



## An Exploratory Study on the Perceptions of Stakeholders in LNG Bunkering Supply Chain

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### Abstract

IMO 2020 regulations force maritime industry to look for alternative fuels for compliance. LNG is a promising option as a fuel considering today's emission control regulations and for measures to be adopted in the future. However, supply chain development for small-scale LNG is not at the expected level. The study examines the development of LNG bunkering supply chain based on different perspectives of stakeholders. The research explores the challenges regarding LNG bunkering development and aims to provide suggestions to overcome these challenges. Semi-structured interviews were conducted through purpose sampling including various representatives of LNG bunkering supply chain. The study identifies barriers in LNG bunkering development, categorizes some key approaches and links challenges from the view point of relevant stakeholders for improvement in supply chain. The research findings indicate that collaboration of stakeholders is the main driver for LNG bunkering development, public opinion, standardisation and transparency are the other outstanding factors to improve LNG bunkering supply chain.

**Keywords:** LNG Bunkering, LNG as Ship Fuel, Emission Control, Small/Mid Scale LNG Supply Chain.

## 1. Introduction

International Maritime Organization (IMO) GHG (Greenhouse Gas) study indicates that CO<sub>2</sub> emissions from the shipping industry could grow by 50% to 250%, depending on economic development and energy demand[1]. In addition to the effect of climate change, shipping-based emissions such as particulate matter (PM), nitrogen oxides (NO<sub>x</sub>), sulphur oxides (SO<sub>x</sub>), unburned hydrocarbons (UHC) can lessen the ozone layer, produce acid rain and GHG effect. The burning process of the main and auxiliary engines produce substantial amounts of air pollutants such as sulfur oxides (SO<sub>x</sub>), nitrogen oxides (NO<sub>x</sub>), carbon dioxide (CO<sub>2</sub>), volatile organic compounds (VOC), carbon monoxide (CO), black carbon (BC) and particulate organic matter (PM)[2], as well as transitional and alkali earth metals (V, Ni, Ca, Fe) and their soluble or insoluble chemical forms (sulphides, sulphates, and carbides)[3]. IMO GHG study estimates that shipping is responsible for 12% of global SO<sub>x</sub> emissions and 13% of global NO<sub>x</sub> emissions[1]. As the international regulatory body of shipping, IMO adopted the first air pollution prevention regulations by Marpol Annex VI, and regulations came into force in May 2005. Sulphur emission restriction compliance is subject to the owners and operators of the fuel-use strategy. Fuel prices, environmental impacts, and payback time of investments are the factors for choosing emission mitigation measures[4]. There are three main sulphur emission reduction strategies for Emission Control Area (ECA) compliance: low sulphur distillates, scrubbers, and liquefied natural gas (LNG)[5]. The three viable alternatives have different aspects for decision making, such as the price of the fuels, trading area, regulations, remaining lifetime of the vessel, time at sea, and port[6]. Low Sulphur distillates require low capital expenditure, but the unit price is higher than the

alternatives. IMO Tier III compliance needs additional investment. Scrubber and HSFO alternatives require retrofitting for the scrubber. Vessel's stability or constraints could be an issue for installation. On the other hand, LNG has a significant positive effect on air pollution as it provides complete removal of SO<sub>x</sub> and PM, reduction of NO<sub>x</sub> up to 85% and reduced CO<sub>2</sub> emission at least 20%[7]. However, there are several challenges, such as lack of infrastructure and operational standards, that prevent faster developments. Though LNG ship fuel is to be used by LNG driven vessels -that is under shipowner discretion; LNG fuel supply is controlled by other stakeholders of the shipping -ports, terminals, suppliers, etc.

This study aims to contribute to LNG bunkering development as a business case that needs to be investigated through different perspectives of supply chain stakeholders. Shipowners, port authorities, technology providers, and suppliers have various concerns for overall supply chain development.

The structure of the study is followed by section two, which explores related literature, section three describes the research method and data collection; section four analysing data and presenting the findings. Section five discusses empirical findings, their relations, and LNG bunkering development, and the study ends with concluding remarks and suggestions for future research.

## 2. Literature Review

LNG bunkering supply chain problem is a relatively new subject in literature. LNG fuel option for shipping has been discussed with different perspectives in literature. The port operation side is also investigated by various research. However, the entire network design of the LNG bunkering supply chain with different stakeholders' perspective is somewhat limited.

LNG bunkering operation brings ship and port dynamics side by side. The same perspective is observed within the literature review. Some studies propose LNG bunkering handling terminal or jetty design alternatives [8–10], some others operational efficiency of ships [11]. Another important factor has been seen as the safely handling of LNG for bunkering, safety zones, simultaneous operations, collision risk, gas leakage, onboard safety systems, and hazardous consequences are discussed [12–16]. Regulatory discussions are relatively less than other perspectives [17–20]. Economic framework and demand are widely discussed, along with comparative analyses of the other alternative fuels evaluating through different methods and variables [21–29]. Some articles bring more broad approaches to LNG bunkering. Wang and Notteboom [30] carry out a systematic review of the present reports, papers, articles, presentations, and it provides a holistic approach to the challenges of LNG fuel propulsion. Another study of Wang and Notteboom [31] explores the LNG bunkering development with a port perspective; however, the study is limited with only North Europe ports within the ECA area. Only a few articles in literature investigate the supply chain viewpoint of LNG bunkering. Aymelek et al. [32]’s research covers up challenges of LNG bunkering and proposes a network model with a system approach for deep-sea liner shipping. Jafarzade et al. [33]’s system engineering approach explores technical aspects of LNG fuelled systems and significantly contributes to the decision making process while taking into account operation, safety, and economic perspective. However, the study is limited to fishing vessels and the Norway case. Calderon et al. [34] explores the LNG bunkering development by port perspective and investigate safety standards, logistics, and financial aspects, based on secondary

