Exploring the Usage of the LNG as Fuel for Offshore Vessels

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Abstract

Purpose: *This paper evaluates the benefits of using natural gas in offshore vessels and the challenges faced by using natural gas in offshore vessels.*

Design/Methodology/Approach: *A comprehensive questionnaire was developed and distributed to experts in offshore vessels. The crucial critical factors were selected utilizing an AHP technique from those found common characteristics.*

Findings: *The results found that operational challenges are considered the most important ones as they come in the first place, while technical challenges come in the second place, safety challenges in the third place, and systematic challenges in the fourth place.*

Key-words:
Offshore vessels, natural gas usage, challenges of natural gas, fuel challenges in maritime.

INTRODUCTION

The shipping sector is about to undergo a significant change in order to enhance its environmental emissions profile, particularly those to air. Among other things, the development of Liquefied Natural Gas (LNG) as a practical clean fuel source has been impacted by present national, municipal, and projected worldwide environmental legislation. Despite the fact that the world's LNG carrier fleet has been utilizing it for more than 40 years, other marine businesses, such as Offshore support vessels (Is it support or supply? As in next page?? (OSVs), have only lately begun using LNG. As a result, designs for LNG-fueled boats, including OSVs, are being developed globally for this market, and some LNG-fueled vessels have already been delivered or ordered (Hodgson and Lee, 2012).

There are currently just a few LNG distribution trucks for the few LNG-fueled vessels used, like passenger ferries, as well as small-scale stations offering direct bunkering from shore installations. These facilities serve the LNG shipping industry. Despite the brief history of LNG as a ship fuel, it is now prepared to take off. The first classification criteria for gas-powered ships were created by DNV in 2000, while the first LNG-fueled ferry in the world was being constructed (Blikom, 2012).

In order to promote domestic natural gas usage and virtually eliminate local emissions from the ferry operation, the Norwegian government made it plain that they intended this particular boat route to be powered by natural gas. This project involves building the first LNG-fueled ferry in the world. Currently, the fleet consists of 22 gas-powered ships, including ferries, offshore supply ships, and coast guard boats. All of them are active in Norwegian waters, and the ongoing efforts of the Norwegian government are crucial to their continued existence. After ten years of use, however, ship owners and their crews seem to be mostly in agreement with their positive experiences with this type of fuel (Blikom, 2012).

There has never been a time when the significance of Natural Gas (NG) has been more crucial than now, when strict environmental regulations, improved energy security, and growing competition drive up demand for natural gas while expanding supply and infrastructure to ensure its availability at affordable prices. The constant demand for NG produces enough money and interest to research many facets of the natural gas supply chain with the goal of making it both lucrative and energy efficient. The majority of the vessels in use today are propelled by heavy fuel oils. Although these fuels are inexpensive, they generate a lot of harmful emissions. NG is becoming a compelling alternative for merchant ships in order to comply with International Maritime Organization (IMO) regulations (Burel et al., 2013).

Therefore, this paper evaluates the benefit of using natural gas in offshore vessels and the challenges faced by using natural gas in those vessels.

OFFSHORE VESSELS

Offshore support vessels (OSV) are important players in the global oil and gas sector. The offshore service sector provides goods and services to offshore activities. These services include delivering supplies, equipment, gasoline, water, and food; towing rigs and installing and removing rig anchors; and helping with offshore construction projects. Workers are also transported to, from, and between offshore locations and rigs. All offshore activity, whether it occurs in the (Give full name in the first usage) (GOM) or any other offshore basin worldwide, shares some features even if each operation is unique and job-specific. Supply vessels provide assistance for all exploration and production tasks, such as development, production, and abandonment (Kaiser and Snyder, 2010).

The logistics of offshore oil and gas operations are essential to their effectiveness but have received little attention in the academic literature due to the operations' complexity and the difficulties connecting service vessel utilization to offshore activities. Quantitative models of ship and helicopter movement (Gribkovskaia et al., 2007), fleet design (Aas et al., 2009), information management (Holland et al., 2005), outsourced decision-making (Aas et al., 2008), sustainability (Matos and Hall, 2007), market constraints (Cairns and Harris, 1988), geographical difficulties

(Parola and Veenstra, 2008), and facility siting regulation (Gale and Albright, 1993) have been the main topics of academic research on offshore logistics.

The logistics of the upstream offshore industry have been the subject of numerous studies, but neither have they been thoroughly developed nor rationally harmonized. Additionally, no empirically based analyses or models have been created. It is also unclear how many OSV visits are necessary to support a particular activity. This essential knowledge is necessary to address a variety of academic, planning, and policy concerns (Kaiser and Snyder, 2010).

