Towing Operations	○	○	○	○	○	○	○
Offshore work-Normal Support	○	○	○	○	○	○	○
Offshore work-Dynamic Positioning	○	○	○	○	○	○	○
Utility services	○	○	○	○	○	○	○
Anchor handling	○	○	○	○	○	○	○

Platform support, Offshore Construction, ROV support, Multipurpose Support, Diving Support etc. Vessel Types (PSV/OCV/ROV/MPSV/DSV etc): *

	1: Equally Important	2: Weak	3: Moderate	4: Moderate plus	5: Strong	6: Very strong	7: Extremel importar
Port or Harbour-Idle/Along Side	○	○	○	○	○	○	○
Port or Harbour-Preparation	○	○	○	○	○	○	○
Loading/Discharging	○	○	○	○	○	○	○
Passage/Sailing	○	○	○	○	○	○	○
Standby/Waiting	○	○	○	○	○	○	○
Manoeuvring	○	○	○	○	○	○	○
Towing Operations	○	○	○	○	○	○	○
Offshore work-Normal Support	○	○	○	○	○	○	○
Offshore work-Dynamic Positioning	○	○	○	○	○	○	○
Utility services	○	○	○	○	○	○	○
Anchor handling	○	○	○	○	○	○	○

Safety Standby/Oil Recovery/Security Vessel Type: *

	1: Equally Important	2: Weak	3: Moderate	4: Moderate plus	5: Strong	6: Very strong	7: Extremel importar
Port or Harbour-Idle/Along Side	○	○	○	○	○	○	○
Port or Harbour-Preparation	○	○	○	○	○	○	○
Loading/Discharging	○	○	○	○	○	○	○
Passage/Sailing	○	○	○	○	○	○	○
Standby/Waiting	○	○	○	○	○	○	○
Manoeuvring	○	○	○	○	○	○	○
Towing Operations	○	○	○	○	○	○	○
Offshore work-Normal Support	○	○	○	○	○	○	○
Offshore work-Dynamic Positioning	○	○	○	○	○	○	○
Utility services	○	○	○	○	○	○	○
Anchor handling	○	○	○	○	○	○	○

Submit

Clear form

Survey form 2

Ranking form

Your response is required as per ranking for each type of operational factors performed by different types of offshore support vessels categorized as below:

Your Name: *

Your answer

Your Company Name: *

Your answer

Your Designation: *

Your answer

Your Age: *

Your answer

Your Area of expertise in industry: *

- [ ] Owner/Ship Management
- [ ] Technical Management
- [ ] Regulatory (QHSE/Flag/Class/Port)
- [ ] Seafarer
- [ ] Others

Your Experience in the industry: *

○ less than 5 years

○ 5 to 10 years

○ More than 10 years

Supply Vessel/Utility Type: *

	Rank1	Rank2	Rank3	Rank4	Rank5	Rank6	Rank7	Rank8	Rank9
Port or Harbour-Idle/Along Side	○	○	○	○	○	○	○	○	○
Port or Harbour-Preparation	○	○	○	○	○	○	○	○	○
Loading /Discharging	○	○	○	○	○	○	○	○	○
Passage /Sailing	○	○	○	○	○	○	○	○	○
Standby /Waiting	○	○	○	○	○	○	○	○	○
Manoeuvring	○	○	○	○	○	○	○	○	○
Towing Operations	○	○	○	○	○	○	○	○	○
Offshore work-Normal Support	○	○	○	○	○	○	○	○	○
Offshore work-Dynamic Positioning	○	○	○	○	○	○	○	○	○
Utility services	○	○	○	○	○	○	○	○	○
Anchor handling	○	○	○	○	○	○	○	○	○

Section 2 - Anchor Handling, Towing, Escort Vessel Type

Anchor Handling, Towing, Escort Vessel Type: *

	Rank3	Rank4	Rank5	Rank6	Rank7	Rank8	Rank9	Rank10	Rank11
Port or Harbour-Idle/Along Side	○	○	○	○	○	○	○	○	○
Port or Harbour-Preparation	○	○	○	○	○	○	○	○	○
Loading /Discharging	○	○	○	○	○	○	○	○	○
Passage /Sailing	○	○	○	○	○	○	○	○	○
Standby /Waiting	○	○	○	○	○	○	○	○	○
Manoeuvring	○	○	○	○	○	○	○	○	○
Towing Operations	○	○	○	○	○	○	○	○	○
Offshore work-Normal Support	○	○	○	○	○	○	○	○	○
Offshore work-Dynamic Positioning	○	○	○	○	○	○	○	○	○
Utility services	○	○	○	○	○	○	○	○	○
Anchor handling	○	○	○	○	○	○	○	○	○

Section 3 - Platform support. Offshore Construction. ROV support. Multipurpose Support. Diving Support etc. Vessel Types (PSV/OCV/ROV/MPSV/DSV etc)

Platform support. Offshore Construction. ROV support. Multipurpose Support. Diving Support etc. Vessel Types (PSV/OCV/ROV/MPSV/DSV etc): *

	Rank1	Rank2	Rank3	Rank4	Rank5	Rank6	Rank7	Rank8	Rank9
Port or Harbour-Idle/Along Side									
Port or Harbour-Preparation									
Loading /Discharging									
Passage /Sailing									
Standby /Waiting									
Manoeuvring									
Towing Operations									
Offshore work-Normal Support									
Offshore work-Dynamic Positioning									
Utility services									
Anchor handling									

