Common Guidelines for LNG Bunkering Operations at Spanish Ports

BOOK II - PROCEDURE GUIDE

EU Core LNGas hive Project (ET1)

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Core LNGas hive:

CLEAN POWER FOR TRANSPORT

The project is developing a safe and efficient, integrated logistics and supply chain for LNG in the transport industry (small scale and bunkering), particularly for maritime transport of the Iberian Peninsula.

ET 1 Study:

Technical, Safety & Environmental Specifications on LNG

Analyse operational procedures for LNG supply in different technologies, both in maritime and port services in order to reach a set of tested specifications.

Lead by:

Organismo Público Puertos del Estado (OPPE)
Dirección General de la Marina Mercante (DGMM)

Aim of the Common Guidelines:

This guidance document aims to assist the Spanish Port Authorities (PA) in the process of facilitating the safe and environmentally responsible supply of LNG as a marine fuel in their area of responsibility. The document aims to equip PAs with relevant information that delivers knowledge about the characteristics of LNG as a marine fuel product, equipment and supply methods, as well as potential risks, authorized areas and mitigation measures, the role and responsibilities of the stakeholders involved, and the training of the personnel involved in supply operations.

Use of Book II:

This book is oriented to call PA to action and assists PA in the implementation of the Common Guidelines in its port. It provides clear procedures PAs should follow when planning LNG bunkering operations to take place within the port, when stablishing the technical requirements to grant licenses and when managing the day-to-day supervision of the LNG bunkering at the port. This book content is also intended to align with Spanish Pot System governance and regulation.

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Common Guidelines for LNG Bunkering Operations at Spanish Ports

This Guide has been prepared within the framework of the CORE LNGas HIVE project with the aim of assisting the Spanish Port Authorities (PA) in the process of facilitating the safe, and environmentally responsible supply of LNG as marine fuel in their area of responsibility. The Guide aims to equip PAs with the relevant information that delivers knowledge about the characteristics of LNG as a marine fuel product, equipment and supply methods, as well as potential risks, authorized areas and mitigation measures, the role and responsibilities of the stakeholders involved, and the training of the personnel involved in supply operations.

This Guide does not intend to substitute nor override existing regulations, nor standards or industry guidelines and recommendations; instead, it aims to assist PAs on adopting the right references to establish the safety operational framework that best suits the port requirements while ensuring regulatory compliance.

Background

Maritime transport, like other sectors of the economy, must address the challenge of decarbonization and reduction of polluting gases. LNG provides a significant reduction in emissions when considered as an alternative marine fuel to oil derivatives. LNG will also allow for the partial or total incorporation of renewable gases: biogas or hydrogen derivatives. In this context, LNG is expected to gain share as a marine fuel in the coming years while new carbon-neutral fuel technologies are developed and matured. This guide will remain valid as long as the non-fossil LNG properties consumed onboard match with conventional natural gas. In order to promote LNG as a marine fuel, Directive 2014/94/EU established objectives for member countries to facilitate the supply of LNG in ports of the European core transport network (TEN-T) by 2025.

Ports have facilitated the safe bunkering of conventional marine fuels for many years by developing world-class safety procedures and standards. Due to its low ignition point and the cryogenic characteristics of the LNG as a fuel product, LNG bunkering requires planning, risk analysis and implementation of specific safety procedures in the port.

While this guide is solely focused on LNG bunkering, the methodologies developed by this guide would be a valid blueprint to consider when planning for the implementation and provision of new alternative marine fuels to come.

The role of the port

Efficient bunkering services, - offering a wide range of energy products -, improve the competitiveness of the port attracting traffic and increasing port services activity. Therefore, it is in the interest of the port to develop its bunkering service offering and infrastructure to support this activity. This guide will not address the commercial development of the bunker activity but rather focus on the safety and environmental technical aspects that relate to the landlord and regulator role of the port.

As port space landlords, PAs should determine the locations where bunkering operations can be performed and plan for future needs in bunkering services development. As regulators of the port activity, PAs should ensure the minimum safety and environmental procedures are defined and implemented by the corresponding stakeholders. Through the licensing and authorization process the port will ensure operators can apply all the necessary means and procedures required. It is the role of the port to monitor compliance with procedures and agreed regulations during regular port operations by all the stakeholders involved and to adapt its requirements to potential impact of changes affecting them. Safe and environmentally friendly LNG bunkering operations at port require the coordination of the two main players in operations, those being the receiving vessel and the bunkering supplier, as well as other players, namely the terminal where the operation takes place, and the PA shore and marine traffic control and emergency response personnel who participate in the operation. It is the role of the port to establish the framework to facilitate an efficient and safe coordination among all these stakeholders.

With the support of this Guide, PAs will be able to address the planning stage prior to the development of LNG bunkering activities in their ports, establishing the framework of minimum-safe conditions in the LNG supply. Later, in the authorization phases, PAs will be evaluating how operators comply with technical safety considerations to access the operation license and obtain supply authorization. Finally, during the management phase, PAs need to supervise the correct provision of the day-to-day services, and the incorporation of new operations in compliance with the established security and safety procedures.

It is the objective of this Guide to equip ports with the necessary knowledge to allow them to undertake the necessary actions and address properly all their competencies when it comes to facilitate the safe provision of LNG bunkering at their premises in compliance with their binding regulations.

Using the guide

This guide is structured in two separate and closely intertwined books:

❖ **BOOK. I TECHNICAL GUIDELINES to safe and environmentally friendly LNG bunkering**

This book is intended to provide knowledge and recommendations on all the different aspects of the LNG bunkering activity. After a general introduction to LNG as bunkering fuel, if follows with seven thematic chapters covering subjects such as: regulation, equipment, procedures, personnel, roles and responsibilities, risks assessment, etc. Each topic is presented as a unit of knowledge and is broken down into the most relevant aspects that the PA should know about, including recommendations when there are alternatives. References to other sources of regulations, standards and industry recommendations are also provided for the consideration of the PA.