While OSVs are referred to be the "workhorse" of the industry and the "trucks" of the ocean, crew boats are largely used to transport workers to and from manned platforms and rigs. OSVs are designed to carry a variety of cargo, moving supplies both above and below deck. The wide-open bay ("well") astern, high bow, and forward accommodations of the OSV make it perfectly suited for the storage and delivery of containers, drill pipe, tubing, anchors, and other large and gigantic equipment. The refrigerated cargo holds and special-purpose tanks make it easier to transport commodities like food, drinking or industrial water, diesel fuel, drilling fluids, mud, cement, methanol, and other things below deck. OSVs are normally 10 to 12 knots in speed and range in length from 160 to 260 feet (Aas et al., 2009).

The main types of offshore vessels include: PSV (Platform Support Vessels), AHTS (Anchor Handling, Tug, Supply), and OSCV (Offshore Construction Vessels). PSVs carry supplies to drill ships, offshore construction vessels, and production platforms from a base on land. Storage tanks for liquid and dry bulk cargo are located beneath the deck, which is generally the open area of the ship's aft cargo deck. To maintain the ship close to the platforms while the cargo is being unloaded, it needs good maneuverability and dynamic placement (Erikstad and Levander, 2012).

Platform anchors are correctly positioned, retrieved, and repositioned as needed using AHTS vessels. A ship that has a large bollard pull capability as well as greater anchor handling winch pulling power is required due to the weight of lengthy chains in deep sea. Platform and drilling rig towing also need powerful machinery and a lot of pulling force. The construction and upkeep of platforms, well heads, pipelines, power cables, and undersea pumping systems all include the usage of offshore construction vessels. Moon pools, pipe storage, spacious open work decks, and cable carousels are among the amenities. Additionally, they frequently have remote-controlled underwater vehicles and diving equipment (ROV). Accommodations are required for both the crew of a ship and the labor force working on construction projects. OSCVs occasionally serve as landing pads for helicopters to transfer troops from one ship to another (Erikstad and Levander, 2012).

THE BENEFIT OF USING NATURAL GAS (NG) IN OFFSHORE VESSELS

Heavy fuel oils (HFOs) are used today by the majority of vessels for ship propulsion. Although these fuels are inexpensive, they generate a lot of harmful emissions. LNG is emerging as a viable alternative for vessels to comply with IMO regulations.

Burel et al. (2013) examined the potential economic benefits of using LNG as a fuel for vessels and evaluated the environmental implications of its use. To determine which types of merchant ships would most benefit from using LNG as a fuel for ship propulsion, a statistical analysis of maritime traffic was conducted in the first section. The world ship traffic data for the months of May 2008, 2009, and 2010 were examined. The best prospects for using LNG are roll-on/roll-off (RoRo) and tanker vessels because they spent the majority of their time at sea in Emission Control Areas. The utilization of LNG was particularly advantageous for tanker ships. The operational expenses and the decrease in pollutant emissions for tanker ships were calculated in the second section. Results indicated that using LNG reduced operational expenses by 35% and CO_2 emissions by 25%. Analysis of the potential for increasing energy efficiency on board took into account the cleaner exhaust gas heat recovery combustion gases produced by LNG. Simple heat recovery and heat recovery to power a turbine were the two possibilities that are examined Give the full name first time (ORC). The findings demonstrated that a 15% fuel usage reduction is feasible.

Hao et al. (2016) clarified significant information on NG life-cycle emissions in comparison to conventional petroleum-based fuels for marine. While local air pollutants like sulfur oxides and particulate matter will be lessened by NG, the effects on greenhouse gases depend on how the NG is produced, processed, delivered, and consumed. Using a technological warming potential approach (TWP), NG as a maritime fuel reaches climate parity with conventional fuels in 30 years for diesel-ignited engines, while it may take as long as 190 years for spark-ignited engines. The use of NG as a maritime fuel was increasingly popular, and in some areas, the right conditions already existed for a quick switch. Where NG-friendly economics were combined with governmental air pollution targets, LNG in marine transportation was likely to be encouraged. In comparison to conventional marine petroleum fuels, LNG fuels offered significant local pollution emissions advantages in the maritime transport sector. When used in maritime transportation applications, NG significantly lowers both proposed and current emissions regulations for traditionally fueled marine diesel engines while maintaining NOx emissions for critical criterion air pollutants (SOx and PM10). When NG was compared to high-sulfur fuels, air emission reductions are larger, especially for SOx and PM10. These savings would be realized right away and would last for the whole lifespan of gas-powered marine engines with the conversion to NG.