Safety Standby/Oil Recovery/Security Vessel Type: *

	Rank1	Rank2	Rank3	Rank4	Rank5	Rank6	Rank7	Rank8	Rank9
Port or Harbour-Idle/Along Side	○	○	○	○	○	○	○	○	○
Port or Harbour-Preparation	○	○	○	○	○	○	○	○	○
Loading /Discharging	○	○	○	○	○	○	○	○	○
Passage /Sailing	○	○	○	○	○	○	○	○	○
Standby /Waiting	○	○	○	○	○	○	○	○	○
Manoeuvring	○	○	○	○	○	○	○	○	○
Towing Operations	○	○	○	○	○	○	○	○	○
Offshore work-Normal Support	○	○	○	○	○	○	○	○	○
Offshore work-Dynamic Positioning	○	○	○	○	○	○	○	○	○
Utility services	○	○	○	○	○	○	○	○	○
Anchor handling	○	○	○	○	○	○	○	○	○

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Appendix D –Analysis of Operational Barriers Questionnaire

Select the best and worst factor. Thereafter identify the best and worst for their subfactors using the scale: Very low - 1; Low - 2; Average - 3; High - 4 and Very High - 5

Select the Best	Solution Code of best soln.

Select the Worst	Solution Code of worst soln.

Best to Others	M1	M2	M3	M4	M5	M6

Others to the Worst	Worst solution
M1	
M2	
M3	
M4	
M5	
M6	

Best to Others	O1	O2	O3	O4	O5	O6

Others to the Worst	Worst solution
O1	
O2	
O3	
O4	
O5	
O6	

Best to Others	I1	I2	I3	I4	I5

Others to the Worst	Worst solution
I1	
I2	
I3	
I4	
I5	

Appendix E: Fuzzy AHP analysis questionnaire for Vessel Types

Questionnaire for Expert Inputs

Please rate the following in terms of relative importance on the following scale: Equal Importance - EI; Very Low importance - VLI; Low importance - LI; Average importance - AI; High importance - HI; Very High importance - VHI; and Extremely High importance - EHI.

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
C1				HI							
C2											
C3											
C4											
C5											
C6											
C7											
C8											
C9											
C10											
C11											

Appendix F -RESEARCH PUBLICATIONS/CONFERENCES

Research Paper 1

"Volatility in tanker freight markets"
Case Studies on Transport Policy 12 (2023) 100993

https://doi.org/10.1016/j.cstp.2023.100993

Research Paper 2

"Efficiency in Jet Fuel Markets"
Empirical Economics Letters, 22 (1): (January 2023) ISSN 1681 8997

https://doi.org/10.5281/zenodo.7799218

Research Paper 3

"Factors Affecting Container Shipping Through Inland Waterways "

Journal of ETA Maritime Science 2022;10(3):156-167

DOI: 10.4274/jems.2022.86094

Research Paper 4

"Energy Efficiency of Offshore support vessels "

2022 6th Asian conference on Environmental, Industrial and Energy Engineering' Conference Series: Earth and Environmental Science (Volume 1044) 2022

Doi:10.1088/1755-1315/1044/1/012005

Research Paper 5

"Review of energy efficiency in offshore vessels "

2018 IJRAR December 2018, Volume 5, Issue 04

IJRAR1944026 International Journal of Research and Analytical Reviews

(E-ISSN 2348-1269, P- ISSN 2349-5138)

BRIEF BACKGROUND- AJITH PJ

I am currently working in the role of Managing Director (Projects), Aries Marine, UAE

Qualifications & Accomplishments:

I hold an Engineering Degree in Naval Architecture & Ship Building and an MBA in Technology Management.

Accomplishments:

I started career as an Engineer attached with the Cochin Shipyard in India and over the past 22 years is working with Aries Marine with its headquarters in the UAE and branches in 25 countries. I accumulated experience in marine consultancy and specializes in implementing strategic and operational turnaround in Marine/Offshore Projects. I worked extensively with various shipyard projects worldwide and manages projects both as a Project Manager and as a consultant advisor in Marine & energy sector..

My experience includes carrying out research, due diligence consultancy of Marine projects, Techno-economic Analysis, Efficiency improvement and carrying out feasibility studies with core focus in the offshore support sector.

- Fellow of **Society of Naval Architects & Marine Engineers from Middle East.**
- Founder Chair of Society of Naval Architects & Marine Engineers-UAE
- Chartered Engineer(I) for Marine Engineering
- Chartered Engineer(SESI) for Solar
- Qualified ISO/ISM Auditor
- Life Member -INSTITUTE OF ENGINEERS, INDIA
- Marine Expert in Federal Courts, UAE
- Member – American Bureau of Shipping –SEA & ME Technical committee
- Member – Lloyds Register of Shipping Regional advisory committee
- Presented/Panellist Various Papers during Conferences/Events including
    - " Energy Efficiency of Offshore support vessels " 2022= 6th Asian conference
    - Define design parameters of offshore supply vessels: Benefit operational applications
    - Offshore support vessels: Adding functional elements
    - OSVs-Design and technological demand drives in Middle East
    - ADIPEC : Offshore Conference Panelist on Topic: Challenges in Offshore Sector

PLAGIARISM REPORT

Phd thesis MEASURING ENERGY EFFICIENCY OF OFFSHORE SUPPORT VESSELS IN UAE FOR DEVELOPING AN OPERATIONAL FRAMEWORK AND PERFORMANCE INDEX

ORIGINALITY REPORT

11%	9%	6%	3%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	dr.ddn.upes.ac.in:8080 Internet Source	3%
2	P J Ajith, T Bangar Raju, Syed Aqib Jalil, B K Chaturvedi. "Energy Efficiency of Offshore Support Vessels", IOP Conference Series: Earth and Environmental Science, 2022 Publication	1%
3	Submitted to Indian Institute of Technology Tirupati Student Paper	1%
4	www.researchgate.net Internet Source	1%
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