❖ **BOOK. II PROCEDURE GUIDE for LNG Bunkering Operations at Spanish Ports**

This book is oriented to call PAs to action and assists them in the implementation of the Common Guidelines in their port. It provides clear procedures that PAs should follow when planning LNG bunkering operations to take place within their port, when establishing the technical requirements to grant licenses and when managing the day-to-day supervision of LNG bunkering at the port. This book content is also intended to align with the Spanish Port System governance and regulation.

To facilitate its usage, both books contain direct link references to chapters, sections or tables contained in the same book, the other book and in other external references. These references will be identified with [actions links] highlighted this way. Additionally, the following text color code is used throughout BOOK II: **Text in red, represents a call for attention to important information that needs to be addressed by the PA.** **Text in blue is used to indicate recommendations based on best practices on specific subjects.**

Ports Authorities already familiar with the LNG bunkering activity could use BOOK II as a reference to assure compliance with all port's obligations by comparing their current regulatory framework with the

Guide. Those ports approaching LNG bunkering for the first time are encouraged to use BOOK I first, at least those sections related to the expected service mode: truck to ship, ship to ship or pipe to ship.

Although the Guide deals mainly with guidance for PAs to comply with their competences, it is also considered a valuable source for future operators planning to offer LNG bunkering services in Spanish ports, ship owners or agents planning to use these services, terminal operators that will host such operations and regional/municipal safety agencies hosting the ports.

General adoption of the framework of this guide by the Spanish Port System will ease the complexity to both operator offering services in more than one port and vessels calling at Spanish ports. As the guide is based on EMSA, ISO and other widely adopted industry guidelines and standards, the Spanish ports would become aligned with the core of the European framework and requirements related to procedures for LNG bunkering.

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Glossary of Terms and Definitions

Accredited Body – In the context of LNG bunkering, an accredited body is recognized as having the competence and experience in carrying out the certification work against international standards of components, equipment, software, and systems forming part of the LNG bunkering system.

Boiling-Liquid-Expanding-Vapor Explosion (BLEVE) – A phenomenon resulting from LNG tank rupture, were LNG contained under pressure is rapidly depressurized, causing a nearly instantaneous transition from liquid to vapour. A BLEVE results in the release of a large aerosol followed by a fireball.

Boil-Off Gas (BOG): The Boil-Off Gas (BOG) is the continuously evaporated or boiled LNG vapor that causes the pressure inside the tank to rise due to heat entering the cryogenic tank during storage and transportation, which changes the quality of LNG over time. This BOG is generated primarily due to heat leakage from the atmosphere through tank insulation, loading, unloading and recirculation pipeline system insulation, and it is re-routed through a boil off gas refrigeration compressor and re-pressurized for designated service to the storage tank or other utility systems.

(LNG) Bunker Asset – describes the truck, ship (or barge) or fixed storage tank arrangement containing the LNG including appropriate LNG transfer system able to undertake bunkering operations to the receiving ship.

Bunkering: operation of transferring LNG fuel to a vessel (ISO 20519 definition)

Bunkering facility operator (BFO): the company responsible for the operation of the bunkering facility.

Bunkering System: is the interconnected system comprising of LNG bunkering equipment, components, piping, hose, and control software in the LNG bunkering asset and receiving vessel forming an integrated system for the purpose of safely transferring LNG.

Bunkering station: Fuel receiving stations, usually at an upper deck level, port and starboard, furnished with valves, elbows, pressure gauges, filters and relief valves required to manage the transfer of the product.

Bunkering terminal: fixed operation on or near shore that is not regulated as a vessel that can be used to provide LNG bunkers to a receiving vessel (ISO 20519 definition)

Certification – refers to the evaluation and confirmation of the LNG bunkering system and operations against recognized standards, mandatory rules and regulation. The evaluation will include the form factor, functionality and characteristics of an LNG component, equipment, software, system but also operational practices such as bunkering procedures, emergency response and the qualification of personnel.

Classification – describes the verification and validation activities relevant to the structural strength and integrity of the ship's hull and its appendages, and the reliability and function of the propulsion and steering systems, power generation and those other features and auxiliary systems which have been built into the ship to maintain essential services on board. Classification Societies achieve this objective through the development and application of their own Rules and by verifying compliance with international and/or national statutory regulations on behalf of Flag Administrations.

Classification Society: non-governmental organization that establishes and maintains technical standards for the construction and operation of vessels and offshore structures (ISO 20519 definition)

Controlled zones: areas extending from the bunkering manifolds on the LNG receiving vessel and the LNG supply source during LNG bunkering operations that have restrictions in place. These restrictions include limitation on personnel access, sources of ignition and unauthorized activities. The controlled zones are subdivided into hazardous zones, safety zones and the monitoring and security areas (ISO 20519 definition)

Dangerous goods: Dangerous goods or hazardous goods are solids, liquids, or gases that can harm people, other living organisms, property, or the environment.

Dry-disconnect/connect couplings – are specialized couplings, with self-sealing capability that allows for the quick and spill free, connection and disconnection of LNG hoses and piping between the LNG bunkering asset and the receiving vessel.

Emergency-release coupling (i.e. dry break-away couplings) – is a specially designed coupling that links the LNG bunkering asset and the receiving vessel's LNG transfer hose. It can disconnect automatically with minimal LNG release upon exceeding a pre-defined separation force. There are two valves at either end that close immediately upon separation, preventing LNG from leaking out of the separated transfer pipe/hose segments.