data obtained through port websites, reports, and IHS database. Guçma et al. [35] propose a model of the LNG distribution concept based on the location-routing problem (LRP). The research on the small-scale LNG supply chain is somewhat limited, and they focus on the optimisation of LNG distribution [36–39]. Jokinen et al. propose a model for regional small-scale supply chain utilization in Finland based on fuel procurement cost by mathematical modelling [36]. A small-scale LNG supply chain has been explored by Bittante et al. at tactical and strategic aspects in which the distribution problem has been solved with mixed-integer linear programming. The optimum size of satellite terminals, convenient ports, optimal fleet deployment, including ships and trucks, were determined [38]. Bittante et al., in another research, propose a model for Caribbean small-scale LNG distribution based on fleet size and mix vehicle problem with mathematical modelling methodology at the strategic level while taking into account uncertainty in demand [39]. A recent study by Wan et al. [40] proposes a model to evaluate LNG fuelled vessels based on Norway, China, and USA data. The authors used SWOT analysis, AHP, and evidential reasoning approach (ER) in order to deal with qualitative and quantitative features of the problem.

There are two dimensions in the literature; the points dealt with on the one side explore the ship side: engines, emission control measures, sustainability, and economic feasibility, another side investigates port developments, feasibility as LNG bunkering. The other studies can be grouped as safety standards, operational, and technical challenges for LNG bunkering development. The general two-sided approach in the literature is reflected in real life as the ‘chicken-egg’ problem. These arguments could be categorized as Safety, Operational Challenges, Technical

Challenges, Regulatory Framework, Commercial Factors, and Sustainability. The shipping industry is in a truly international context, and taking a further step is not an easy decision. Therefore, understanding barriers in LNG bunkering development, a holistic approach that merges different perspectives, covering not only various stakeholders but also different regions across the world, is needed. There are limited number of studies focusing on the factors affecting LNG bunkering development. However, no specific research has been found in the literature regarding the factors affecting LNG bunkering supply chain development based on expert views. This study provides a comprehensive and detailed qualitative analysis while taking into account the views of the related stakeholders.

Based on the relevant literature, two research questions have been formulated in this research in order to address LNG bunkering development with a holistic approach: RQ1-What are the main factors affecting LNG bunkering development, RQ2-How do different stakeholders contribute to LNG bunkering supply chain development. RQ1 is critical to identify the present challenges in front of LNG bunkering, which is not at an expected level in the shipping industry. RQ2 is formulated to address how to cope with challenges and which stakeholders are linked.

### **3. Methodology**

The literature covering LNG bunkering, LNG Supply Chain, Small/Mid Scale LNG has been reviewed in order to see the LNG bunkering supply chain development. Six main themes were derived from the literature review: Safety, Operation Challenges, Technical Challenges, Regulatory Framework, Commercial Factors, and Sustainability perspectives as inputs of the supply chain. The interviews help researchers to collect valid and reliable

data that are relevant to the research questions. There are different typologies in the literature to categorize interviews; commonly, interviews are classified as structured, semi-structured, and in-depth (unstructured)[41]. While structured interviews are designed to identify general patterns in descriptive studies, unstructured interviews help to explore new insights. On the other hand, in the semi-structured interviews, the researcher has lists of themes and questions that may vary for different respondents. Some questions may differ according to the flow of the interview or could be focused on specific points according to the context and provides flexibility for the researcher to explore the new phenomena. This approach in semi-structured interviews allows researchers to conduct an exploratory and explanatory study. Therefore, as this study aims to explore a relatively new concept in the industry, a semi-structured interview method was employed.

The researchers prepare a list of themes and questions to be covered; however, this could be varied from interview to interview. Additional questions could be asked according to the flow of the interview in order to explore the research questions and the objectives. The exploratory study is particularly used to understand the problem and provides insight into the phenomenon. It creates casual relationships between variables and explains the relations [41]. Therefore, open-ended questions were preferred in order to reveal and understand the 'what' and 'how' but also exploring the 'why' for LNG bunkering development as it allows us to make exploratory and explanatory research.

The interviews were planned to be conducted through the leading experts in the industry during the LNG bunkering summit 2019 in Amsterdam. Company profiles, organizations, company reports, or other publications related to LNG bunkering

along with company representatives' profiles were investigated in order to be prepared for a possible interview opportunity, demonstrate credibility and to encourage the interviewees for more detailed data. The purposive sampling strategy was used with a maximum variation approach as a sampling method in order to reach the research objectives, which requires different perspectives in the supply chain as it was categorised as suppliers, shippers, regulatory bodies, and technical service providers [42]. Samples were selected deliberately in accordance with the research objectives. The size of the samples was restricted in line with theoretical saturation, i.e. until data collection generates no new insight. The themes of the interview were given to the participants in advance to promote validity and reliability as the participant was allowed to be prepared or gather related information before the interview.