Cleaner fuels and fewer emissions from all maritime operations are now required by new environmental rules. Mariners can use NG as a fuel to comply with rules, although there are few data on the emissions of NG used in maritime activities. Peng et al. (2020) evaluated the effects on pollutants, human health, and climate change after measuring emissions of criterion, hazardous, and greenhouse pollutants from a dual-fuel marine engine that could run on either NG or diesel fuel. The results showed that switching from diesel to NG reduced particulate matter (PM), black carbon (BC), nitric oxides (NOx), and carbon dioxide (CO_2) by 93%, 97%, 92%, and 18%, respectively. For the numerous port communities that struggle to fulfill air quality regulations, reductions of this size offer a useful tool. Formaldehyde (HCHO), carbon monoxide (CO_2), and methane (CH4) increased significantly when these pollutants were decreased.

Due to their effects on the environment's degradation, particularly the atmosphere's global warming, emissions from vessels are a serious environmental problem. Therefore, the IMO gives careful consideration to environmental preservation through the reduction of exhaust pollution and enhancement of energy efficiency through technological and operational measures. When it comes to the recommendations made by the IMO, NG is preferred over other fossil fuels for usage as an alternative. Elkafas et al. (2021) explored how employing NG in a dual-fuel engine affected the environment and energy efficiency. An inquiry has been made into a container ship. According to the analysis findings, employing a dual-fuel engine powered by NG instead of a diesel engine powered by HFO would result in CO_2, NOx, and SOx emission reductions of roughly 30.4%, 85.3%, and 97%, respectively. Additionally, it was discovered that the dual-fuel engine's NOx and SOx emission rates complied with the IMO 2016 and 2020 limits, respectively. Additionally, the Energy Efficiency Design Index value for a dual-fuel engine is around 30% lower than the value for a diesel engine, and it will be 77.18%, 86.84 %, and 99.27% of the needed value for the first, second, and third stages, respectively, according to IMO advice.

CHALLENGES FACED BY USING NATURAL GAS (NG) IN OFFSHORE VESSELS

Using NG in offshore vessels has received a lot of positive opinions and comments, but there are still several systemic, operational, technological, and safety obstacles to be resolved. These challenges can be summed up as follows in their essential elements (Aymelek et al., 2014):

Systemic Challenges

The hardest obstacles for business owners to overcome so as to accomplish micro-level goals are those on a macro scale. Major systemic obstacles that employ NG in

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offshore vessels would confront systematic challenges including political instability, the risk of war, the financial crisis, the volatility of NG prices, and potential future environmental regulation. The ability of Microsystems to adapt directly relates to overcoming systemic difficulties (Aneziris et al., 2020).

Operational Challenges

The availability of LNG bunkering facilities in ports of call and the sustainable supply of LNG to bunkering stations are the main operational concerns associated with employing NG in offshore vessels. Another operational obstacle for swiftly fulfilling ship-owner orders for LNG-fueled ships is new-generation strategic shipping alliances on deep-sea container shipping liner services with recently constructed enormous ships (Peng et al., 2021).

Technical Challenges

For an LNG bunker to have the same weight as HFO, a ship's fuel tanks would need to be about 80% larger. Therefore, creating a design with enough LNG tanks on ships is a difficult technological task. Replacement of the LNG fuel system for existing ships should be done correctly in accordance with the ship's operational characteristics and stability (Foretich et al., 2021).

In addition, it costs a lot of money to adapt LNG to ships through retrofitting or new construction and to supply LNG to ships for bunkering. Investments in ships powered by LNG are generally 15-20% more expensive than those powered by HFO+MGO. It also accounts for the costs of technical and educational adaption for businesses. Companies require assurances about the suggested conjectures and the LNG bunker supply and demand balance. As a result, gas producers and bunker suppliers are reluctant to make the infrastructure investments required for LNG bunkering until there is enough commercial shipping demand for LNG fuel. Moreover, if there is no improvement in the supply of LNG bunkers on major shipping routes, ship-owners will lose interest in LNG-fueled ships (Wang and Notteboom, 2014).

Safety Challenges

The biggest issue with using NG in offshore vessels is safety. Asphyxiation risk of bunker workers, cold material handling capabilities of relevant ship structures, pool fires, vapor cloud fires, explosions, and rapid phase transitions may all be regarded as safety challenges that should be avoided by further technological advancement and, in particular, by crew and bunkering employee training (Park et al., 2018).