Emergency release system (ERS) – an integrated system designed to protect the LNG transfer system (e.g. piping attached to mechanical arms, hose supported by intermediate structure) in case of excessive movement, beyond its defined working envelope. The emergency release system works by automatically isolating and disconnecting either end of the LNG transfer system, allowing a receiving ship to safely separate from the bunkering asset. Also see ESD II emergency release functionality.

Emergency Shutdown System (ESD) – is an integrated system designed to minimize the consequences of different LNG emergency scenarios. This includes hazards emerging from upsets, failures of the LNG bunkering operation but also external hazards such as collisions, adjacent fire that pose safety consequences to the LNG bunkering. There are two types of ESD activation, ESD I results in the controlled stoppage and isolation of the LNG bunkering system. ESD II initiates the abrupt stoppage, isolation, and separation of the LNG bunkering system.

Flash Point – is the lowest temperature at which a liquid can generate vapour that in turn can form an ignitable mixture in air near the surface of the liquid. In general, the lower the flash point, the easier it will be to ignite the fluid. HFO has a flash point of 60C while LNG has a flash point of up to -188C.

Failure modes and Effects Analysis (FMEA) - is the process of breaking down and reviewing elementary (replaceable) parts forming a component, equipment to identify their potential failure modes including their root causes and consequent effects.

Gas: a fluid having a vapor pressure greater than 0.28 MPa at 37.8^{o} C.

Harbour Master: Official who is in charge of marine port traffic according to article 266 of Consolidated Legislation of Ports and Merchant Navy – RDL 2/2011

Hazard - is something that has the potential to cause harm to people, assets, and the environment. LNG bunkering hazards come from a variety of sources such as equipment failure, human error, etc.

Hazard Identification (HAZID) study - is a method for identifying relevant LNG hazards to prevent and reduce any adverse impact that could cause harm to personnel, including the damage or loss of asset and environment.

Hazard and Operability (HAZOP) study - is a systematic process of understanding the hazards in the LNG bunkering equipment, control software and systems to define and understand different vulnerability during operations.

Hazardous (Area) Zone - an area in which an explosive atmosphere may occur in quantities such as to require special precautions to protect the safety of personnel and asset. These special precautions refer to the requirements for the construction, installation and use of components and equipment described in BS EN 60079 -10-1.

Higher Flammable Limit (HFL) – defines the concentration of flammable gas/vapour in air above which there is excessive amount of the combined vapour/gas with air to sustain the combustion. In case of methane the HFL is about 15% volume in air.

Holding time: Time of the pressure increase in the inner tank measured from a starting pressure of 0 bar at the corresponding boiling point of liquefied natural gas (LNG) (−164° C) up to the maximum allowable working pressure (MAWP) of the inner tank.

Inerting – is the systematic process of replacing LNG, gas vapour during loaded condition but also displacing oxygen (air) during empty condition of LNG tanks, piping and equipment, using an inert fluid such as nitrogen (N2).

International Safety Management Code - An IMO code standard for the safe management and operation of ships, and for pollution prevention. Operators of ship's subject to the International Safety Management Code are required to effect a management system (ISM) that meets the code and have their compliance with the ISM audited, first by the Company (internal audit) and then each 2.5 to 3 years by the Flag State Maritime Administration to verify the fulfilment and effectiveness of their Safety Management System.

LNG (Liquefied Natural Gas) – methane gas stored in liquefied form at approximately -163C and atmospheric pressure conditions.

LNG Bunker Management Plan (LNGBMP) – IACS defines an LNG bunker management plan as an integrated document used by the bunker provider and receiving vessel to agree technically and commercially on methodology, flow rate, temperature, pressure of the delivery of LNG and receiving tank. This plan gathers all the information, certificates, procedures, and checklist(s) necessary for an effective and safe LNG bunkering operation.

LNG transfer system - as defined in ISO 20519 consists of all components and equipment between the bunkering manifold flange on the bunkering asset providing LNG fuel and the bunkering manifold flange on the receiving LNG fueled vessel. This will include but are not limited to; Ship to ship transfer arms, LNG articulated rigid piping and hoses, Emergency Release Coupling (ERC), insulating flanges and quick connect/disconnect couplings (QC/DC), bunkering control software, ESD Ship/Shore Link or Ship/Ship link used to connect the supplying and receiving ESD systems.

Lower Flammable Limit (LFL) – defines the concentration of flammable gas or vapour in air below which there is insufficient amount of the combined vapour and air to support and sustain combustion. In case of methane the LFL is about 4.5% volume in air.

Management system: set of procedures an organization needs to follow to meet its objectives (ISO 20519 definition)

Maneuvering: for the purpose of this guideline, a ship is said to be maneuvering when it is either:

-Making its final approach to another ship for the purpose of mooring alongside the other to perform a ship-to-ship bunkering operation; or

-Separating from another ship following an unmooring operation until both ships are safely clear of each other.

Member state authority: legal authority within a member state that has jurisdiction over maritime or port activities within that state (ISO 20519 definition)

Mobile facility: mobile facilities are trucks, rail car or other mobile device (including portable tanks) used to transfer LNG to a vessel (ISO 20519 definition)

Monitoring and security area: area around the bunkering facility and vessel where vessel traffic and other activities are monitored to mitigate harmful effects (ISO 20519 definition)

Permitting - is an official and documented process of formally providing consent to LNG bunker providers granting them the authorization to build, implement and operate the LNG bunkering within the port. This is achieved via the analysis and demonstration of compliance with regulations and standards relevant to the LNG permitting process.