Before each interview, some terms such as the aim/scope of the research, the researchers' background were explained to establish credibility. At the end of the interviews, a brief summary was made in order to test the researcher's understanding. The interviewee was able to evaluate the researcher's understanding and correct it if deemed necessary. The coding of the interviews was compared with an expert who carried out coding separately using Maxqda18 and evaluated based on statistical data. The participants were selected on purpose to represent different stakeholders, titles, and companies in order to assure transferability. In order to achieve confirmability, the researcher made clear his own background and position in advance against potential bias. The coding and theme creating processes were clarified and the findings were linked to the conclusion. The research was conducted with ethical principles through which the participants' consent was gained; their

views were represented as accurately as possible, the names and company details were kept confidential so as to assure the integrity of the research.

A mobile phone interview application was used for recording, and notes were taken during the interviews. The participants were informed regarding voice recording in advance and some of them declined to speak over the recorder. In these cases, only notes were taken. Some of the interviews were declined as well, due to the length of the meeting or due to some technical reasons. Finally, twenty interviews were clarified, which included six suppliers, five shipowners, five technical service providers, and four interviews represent regulatory bodies from ports, flag, and classification society. All participants are already in the LNG bunkering business as different stakeholders and experts in this field with titles of one Chairman, one Vice President, one Chief Operating Officer, one Chief Financial Officer, six Directors, nine Managers, and one Senior Safety Advisor. All participants represent companies that are already in LNG bunkering business.

Shipowners representatives run container fleet, ferryboats, LNG vessels, and tankers. The participant covered under the regulatory body, represent one of the leading ports in shipping. Truck to ship and ship to ship operations are currently conducted, and simultaneous operations have just started. The port develops regulatory content and sets standards in order to perform safe and effective LNG bunkering operations. The second port respondent represents one of the busiest ports in Europe for Ro/Ro shipping, container, and LNG handling. The port also provides ship to ship LNG bunkering facility. Classification society representative already has LNG fuelled vessels under their service. Suppliers are either major oil representatives taking part in every stage of the supply chain, or

conventional bunker supplier recently who invested in LNG bunkering, or LNG suppliers who recently started to provide marine fuel. Technical service providers represent engine manufacturers, safety equipment manufacturers for gas systems and infrastructure developers for gas supplies. LNG bunkering operations are very limited across the world, and it's still only possible at specific locations. The dedicated LNG bunkering summit provided the opportunity to reach out to senior-level experts in this newly developing field.

Face-to-face interviews, skype interview, notes taken during interviews were transcribed. To analyse this primary data obtained from the interviews, Maxqda 18.1.1 Software was used. The qualitative data were coded on software. The study was conducted in four stages: 1-Open Coding, 2-Creating categories, 3- Generating themes, 4-Comparing the themes, analysing and integrating [43].

#### 4. Analysis

Maxqda descriptive statistics were evaluated in order to gain insight into

LNG bunkering. The distribution of codes and parent codes were analysed. The respondents were grouped into four categories: Shippers, suppliers, technical service providers, and regulatory bodies. The codes were explored based on different stakeholders' views.

During the first round of coding, the transcripts were read through and coded with the open coded approach with no limitations or segmentations. In the second round, transcripts were coded based on the interpretation of the raw data. In the third round, higher-level codes and lower-level codes were defined. After the third round, the codes were refined, and the most highlighted codes were determined. The location/Operational region was determined as the highest frequency in data -emphases in nineteen documents. The top ten frequent codes were listed in Table 1. Demand, LNG bunkering price, LNG price were found as other significant factors. Infrastructure was mentioned in 14 different interviews and followed by oil prices, market conditions, and crew training factors.

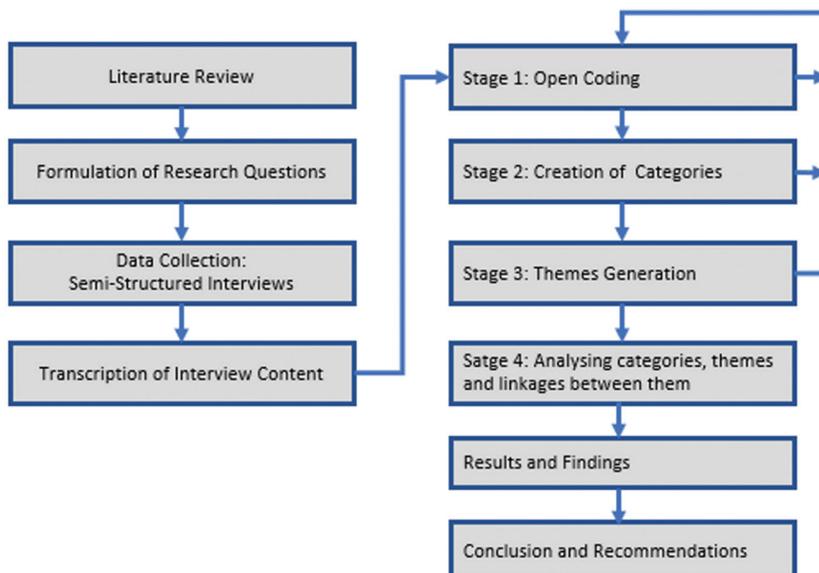


Figure 1. Flowchart of the Research Method

**Table 1.** Distribution of Codes based on Frequency

Code	Frequency	Documents
Location/Operation Region	5,79	19
Commercial Factors\Demand	4,52	12
Commercial Factors\LNG Bunkering price	4,34	15
Commercial Factors\LNG Price	3,98	13
Infrastructure	3,80	14
Safety	3,80	13
Commercial Factors\Oil Prices	3,62	12
Collaboration	3,62	10
Commercial Factors \Market	3,44	12
Safety\Crew Training	3,44	11