RESEARCH METHODOLOGY

Based on literature review and discussions with the experts, a comprehensive questionnaire was developed and distributed to experts in offshore vessels. Subsequently, the returned questionnaires were examined, and the most prevalent standards approved by various organizations were determined. The crucial critical factors were selected utilizing an AHP technique from those found common characteristics. Figure 1 illustrates the steps of the solution methodology used in this investigation.

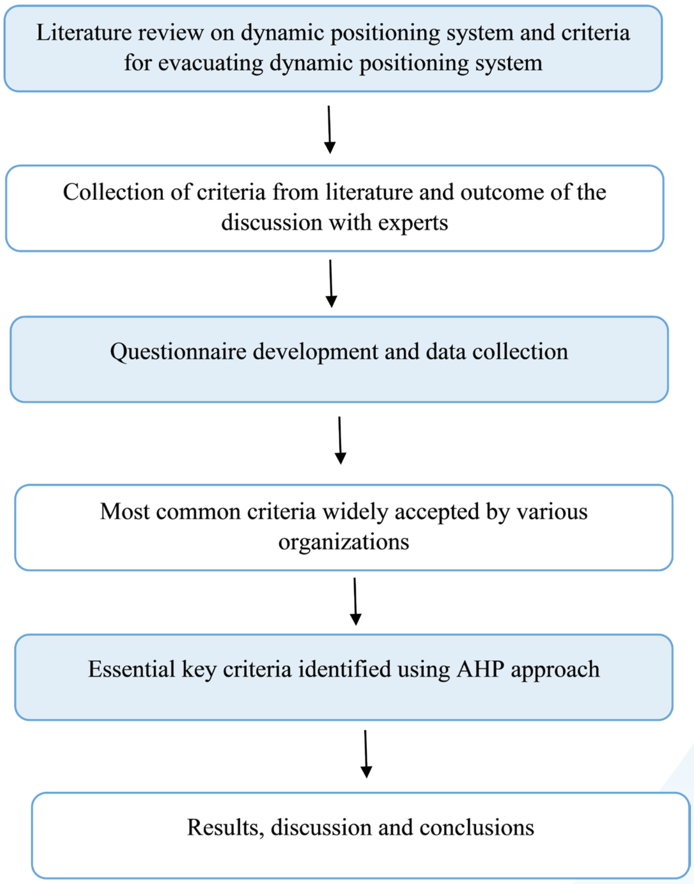

Fig. 1. Flowchart of Research

The analytical hierarchy process (AHP) is a Multicriteria decision-making procedure that offers a systematic strategy for evaluating and integrating the influences of different factors. It involves numerous tiers of dependent or independent qualitative as well as quantitative information (Uyan, 2013). The AHP method capacity to combine subjective and objective impressions, or physical and intangible assessments based on straightforward pair-wise comparison matrices, is one of its key advantages (Ahmad and Tahar, 2014). It has been defined as a straightforward and practical methodology that enables pair-wise comparisons within the analyst's area of expertise (Govindan et al., 2014).

AHP uses the idea of paired comparison along with a hierarchical structure or network analysis to choose the best option from a list of viable options. An AHP's main objective is to choose an alternative from a list of options that best meets a given set of criteria, or to calculate the weight of the criteria in any application by employing the decision maker's or expert's experience or knowledge in a matrix of pair-wise comparison of attributes (Aminbakhsh et al., 2013).

The AHP methodology uses a natural, pair-wise mode to compare criteria or alternatives in relation to a criterion. The three parts of the AHP approach are: (1) identifying obstacles and designing a hierarchy prioritizing model, (2) creating a questionnaire and gathering data, and (3) figuring out normalized weights for each category of barriers and each individual barrier (Haq et al., 2014).

DATA ANALYSIS

In this section, it will be shown how to apply AHP to evaluate the challenges faced by using NG in offshore vessels.

Application of AHP to Assess the Criteria of Dynamic Positioning System

Three main criteria for the challenges faced by using NG in offshore vessels will be considered, which are: (1) Systemic Challenges (SC); (2) Operational Challenges (OC); (3) Technical Challenges (TC); and (4) Safety Challenges (STC).

A recognized pair wise comparison matrix of the challenges faced by using NG in offshore vessels, provided by one of the specialists involved in the investigation, is shown in Table 1. Operational challenges are given the most weight, followed by technical challenges, safety challenges, and systematic challenges.