Person In Charge (PIC): For each bunkering operation, a qualified person in charge (PIC) for the receiving vessel (RSO-PIC) and a person in charge for the LNG provider (BFO-PIC) shall be assigned. These people shall have no other duties during the bunkering operations that can interfere with them performing their duties as a person in charge including being able to activate the ESD immediately if an unsafe condition occurs (ISO 20519 – 6.5.2.1.)

Port Authority (PA): is the public body responsible for running and managing the state-owned ports under its operation. The PA reports to the Ministry of Development and is governed by Spanish Legislative Royal Decree 2/2011 of 5 September under which the recast text of the Spanish Law on State-Owned Ports and the Merchant Navy was passed.

Port service provider (PSP): Port service providers are operators of tugs, lighters, barges, line handling boats, pilotage services, as well as any other contractors/providers that use the port facilities, being previously licensed by the Port Authority.

Qualification – describes the attainment of an individual, in demonstrating their knowledge and experience in the correct and safe operation of LNG bunkering operations. Qualifications are achieved via the successful completion of educational and training programs relevant to LNG bunkering.

Receiving Ship Operator (RSO): the company responsible for the operation of the receiving ship, in particular during the bunkering operations.

Receiving vessel : ship to be bunkered

Recognized organization (RO): competent organization with delegated authority on behalf of an Administration to assist in the uniform and effective implementation of IMO Codes and Conventions (ISO 20519 definition)

Restrictions – describes the limitations in terms of the function, usability and capability of components, equipment, and systems relevant to LNG bunkering operations.

Risk – is the combination of the severity/ consequence of a given hazard including its probability of occurrence given its historical statistics.

Risk matrix (level of risk) - is a matrix that is used during LNG bunkering risk assessment to define the level of risk by considering the category of probability or likelihood against the category of consequence severity. This is a mechanism to increase visibility of risks in LNG bunkering and assist decision making in terms of changes and/or operational mitigations.

Safety Zone - area that is defined and enforced during LNG bunkering operations within which only essential personnel are allowed and potential ignition sources are controlled. The extent of the safety zone can be defined by the worst credible leakage analysis or alternatively via quantitative risk assessment.

Security Zone – closely follows the safety zone required during LNG Bunkering, for the purpose of establishing a wider perimeter to control access, road traffic and other port activities in the vicinity of the LNG bunkering operation.

Shipowner: A shipowner is the owner of a merchant vessel (commercial ship) and is involved in the shipping industry. In the commercial sense of the term, a shipowner is someone who equips and exploits a ship, usually for delivering cargo at a certain freight rate, either as a per freight rate (given price for the transport of a certain cargo between two given ports) or based on hire (a rate per day). Shipowners typically hire a licensed crew and captain rather than take charge of the vessel in person. Usually, the shipowner is organized through a company, but also people and investment funds can be ship owners. If owned by a ship company, the shipowner usually performs technical management of the vessel through the company, though this can also be outsourced or relayed onto the shipper through bareboat charter.

SIMOPS = Simultaneous Operations: Defined as two or more activities that occur at the same time, one of which involves a LNG Bunkering process, and the combination of which may lead to an increased safety risk. Parallel activities include, but are not limited to, disembarkation / boarding of passengers and / or crew, picking up passengers, vehicle loading / unloading, cargo handling, refueling or lubrication, cleaning / repair work etc. (ISO 20519 definition)

Technical Specification - refers to a set of documented requirements to be satisfied by the LNG bunkering system including its components, equipment, software, and safety provisions. ISO, API are technical standards that normally from the basis of technical specifications.

Technical standards: standards that prescribe requirements for one or more of the following: operations, equipment design/fabrications or testing methodology. Auditors cannot issue a certification or approval to a company that claims compliance with a Technical Standard unless that standard is incorporated into a recognized management system as a management objective (ISO 20519 definition)

Terminal Operator (TO/COS): the entity responsible for a physical part of the Port and for the conduct of an operation or range of operations that take place within in.

Transfer arm: articulated metal transfer system used for transferring LNG to the vessel being bunkered. It can be referred to as a “loading arm” or “unloading arm” (ISO 20519 definition)

Vapour Management System (VMS): It is the system via which the PSP and the RSO during bunkering operations should ensure that no LNG vapour (methane) will emit to the environment as a result of normal bunker transfer. A vapour management system should be fully integrated with the bunkering Operating Procedures to ensure that no vapour pressure throughout the LNG bunkering operation will exceed the relief valves maximum operating pressures resulting in over pressurization and relief. BOG generation is the most important aspect to be managed within a VMS.

Vessel: includes ships, barges (self-propelled or no propulsion) or boats of any size in domestic or international service. A bunkering vessel (BV) is a vessel used to transport LNG to a vessel using LNG as a fuel. A receiving vessel (RSO) is a vessel that uses LNG as a fuel and does not transport LNG as a cargo (ISO 20519 definition)

Zoning - in the context of LNG bunkering operations, zoning is essential to establishing areas of safe refuge from the accidental LNG release and its further consequences.