In the second stage, the codes were customized, and the categories were created. Parent codes and sub-codes were shaped in hierarchical order. In the third stage, twelve main themes were generated. Commercial factors represent the most emphasized factors that have 34% frequency and mentioned in all documents. Other theme frequencies are between 1.65 and 9.9%. Safety consideration took second place, with 9.9% narrowly in front of the environmental considerations (8.55%). Related codes were gathered under the regulatory framework, technical factors,

and infrastructure. Themes were created as Location/Operation Region, Operation factors, Collaboration, Fleet Type, and Supply Chain. Some factors, which are considered important but not frequently mentioned in data sets, were grouped under 'Others.' These include transparency, work management, strategy, public opinion, etc. Parent code distribution is summarized in Table 2.

As the study aims to explore different stakeholders' insight into LNG bunkering, the respondents were grouped as Suppliers, Shipowners, Technical Service

**Table 2.** Distribution of Parent Codes based on Frequency

Main Code	Coded segments	Coded segments as %	Documents
Commercial Factors	228	34,18	20
Safety	66	9,90	16
Sustainability/Environmental	57	8,55	15
Regulatory Framework	51	7,65	16
Technical Factors	49	7,35	11
Infrastructure	40	6,00	14
Location/Operation Region	37	5,55	19
Collaboration	37	5,55	10
Fleet type	34	5,10	10
Operational Factors	34	5,10	14
Supply Chain	23	3,45	7
Others	11	1,65	5

Providers/Consultants, and Regulatory bodies -Classification Society, Flag, Port respondents. There were 6 suppliers, 5 shipowners, 5 technical service providers, and 4 regulatory bodies. Commercial factors are the main challenges for all stakeholders. While commercial factors are narrowly leading factors for technical service providers (22%), it represents the far biggest challenge for the shipowner perspective (44%). Infrastructure issues were indicated as the second most significant challenge for the ship owners. On the other hand, the regulatory body perspective considers safety issues as the second important challenge (20.3%). Suppliers frequently mentioned cooperation issues in second place after commercial factors. Technical service providers' perspective is broader than other groups that frequencies are more equally distributed among themes, and not surprisingly, technical factors took second place after commercial factors. The distribution of parent codes based on the stakeholder group is listed in Table 3.

At the fourth stage, theoretical links between categories were investigated in order to analyse, underpin the themes,

and explain the relations between them. The data were refined through asking questions, the findings were compared, analysed, integrated, and the results were presented in a realistic scheme in order to address research questions and objectives.

## 5. Discussion

The study explores LNG bunkering development through different stakeholders' perspectives: suppliers, shipowners, technology developers, and regulatory bodies. As main difficulties are represented as lack of infrastructure and prices, there are other factors are affecting directly or indirectly; so the overall supply chain development is interlinked. Main themes -environmental, safety, operational, technical, regulatory framework, and commercial challenges were critically discussed in order to bring a holistic approach to overall supply chain design.

### 5.1. Environmental Considerations

LNG has a positive impact on air quality as sulphur content and PM are almost zero. Short sea shipping and cabotage shipping require more attention as local

**Table 3.** Distribution of Parent Codes based on Stakeholders

Main Codes	Supplier	Shipowner	Technical SP	Regulatory Body	Sum
Commercial Factors	37,8%	44,7%	22,8%	33,3%	34,0%
Safety	7,8%	5,8%	5,1%	20,3%	9,4%
Sustainability/Environmental	6,7%	10,7%	8,9%	6,5%	8,0%
Regulatory Framework	7,3%	1,9%	8,9%	12,2%	7,8%
Technical Factors	5,2%	1,0%	20,3%	2,4%	8,0%
Infrastructure	2,1%	14,6%	3,8%	4,9%	5,4%
Location/Operation Region	6,2%	8,7%	3,8%	4,9%	5,7%
Collaboration	10,4%	1,0%	7,6%	1,6%	6,1%
Fleet type	3,6%	1,0%	6,3%	6,5%	4,5%
Operational Factors	2,6%	8,7%	8,9%	4,1%	5,7%
Supply Chain	7,8%	1,22%	1,9%	2,4%	3,6%
Others	2,6%	1,9%	1,9%	0,8%	1,9%
Total	6(30,0%)	5(25,0%)	5(25,0%)	4(20,0%)	20(100,0%)