Table 1: A Pair wise Comparison Matrix for Main Four Challenges

Challenges	SC	OC	TC	STC	CW	GM	W	WSV
SC	**1**	**0.25**	**0.2857**	**0.4**	0.48535	0.41487	9.276%	1.94
OC	**3.88**	**1**	**1**	**1** **0.5**	1.85094	1.55807	34.836%	7.32
TC	**3.33**	**1**	**1**	**1**	1.59191	1.36014	30.410%	6.41
STC	**2.625**	**0.66**	**1**	**1**	1.31308	1.13952	25.478%	5.36
Sum	**10.85**	**2.92**	**3.28**	**3.92**		4.47261	1	

CW = ΣSC+OC+TC+STC / 4

Then, λ max, Consistency Index (CI) and Consistency Ratio (CR) are determined by summing the results of multiplying the pair wise comparison's overall value by each of the system's weights.

- λ MAX = Σ (WSC n / CW n)

λ Max= ((1.94/0.48535) + (7.32/1.85094) + (6.41/1.59191) + (5.36/1.31308)) /4 = 4.0166106

- CI = λ MAX / total of criteria – 1

CI= 4.0166106-4 / 4-1 = 0.0055369

- CR = CI / 0.9

For validation

CR = 0.0055369/ 0.9 = 0.0061521 (CR < 0.1 valid)

The pair wise determination is declared valid with this CR value when the CR value is less than 0.1. Table 1 values are acceptable and consistent because CR is less than 0.1.

The pair wise compression matrix's consistency is verified before the decision matrix is obtained as follows:

Table 2: Decision Matrix for Main Four Challenges

Criterion	CW	Rank
SC	0.48535	4
OC	1.85094	1
TC	1.59191	2
STC	1.31308	3

According to Table 2, it could be observed that operational challenges are considered the most important ones as they come in the first place, while technical challenges come in the second place, safety challenges in the third place and systematic challenges in the fourth place.

The weight of the individual system is shown in Figure 1. It could be observed that operational challenges are considered the most important ones as they come in the first place, while technical challenges come in the second place, safety challenges in the third place and systematic challenges in the fourth place.

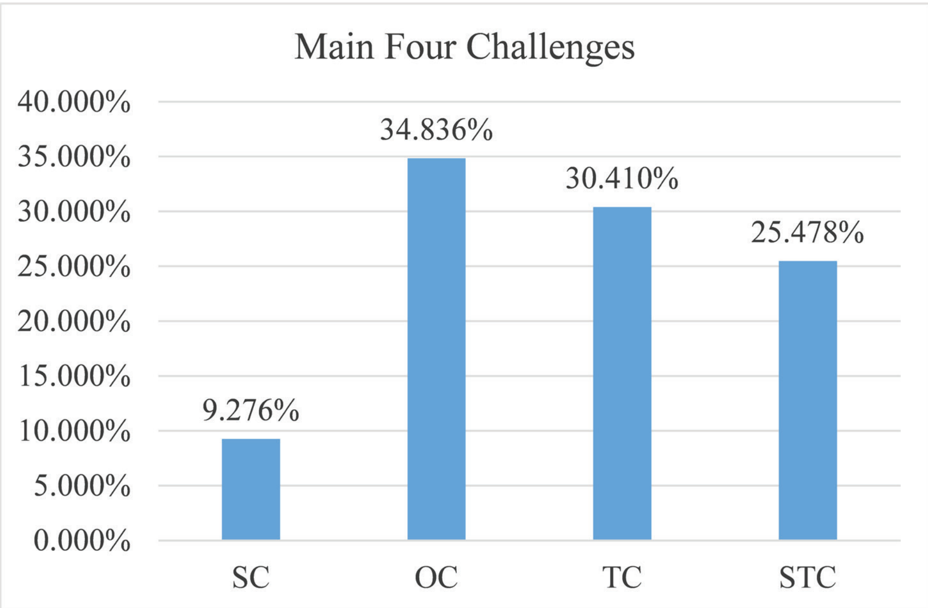

Fig. 2. Weight of Main Four Challenges According to Table 1

CONCLUSION AND DISCUSSION

For offshore vessels, NG is regarded as a viable fuel choice. IT has important economic and environmental opportunities that cannot be ignored despite systemic, operational, safety, and conjectural problems. By 2030, NG is anticipated to rank among the primary fuel sources for offshore boats due to rising costs, increased competition, and environmental regulatory enforcement in shipping.

A questionnaire for challenges faced by using NG in offshore vessels has been provided. The study found that operational challenges are considered the most important ones as they come in the first place, while technical challenges come in the second place, safety challenges in the third place, and systematic challenges in the fourth place.

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