Acronyms

Abbreviation	Description
ADR	European Agreement Concerning the Transport of Dangerous Goods by Road
ALARP	As Low As Reasonably Practicable
BLEVE	BLEVE - Boiling liquid expanding vapour explosion
BFO	Bunkering Facility Organisation
BOG	Boil-Off Gas
EMSA	European Maritime Safety Agency
ERS	Emergency Release System
ERC	Emergency Release Coupling
ESD	Emergency Shut Down
FMEA	Failure Mode and Effects Analysis
FMECA	Failure Mode and Effects Consequence Analysis
FSRU	Floating Storage and Regasification Unit
HAZID	Hazard Identification Study
HAZOP	Hazard Operability Study
IACS	International Association of Classification Societies
IAPH	International Association of Harbours and Ports
IGC	International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (Gas Carrier Code)
IGF	International Code of Safety for ships using Gas or other low-flashpoint fuels
IR	Individual Risk
ISM	International Safety Management Code
ISPS	International Ship and Port Facilities Security
ISO	International Organisation for Standardisation
LBB	LNG Bunkering Barge
LBT	LNG Bunkering Truck
LBV	LNG Bunkering Vessel

Abbreviation	Description
LFL	Low Flammability Limit
LNG	Liquefied Natural Gas
LNG BMP	LNG Bunkering management plan
LNG BSS	LNG Bunkering Specification Sheet
LOC	Loss of Containment (of LNG)
LR	Lloyd's Register
LRV	LNG Receiving Vessel
LSIR	Location Specific Individual Risk
MTTS	Multi truck to ship
NECAs	Nitrogen Emission Control Areas
PA	Port Authority
PERC	Powered Emergency Release Coupling
PIC	Person In Charge
POAC	Person in Overall Advisory Control
PPE	Personal Protective Equipment
PSP	Port Service Provider
PTS	Pipeline to Ship (i.e. Fixed storage tank piping)
QCDC	Quick Connect-Disconnect Coupling
QRA	Quantitative Risk Assessment
QualRA	Qualitative Risk Assessment
RA	Risk Analysis
RAM	Risk Assessment Matrix
RO	Recognised Organisation
RPT	Rapid Phase Transition
RSO	Receiving Ship Operator
RV	Receiving Vessel
SECAs	Sulphur Emission Control Areas
SGMF	Society of Gas as Marine Fuel
SIGGTO	International Gas Tanker and Terminal Operators

Abbreviation	Description
SIMOPs	Simultaneous Operations
SOLAS	International Convention for the Safety of Life at Sea
STCW	International Convention on Standards of Training, Certification and Watchkeeping for Seafarers
STS	Ship to Ship
TO	Terminal Operator
TTS	Truck to Ship
UFL	Upper Flammability Limit
WPCI	World Ports Climate Initiative

BOOK II PROCEDURE GUIDE

1. INTRODUCTION

This guide will assist Port Authorities in preparing their ports to host safe LNG bunkering operations, having considered the particularities of LNG, assuring all binding regulations with procedures supported by industry guidelines and best practices recommendations. This guide is prepared for state-owned Spanish ports regulated by RD 2/2011 *"Royal Legislative Decree RDL 2/2011, of September 5, which approved the Revised Text of the Spanish Law on State-Owned Ports and the Merchant Marine (TRLPEMM due to its Spanish initials)".*

The guidelines herewith provided are intended to be of a practical nature, and as such it is presumed that the reader has knowledge of the terms and concepts related to safe LNG bunkering operations. Otherwise, it its recommended that BOOK I is read before reading BOOK II. Nevertheless, this guide will be referring each relevant section of BOOK I to refresh concepts when necessary.

As describe in [BOOK I] due to the special fuel characteristics of LNG, it is recommended in order to assure LNG operations are performed under equivalent safety conditions as those of conventional fuel products, that proper prior planning and preparation to operate is undertaken by all the stakeholders involved. While there is abundant regulation, standards and industry guidelines that focus on the fuel transfer process targeting the supplier and receiving vessel, this guide addresses the issue from the wider perspective of the Port Authority that will host LNG bunkering operations to receiving vessels from ships, truck or terminal facilities.

The role of Port Authorities in relation to LNG bunkering

The undertaking of industrial, commercial, or service activities in port are subject to the Spanish Law on State-owned Ports and Merchant Marine (TRLPEMM). PAs shall regulate the conditions for the provision of services at the port developing the regulation instruments and powers the law grants them. The following diagram from EMSA reflects graphically the role of Port Authorities in relation with LNG bunkering:

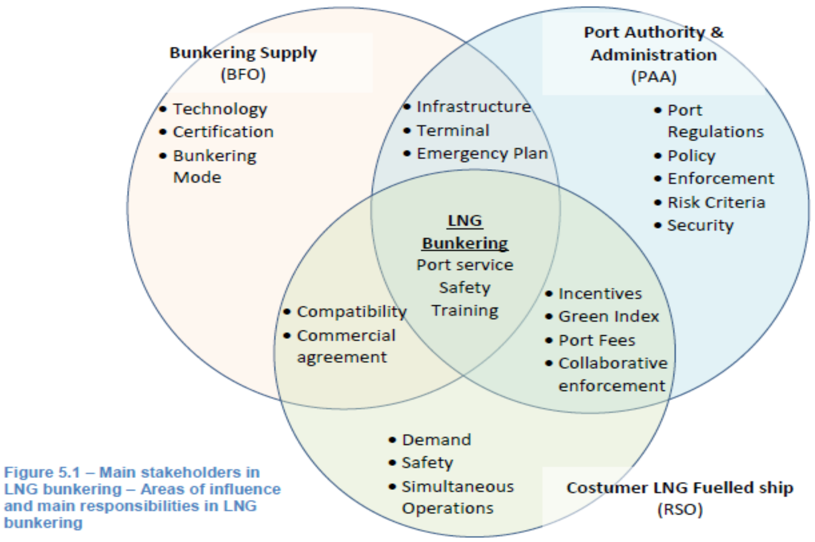

Figure 1.1 Schematics of areas of influence and main responsibilities on LNG bunkering. Source EMSA.

As shown on the diagram above, all parties interact bilaterally, and it is at the bunkering operation itself where all three coincide. Within the port sphere is the terminal who undertakes physical control of the space and control zones where the bunkering operation takes place, including potential simultaneous operations (SIMOPS) with the ship during the bunkering operation. [EMSA Guidance] on LNG Bunkering has a dedicated chapter for ports where responsibilities are detailed.