communities are directly affected. However, one respondent argues that environmental considerations are still neglected as in business context, only economic factors are being discussed without taking into account where we live and how the next generation is to be affected by present air quality. IMO 2020 regulations could be a positive contributor to LNG bunkering development. Stricker regulations have a positive impact on LNG bunkering, however; if major oil/gas companies are not involved in LNG fuel, it will not be future fuel of shipping. Methane slip is still a drawback for LNG as it has thirty times more impact on global warming compared to CO<sub>2</sub>. However, technology improvement is promising. Low distillates and scrubbers are other viable options for shipowners for strict regulations compliance. Shipowners could decide to do nothing and follow low distillates option. In this case, the availability and price of the low distillates could be a question mark as refineries could have difficulties to satisfy the increase in demand. Another option is to install scrubber and take advantage of cheaper HSFO. The scrubber option has two alternatives as closed-loop and open-loop. Closed-loop scrubber installed ships need to deliver their waste to shore periodically. Waste reception facilities, their availability, price of handling, and reluctant port authorities could be an obstacle for ships. On the other hand, open-loop scrubbers drain the washing waters into the sea -rather than air. Some ports across the world already banned open-loop scrubbers within their port limit. As these options look more convenient investment decisions, it is going to be difficult to sustain those solutions. Alternative fuels are still infant compare to LNG either due to global availability, technological competency, or regulatory standards. All parties agree that LNG is a viable option for the environmental sustainability of shipping. While shipowners' calculation is based on

economic variables, technology providers emphasized technological improvement in the methane slip issue, being a transition fuel for future carbon-neutral fuels. Life cycle assessment of LNG as fuel, taking into account the entire supply chain, is arguable as different approaches bring different results.

## **5.2. Safety Considerations**

All stakeholders are concerned about conducting LNG bunkering operations safely. Crew training is the most important part strongly emphasized by different respondents. Safety concerns usually come up with a regulatory framework and safety standards stressed by regulatory bodies. Shipowners focus more on the availability of the qualified crew and higher industrial standards' economic impact on LNG marine fuel. LNG is not a new issue for shipping as already being transported by ships for years and has excellent safety records. The industry has safety standards to handle it as cargo. Special precautions need to be taken to handle it out of LNG carriers. Crew training is a very crucial step to handle LNG as a marine fuel. Crew dealing with bunkering should be qualified with a fundamental understanding of the product. Safety awareness of the crew is highly related to the type of the vessel they work on. Therefore, training of the crew is a primary concern, especially other than the tanker segment. The training process could need a long time as there are not many places where you can get LNG bunkering training. The key risk is a gas release that could lead to ignition or asphyxiation. The liquid release is also important, which causes fractures on steel. Exposure of cryogenic liquid is going to be resulting in life threatening skin burns. Water curtain, personal protective equipment are basic precautions against any liquid release. The location where LNG bunker operation is to be conducted must be safe and to be avoided

from nautical risk areas. Approach area, fendering, mooring, and passing vessels through channels are the factors affecting the safety of the operations. Restricted zones should be set for safety reasons. Flow rate and pressure are the two key indicators to determine the safety zone. Quantitative and qualitative risk assessments should be carried out to see if the risk is acceptable. Location choice is critical in reducing the risks to a reasonable limit. Providing simulator training and hands-on training are critical for crew improvement.

### 5.3. Operational Considerations

LNG bunkering operation has difficulties. Different respondents argue that these are mostly related to lack of experience and globally standardized process, which will be sorted over time. The compatibility of the vessel could be fixed as industrial practices for different sizes of the flanges, and the distance between manifolds can be overcome with flexible hoses. Both facilities exchange information and come up with an appropriate transfer system. However, one respondent argues that the size of the bunker barge could cause some compatibility concerns at loading terminals, as small barge will not fit LNG receiving terminals and some modifications are required. LNG bunker barges are typically designed as Type C tanks, which have no issues with sloshing, and it provides flexibility to load slack cargo according to the client's request. On the other hand, it has been pointed out by one respondent that the capacity and size of the receiving vessel will be a criteria for the supplier in order to reduce the unit cost, fully loading the barge, and then distribute it as much as possible before returning for new loading. Delivered LNG bunker calculation is being made by mass flow meters in Ship-to-Ship transfers. Truck to Ship transfers could be calculated based on the number of trucks. Characteristics of the LNG is different based

on the sources. Therefore, BDN (Bunker Delivery Note) should include the quantity transferred as volume, mass, and energy. Which figure will be taken into account is subject to a contract between the receiver and the supplier. Simultaneous operation is another critical stage for LNG bunkering as it allows us to perform cargo or passenger operation at the same time. Larger vessels require a longer time for bunkering, and simultaneous operation resolves time concerns over LNG bunkering. One of the serious obstacles in front of the shipowners could be sorted.

### 5.4. Technical Considerations

The shipping industry has had experience over LNG handling on a bigger scale for years; however, small or mid-scale handling is relatively new, and some technical problems still exist, or standardized solutions have not been provided yet.

Methane slip at the engine is still one of the biggest drawbacks of the LNG as a marine fuel. Technology providers are very ambitious to minimize it. In addition to the engine, it was highlighted that long hose connections without proper insulation cause leakage and evaporation, which eventually leads to global warming that the industry ignores. The vessels working in long haul need sufficient bunker tank capacity to complete the round trip. The bigger fuel tank means relatively less cargo space. The boil of gas (BOG) problem was pointed out by several respondents. Reliquefaction plant or sub-cooling systems are the solutions to the industry so far. Burning of the BOG in auxiliary engines is another alternative to handle the issue. BOG management is the responsibility of each individual vessel, and it has been incorporated into the design of the LNG fuel system onboard the vessel, and the LNG cargo system onboard the LNG bunkering vessel. Quality and methane number of LNG

affects the performance of the engine. As LNG is provided from different sources with different quality, it's a question mark for the vessels which need to supply bunker across the world. So standardization in methane number is required for the performance of the vessels' engine. Standardization is achieved in a temperature of the LNG as  $-158^{\circ}\text{C}$  in industry. Temperature difference of the LNG also slows down bunkering operation that leads in time concern. Technical obstacles affect the shipowner's investment decision, as it leads to high capital expenditure. Technology providers are optimistic about developments and technical standards. However, the industry still needs to be standardized, and some technical factors are to make LNG marine fuel a more acceptable option globally.

### **5.5. Regulatory Framework**

Handling LNG is already well set by the highest industry standards and regulations. An extended part of the handling LNG involves the bunkering purpose, which is covered by some guidance and best practices prepared by SGMF, EMSA, IMO, SIGTTO, or OCIMF. However, it was observed during the interviews that different stakeholders have different views in terms of implementation, coverage, or practices of the regulatory framework.

Supplier respondents were satisfied with the regulatory coverage of LNG bunkering. However, the other groups were critical in the overall implementation. IGF Code has been developed based on safe handling, environmental considerations in mind; however, it is argued that IMO does not take into account standardization. The implications differ from country to country, even port to port. The process is implemented in various ways, and it makes the process complicated for the ships. Local regulations are different, and they require a different process even within NW Europe. It was highlighted

by a respondent that standards have been transferred from conventional LNG handling to LNG bunkering, and it might be too high and difficult to implement at a small scale. However, small revisions and updates on IGF could be sufficient to cover the industrial needs. The technical service provider argues that even if the regulatory framework is in place, there are different opinions between classification societies, and it's hard to keep balance if working with different societies of classification. Their experiences in LNG bunkering are at different levels, and it is reflected on site. Standards are made by experts, not by regulatory bodies. Therefore, IACS should propose canons to facilitate similar implementations in the industry. Ship-owners have a more optimistic view that as operations are conducted, the industry will set its own standards on the way.

### **5.6. Commercial Considerations**

Inevitably commercial factors are far important criteria for any stakeholders. Energy demand, pricing, contracts, supply and demand along with market structure and available funds were discussed through different perspectives.

Commercial viability of LNG fuelled ship investment is critical for ship owners. They have to calculate financial sources, private equity, indirect finance via shipyards or green funds. European Commission or governments subsidize significant amount of the project, 'green' funds are available for investments, however, it requires some work to introduce it to 'shipping' and how to match with 'green'. LNG bunkering investment decision is not an easy process as it comes up with sum of uncertainties. Supplier side points out that there are not so many vessels available in order to serve at regularly basis LNG to customers so they can organize logistics in advance. Shipowner side argues that the main challenge is supply as they can not reach out

LNG fuel as they want. However, regulatory body and technical service providers see the challenge mostly: lack of demand as supply chain for LNG is already available in many places. However, the market does not really exist yet, in progress, bunkering facilities are still on developing stage.

The market is growing very slowly, and it's a costly decision, it depends on how you operate and where you are going to operate. Normally, volume of the market is the key point to decide, however, it was overridden by big oil majors' decision -irrespective volume of the market and they invested in bunker barge. As LNG bunkering market has not been matured yet, the market development depends on where your client is, and you must see potential demand in order not to pursue your client when supply chain is oversized for a single client. Economies of scale is critical at this stage that suppliers will concentrate bunkering stations at these locations. However, small scale LNG logistics could be very expensive compared to conventional LNG logistics as it requires high CAPEX with unsatisfied demand.

Scalability is important to initiate LNG bunkering supply, relative less investment can afford small amount of LNG by trucks until the market gets matured. The first need is to see the market, and then market will set supplying limits to set the price. One important factor for market development is price. Shipowner side argues that there are very few LNG suppliers in the market without competition, which leads to high LNG fuel prices and it makes the business case for LNG not viable. Availability and the cost related logistics chain is an obstacle. Apart from logistics added cost of LNG, competition with oil price is critical as well. The gap between MGO and LNG will affect shipowners' decisions. Moreover, LNG has different prices in different regions. Pricing in Europe is relatively stable and fluctuating less than that in far east market

where gas price absolutely linked in the contract to the oil prices or where gas price oppositely is linked to the oil price in the USA. Conventional fuels have standard products and limited specifications, then it's easy to price this product. However, in LNG, reference quality does not exist, therefore pricing LNG based on specification is not easy.

Another difficulty is there is not much transparency in the industry, and stakeholders do not have knowledge of LNG bunker prices. It's something that needs to be negotiated by shipowners still another challenge for LNG contracts. Supplier side seeks long term contracts to set infrastructure according to demand. On the other hand, shipowners want to see spot market and don't want to commit to long term contracts as they need flexibility and may change their trade patterns. Therefore, contracts should be short -spot deal agreements. Longer term contracts may provide more price security for both LNG suppliers and the LNG consumers, but take away the opportunity for ship owners/charterers to profit from a drop in LNG prices. As global market is changing, with an impact on price, contracts and LNG bunkering pricing, IMO 2020 regulations and new LNG bunkering infrastructures are expected to have positive impact. However, uncertainties are inevitable in a relatively new business case, and sharing the risk is a critical stage to start up new concept.