Summarizing, PAs competences fall under three categories:

1. **Develop a technical regulatory framework for LNG bunkering in the ports**

   - Establish the risk analysis techniques and risk assessment criteria to authorize LNG bunker operations. Approve the proposal of control zones, establish the marine exclusion zone and determine the operational envelop conditions. Declare authorized SIMOPS and conditions to approve others upon request.

   - Preselect port areas where bunkering is allowed or forbidden, integrating them with the port spatial planning.

   - Establish, when necessary, the port supported standards, procedures and checklists, equipment and personnel qualification.

   - Integrate bunker activities in the Port Emergency Response Plan.

2. **Establish the criteria for granting permits to LNG bunkering operators and authorize specific operations**

   - To comply with TRLPEMM, port service operators must hold a License to perform port services in a specific port. The License must be related to at least one specific operation. These guidelines refer to the technical, safety and environmental requirements that PAs can follow to authorize the specific operations.

   - LNG bunkering activities relate to specific operations needing specific assessments and evaluations (i.e., compatibility, specific risks or stakeholder's coordination). In this context, BFOs must prove compliance with LNG BSS for the specific operation and submit to the PA specific documentation proving safeness for such operation.

   - Due to the specifics of LNG bunkering, and in order to provide responsiveness and fulfill the needs from operators and the market itself within an adequate timeframe, these guidelines assume that multiple authorizations can be granted under the same License. In case a BFO holding a LNG bunkering License for a specific operation wants to operate LNG bunkering with different specifications (i.e. location, receiving vessel, means of bunkering, etc.) a new authorization under the same License should be granted.

3. **Overseeing the safe provision of the LNG bunkering service (Notification and change management systems).**

   - By adopting a Notification system, the BFO will communicate to the PA the intention to commence a specific bunkering operation. Throughout this process the PA will verify that the authorized conditions for the specific operation remain valid.
   - Relevant changes against authorized operations must be notified, reassessed and validated in order to get a new authorization.
   - On an ongoing basis, the PA should develop auditing techniques and other means to enforce the safe provision of LNG and compliance with binding technical, safety and environmental conditions for the specific operations.

Each of the previous three responsibilities will be developed in the next chapters of BOOK II providing guidance, information, recommendations and proposing the content of the documentation a PA needs to consider and elaborate.

A schematic of the proposed life cycle for LNG bunkering permitting is showed in the next figure.

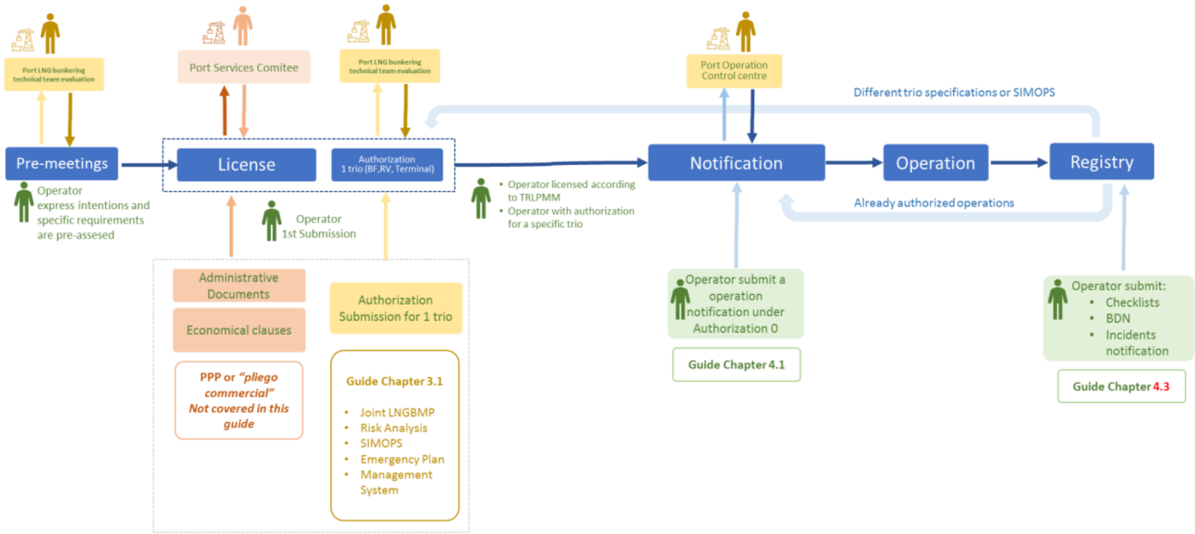

Figure 1.2 Schematics of LNG bunkering operations life cycle

Coping with the complexities of planning, licensing or overseeing LNG operations might in certain aspects exceed the internal PA capacities or technical skills. In such cases, PAs are encouraged to seek external assistance. These guidelines will identify in different sections when such external assistance is recommended due to the complexity of the matter.

The role of the Harbour Master in relation of LNG bunkering

According to art.266.4.b of the TRLEPMM, the establishment for reasons of maritime safety, of the criteria determining the maneuvers, including berthing, to be carried out by ships carrying dangerous goods or presenting dangerous conditions is a competence of the Harbour Master of the port. Additionally, the Harbour Master is responsible for the management of pilotage and towage terms and exemptions.

It is also recommended that the Harbour Master participate in the Risk Assessment procedures and in the approval of the operation, particularly in the approval of marine restrictions.

2. Planning: Developing the port LNG bunkering specification sheet

Spain regulates port activity in ports of general interest, through the Spanish Law on State owned Ports and Merchant Marine (TRLPEMM). Under such legal framework, PAs have the competence of regulating the safe and environmental provision of commercial and industrial services at their premises. In the case of LNG bunkering, due to the nature of the product it is necessary to establish a common framework to assure the supply to vessels is performed under a minimum set of regulated safety and environmental conditions while assuring the effective coordination of all the parties involved. The provisions of such framework will be made public to all stakeholders in a document to be drafted by the PA and will be referred to in this guide as the port **Bunkering Specification Sheet (LNG BSS).**

This guide has provided the knowledge and references to all key technical and safety aspects related to LNG bunkering in [BOOK I]. **This chapter will recommend the minimum content that PAs should consider including its own LNG BSS for the government and safe provision of LNG bunkering**.

The LNG BSS provides clarity and transparency to BFOs as it provides a set of minimum homogenous and transparent criterion for performing bunkering operations in the port and to evaluate the technical readiness of operators to access the license. BFOs operating PTS facilities under the Spanish Gas System Regulation could request additional provisions to their receiving vessels to comply with the mentioned regulation

The recommended chapters to include in the port LNG BSS are:

2.1. Regulatory Framework [B1 C4]

The specific context of LNG as fuel regulations indicates that the PA will have the overall competence for the good governance and the safety framework for LNG bunker operations in the port, ensuring the adequate integration of different LNG bunkering standards within port local regulations. **Within LNG BSS, the PA should declare which regulations apply [B1 C4] and what the chosen governance models are, considering:**

- Imperative to follow:
  - International Regulatory framework (IGF and IGC Code, EU Regulations and Directive)
  - Both ship-side and shore-side regulatory context.
- Particular attention to be given to EU Directives as their transposition into national law leads to different implementation activities between EU Member States (SEVESO, EIA Directive, REGULATION (EU) 2017/352, etc.).
- Develop adequate Port Regulations / byelaws, inclusive of LNG bunkering.
- Refer to Standards in regulations to allow legally binding reference for Operators to follow. Standards are not mandatory instruments unless they are included / indicated in mandatory instruments. As minimum, this guide recommends adopting as mandatory the ISO 20519.
- Ensure adequate level of information to all stakeholders on the applicable regulatory framework to LNG Bunkering.
- Ensure that all Competent Authorities in LNG bunkering are involved and that no conflicting requirements exist.

2.2. License and authorisation system

Under Spanish regulation, port service operators need to be granted a License to operate each service in each port. These licenses are regulated by the law itself and the “Individual Specification”. Ports would normally prepare separate licenses for conventional and LNG bunkering and even specific versions for STS, TTS and PTS supply/transfer modes due to the differences among the services. The Licenses are drawn up by each PA, which are competent to stipulate the administrative and technical conditions to access and provide the service that it considers most appropriate under the above mentioned TRLPEMM regulation. Licenses are approved by the PA, although in the case of *Servicios Portuarios,* a positive feedback would be required from the Maritime Authority (Merchant Navy) and the Government Agency Puertos del Estado. To speed up the approval and implementation of these Licenses, the State Ports might provide a unified reference model of basic specifications, adaptable by each PA.

According to TRLPEMM the minimal content of a license must be:

1. **Access to the service (Not discussed in this Guide)**

   a) Identification of the natural or legal person holding the license and the headquarters of the company.

   b) Type of license granted, general or specific, and the object of the same.

   c) Geographical area to which the service is provided.

   d) Public Service Obligations that apply.

2. **Conditions and quality of the service**

   e) Minimum material means

   f) Minimum human resources and their qualification.

   g) Safety requirements for the provision of the service.

   h) Environmental protection obligations.

   i) Conditions for the provision of the service and, where appropriate, the facilities and equipment associated with it, including minimum levels of performance and service quality.

3. **Economical and administrative clauses (Not discussed in this Guide)**

   j) Tariff structure, maximum tariffs and review criteria, if applicable.) Period of validity...

   k) Guaranties.

   l) Port dues.

According to the previous described structure, a License submission will contain:

- **Folder A (not discussed in this guideline)**: covering points 1 (Access to the service) and 3 (Economical and administrative clauses).
- **Folder B**: collecting all technical documentation to be submitted for each operation characterized by a trio (receiving vessel, terminal and supply means) that BFOs want to perform, covering point 2 (from f to i).

LNG bunkering operations safety and environmental assessment should be customized for the BFO, RSO and TO specific conditions, not only because inherent risks and equipment compatibility may vary if any of these parties change, but also to assure the three parties share procedures to act in a coordinated way. For this reasons, as it is mentioned in Chapter 1, **PAs should develop a procedure to address the evaluation of the technical conditions of the license (see *Point 2 Conditions and quality of the service*) through *authorizations*** in order to swiftly respond to concrete technical and operational needs from operators, in the frame of their competencies.

Bunkering Operators could not start an operation without the corresponding authorization, although a license has been awarded.

An authorization as it is described in this guideline is **a document provided by a PA to LNG bunkering license holders authorizing the supply to a specific receiving vessel in a specific location with specific equipment**.

An authorization submission will include:

- **all the documentation described in section "Documental Folders"** [C 3.1]: joint bunkering management plan, RA collection, SIMOPS, emergency plans and management systems for the specific RV, BFO and Terminal.

- **a synthesis of the main conditions, operational envelopes and particularities that define the operation**.

To provide responsiveness, once the license has been granted, a procedure should be implemented to grant new authorizations, avoiding having to run the whole licensing process again (EMSA good practices recommendation). For this reason, it is recommended that the PA constitute a specific working group in charge of reviewing authorizations' submissions (during license granting and after, and considering other relevant stakeholder's considerations) and to participate in RA meetings.