### **5.7. Infrastructure, Operational Region and Fleet Type**

Lack of infrastructure is an outstanding challenge in front of LNG fuel. Availability and affordability are not established in the industry where owners/operators can be relieved. For the shipowner, the challenges are securing a reliable source of LNG in all ports that the vessel will call. Traditional bunkering hubs where main shipping trade pass through are the key locations

for LNG fuel development as large vessels lift substantial amount of bunker and generate demand. Specific vessel types and trade could be important factors. Container vessels, car carriers or cruise vessels need very large volume of fuel, and usually their port of call list is prepared in advance and they are represented as good customers. The vessels which are on tramp trade still need to see more supply security. Baltic Sea and NW Europe already have infrastructure, busy shipping routes, environmental pressure and subsidies from EU to comply with emission mitigation targets. If there is a cluster of several LNG users or potential users with sufficient LNG demand in around specific location, the investment in an LNG bunker barge will be viable as we have seen in Baltic region or NW Europe. LNG bunkering barge means that large volume of supply and along with less bunkering time.

### **5.8. LNG Bunkering Supply Chain Development**

Challenges in LNG bunkering development were discussed and analysed through different perspectives. Outstanding concerns were defined, and how they are interlinked was highlighted. As the research objective questioned how to develop the LNG bunkering supply chain, challenges that stakeholders faced were identified, and the key factors were proposed to link different parties and bring solutions to these observations.

Collaboration is the core element for LNG marine fuel development. It is a relatively new business case that different stakeholders need to work together. Traditional LNG suppliers are not bunker suppliers. The same implies to another side of the chicken-egg paradox; traditional shipowners are not LNG marine fuel customers. As it is still observed in the industry today- the link between suppliers and shipowners is missing. Both sides are

not willing to take the risk for this high CAPEX investment. A strategic approach in terms of creating clusters in certain regions could link all stakeholders and facility infrastructure development, secure a certain level of demand and competitive prices. Public interest and opinion bring green fund initiatives as well as government subsidies. A network between stakeholders should be set to create a business case and feasibility for new investments. Agreement between parties, a joint venture for bunker barge, or partnership for technology development is necessary.

Transparency is required to cope with uncertainties in pricing. One of the biggest commercial challenges for LNG marine fuel development is 'price'. The price gap between MDO and LNG is an important criterion for investment decisions. However, despite the relatively stable LNG prices, shipowners are still hesitant to take firm decisions, as the LNG bunker price is still speculative and expensive on a small scale. LNG price is listed in TTF, Henry Hub, JKM, or NBP.

These are references to LNG marine fuel. However, logistics cost has not been set, and the profit margin of the supplier is not clear. It's interlinked between suppliers and shipowners. It needs to be negotiated between supplier and receiver sides, and the market needs to see more transparency. The price of LNG fuel is not clear, and it is questionable for ship-owners that they need to do their calculations based on the final price of LNG fuel that needs transparency. Flexibility is required to persuade shipowners into business as they avoid long-term commitments and take the opportunity of the market during up and downs times. Another reason is flexibility in the trading area. It is the case not only for tramp shipping, but also for some container vessels that may change their lines according to the market conditions or manage their fleet without considering

bunkering infrastructure or fuel availability.

Safety culture is critical for LNG marine fuel implementations and starts with training. Training needs were emphasised by all stakeholders. One of the crucial points is qualified crew to handle LNG. Even though shipowners make decisions to shift to LNG fuel today, there are not qualified crew to handle or institution to give proper training. Not only bunkering operations, hose connections, safety precautions, but also engine staff who need to know how to operate dual-fuelled engines are necessary to be adequately trained for this purpose. Shipowners and regulatory bodies are primarily responsible for crew training. Setting safety culture with training and on-board implementations are important to keep LNG's clear safety record and to prevent any resistance that could arise from the public.

Standardisation is still a crucial issue for LNG marine fuel development in some places. There are industrial standards and guidelines in place; however,

implementations are not standardized. Technical standards of classification societies are different, and still handling by expertise is on duty's decision in many places. Each port or country sets its own rules, and even within Europe, complying with these standards is not easy. Unlike conventional bunkers, LNG marine fuel itself is not standardised with specifications in terms of quality. It makes it difficult to set prices commercially and comes up with technical problems on the engine side. Therefore, technical service providers and regulatory bodies need to work together to improve standards clearly to make LNG fuel a more reliable option. Otherwise, the industry in the course of time will set its own standards in different regions, and LNG will not be a viable option for shipowners who trade worldwide at a large scale.

The rationale behind using LNG marine fuel concerns environmental considerations, air pollution, and global warming. IMO's new regulations are coming into force to achieve global CO<sub>2</sub>

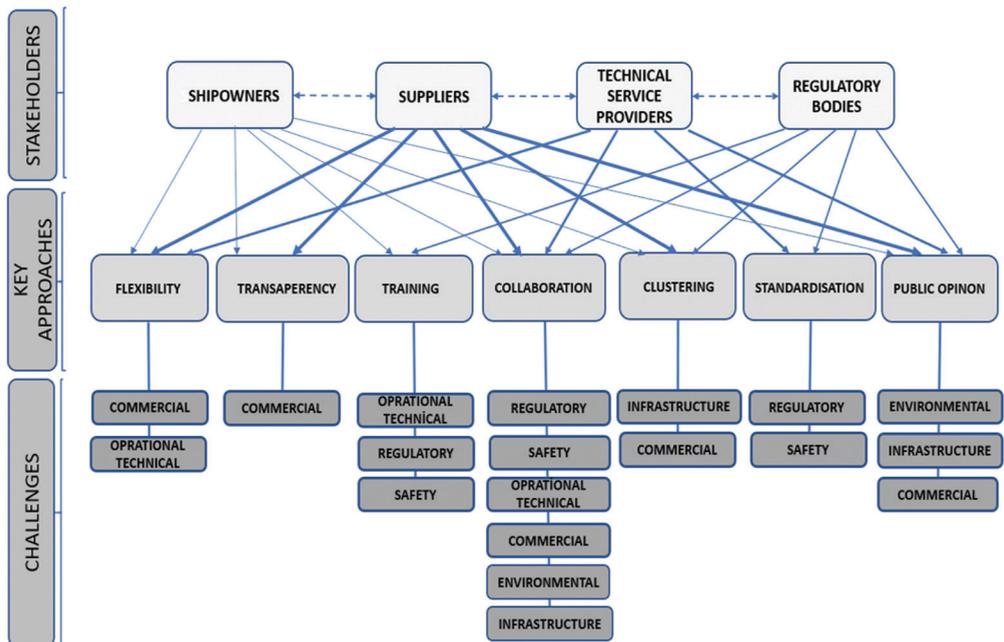


Figure 2. Key Approaches to Overcome the Challenges and Stakeholders' Relation

emission mitigation targets and to reduce air pollution that causes dramatic health problems. Therefore, while discussing alternative fuels or LNG marine fuel, 'public interest' needs to be in the centre rather than just 'economy'. Public opinion on green awareness is vital for environmental sustainability. Shipowners, suppliers, technical service providers, or regulatory bodies all have the responsibility to collaborate and achieve emission targets. Pollution causing health problems as well as public interest and public opinion should be a strong driver for this.

Figure 2 summarises the findings of the research. The fundamental approaches, which are critical in overcoming subject challenges, have been interlinked to related stakeholders, and it is conceptualised as a model.

## **6. Conclusion**

The study brings together the views of different stakeholders for LNG bunkering supply chain development, which comprises determining the challenges and proposing key approaches for LNG bunkering supply chain improvement. The outcome of the research reveals the main factors affecting LNG bunkering development and provides suggestions for how different stakeholders overcome the present challenges as a business case based on expert views and the related literature. Interviewees represent different continents such as America, Europe and the Far East, which are critical to gain holistic insight for LNG bunkering, as LNG has different dynamics at different continents in terms of supply, demand and pricing. LNG bunkering operations are very limited across the world and reaching expertise knowledge, and on-site experience is an important contribution of the research. The key approaches, which are revealed after the analysis, could be practical guidance to cope with the present difficulties for suppliers, shipowners

and the other industrial actors who are already in LNG bunkering business or for those willing to enter. The study could also be benefited by policymakers as it identifies the weak points in the regulatory framework and provides suggestions on how to improve them. The research is one of the few papers in this field in terms of methodology and the content. The study contributes to knowledge through semi-structured interviews which provide insight from experts and reflects different stakeholders' views in a holistic approach. It provides a base for future research in academia in this field.

IMO 2020 regulations force the industry to look for compliance strategies. LNG as a ship fuel has great advantages in terms of compliance with the new regulations and availability across the world compared to the other alternative fuels. On the other hand, there are some drawbacks that the industry needs to tackle. These are grouped under environmental, safety, operational, technical, regulatory framework and commercial considerations. LNG bunkering is relatively new for the shipping industry, but LNG as cargo has a history with very clean safety record. LNG industry applies the highest industrial standards, and it is reflected in the entire supply chain. Small/mid-scale LNG is not only an extended part of the LNG supply chain as it involves different stakeholders. Therefore, transferring this experience into small scale needs some adjustments in the operational, commercial or regulatory framework.

The research findings indicate that different stakeholders have different concerns according to their points of view: suppliers are not confident about demand, shipowners' biggest challenge is the lack of infrastructure, poor technical standardisation is a barrier for technical service providers, and regulatory bodies still need to work on improvement for worldwide implementations and take crew

training as an important issue. Integrating different views in a holistic approach reveals that there are other factors affecting LNG bunkering development. Shipowners out of gas transportation are not familiar with LNG as fuel and suppliers have no experience in LNG bunker delivery. The link between two stakeholders is missing, and it leads to some other challenges as highlighted above. The collaboration of stakeholders is a must to fight against the concerns, and it comes along with transparency, flexibility, and standardisation. Public interest is a strong argument to support initiatives. Developing clusters in some regions along with public opinion in green awareness brings green funds and substantial subsidies from authorities, which is what the industry needs to cover high investment costs.

The research has some limitations to be emphasized: Total twenty Interviews were evaluated, and all of them were conducted during and after the LNG bunkering summit. LNG bunkering is a relatively new subject in bunkering; therefore, historical data is very limited, and operational experience still is to be matured. Further researches should be done in facilitating LNG bunkering at port and risk assessment. How to optimise small/mid-scale LNG supply chain at the operational, tactical and strategic level, could be another research direction in order to contribute to the shipping industry as well as mitigating air pollution and global warming.

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