It is recommended that Authorizations expire after a 3 year period.

Despite holding a valid license and the associated authorization, operators should still notify each operation in advance to the corresponding PA operating office that will verify the operational conditions are met. A proposal on a notification system is detailed in [C 4.1].

2.3. Personnel involved in LNG Bunkering [B1 C7]

At least the following people shall be involved in the bunkering operation and shall be responsible for the operation and its safety:

- **Operation responsible (BFO-PIC/ROS):** should be designated by the Bunkering Operator and its main responsibility is to verify that the bunkering operation is carried out correctly and safely. Bunkering ROS shall be focused exclusively on bunkering operations.

  A list of minimum responsibilities for this role are collected in [B1 C 7.2.1].

  For TTS supply transfer mode, it is recommended to appoint a specific person with the adequate qualification and training, apart from the truck driver.

  For STS transfer mode, the role could be undertaken by the Master of the bunkering vessel or any official on board with required qualification and training.

  For PTS transfer mode, the role could be undertaken by the Loading Master of the supply terminal.

- **Receiving ship operator PIC (RSO-PIC):** could be the Master or a representative **and** is the main person responsible of the operation on the receiving side and will retain control over his vessel throughout the whole bunkering operation, with right to stop it whenever conditions deviate from those planned and agreed.

  A list of minimum responsibilities for this role are collected in [B1 C 7.2.2].

  The RSO PIC shall be focused exclusively on monitoring the operation and shall not attend to other simultaneous operation in progress.

  Although it is recommended that this role is taken by the Master of the ship, a representative should be appointed in order to assist pre meetings and leverage local knowledge (i.e. Ship's Company representative Inspectors).

- **Bunkering operator hose watcher (BFO-HW):** should be designated by the Bunkering Operator to be in charge of the transfer operations on the bunkering side, their main responsibilities being:

  - Checking the tightness of all equipment involved in the product transfer.
  - Making the connections required and begin the operation when ROS gives the order.
  - Monitoring bunkering parameters on the bunkering side.
  - Management of safety venting in emergency situations, always by coordination with the PIC.
  - Emergency communication.
  - Management of inerting process after bunkering.

  In TTS transfer mode, the bunkering operator could be the driver of the tank truck.

  In STS and PTS transfer mode, the role may be carried out by the BFO-PIC but, it is recommended to appoint a delegate officer to ensure that operational tasks do not cause interference with any activity that needs to coordinate between three parties.

- **Receiving vessel manifold watcher (RSO-HW):** should be designated by Receiving Vessel Operator to oversee the transfer operations in the receiving side, their main responsibilities being:

  - Checking the tightness of all equipment involved in the product transfer.
  - Operating the valves to allow the product transfer.
  - Connections in the vapour phase (if applied).
  - Monitoring bunkering parameters in the destination tank.
  - Monitoring filling and overflow in the destination tank.
  - Management of safety venting in emergency situations, always by coordination with the PIC.
  - Emergency communication.
  - Management of the gas phase contained in the ship's system.

- **Terminal representative (TO/COS):** should be designated by the terminal or in case of a public wharf or anchor, by the PA.

  - Before bunkering, the TO/COS must validate the risk analysis performed by the BFO and confirm that they are in accordance with terminal characteristics and normal operation,
  - Is responsible for establishing coordination between the bunkering activity and any other activity that may be performed in and outside the terminal/anchorage area that could have an impact on the bunkering operation. This role will be key in case of SIMOPS or TTS supply where coordination with shore-side is especially important.
  - During bunkering, communicate any exceptional situation that modify the accepted bunkering parameters or requires stopping the bunkering operation,
  - Is responsible for the activation of the terminal's emergency plans and coordination with external services such as fire brigades.

- **SIMOPS Supervisor (Optional):** EMSA guidelines recommends that a specific person is appointed as in charge of the coordination of SIMOPS to ensure adequate overview, communications, and alarm dissemination through all the involved stakeholders in the operation. This will allow either BFO-PIC or RSO PIC to be released from the responsibilities of SIMOPS overview and coordination. The SIMOPS supervisor would be in charge of communications with all operators involved in SIMOPS and alarm dissemination.

2.3.1. Qualification and training

All the personnel assigned to perform the activity shall have the technical skills and sufficient training to perform each of the tasks entrusted to them in the provision of the activity and in the emergency phase. Specifically, in the case of STS transfer the Master, Engineer Officers, and all personnel on board a LBV or LBB must have completed basic or advanced training in accordance with the provisions of STCW Code A-V/1-2-3 and licensed accordingly.

According to international and national standards, the required qualification and training for each role should be, at least:

- **Operation responsible (BFO PIC/ROS)**:

  In all cases should speak English fluently and understand marine equipment terms and vocabulary, having in mind he/she must sign the LNG bunkering check lists as representative of the BFO and understand its terms and implications.

  STS mode

  - STCW V/1-2 “Advanced Training for Liquefied Gas Tanker Cargo Operations” (IGC code).

  TTS mode

  - Future certification derived from INCUAL’s competence framework UI_7019_3 “Supervisar operaciones de suministro de GNL desde cisternas o contenedores a buques”. Until framework approval, the BFO company could sign a responsible declaration stating the personnel capacitation according to their experience in LNG bunkering.
  - It could be recommended to include the Sedigas certification “*Técnicos de Plantas Satélite de GNL Alcance Tipo* C” for expanding the knowledge about tank truck equipment, but this is not a bunkering specific certification.

  PTS mode

  - Future certification derived from INCUAL’s competence framework “Supervisar operaciones de suministro de GNL desde instalaciones fijas a buques”. Until framework approval, the BFO company could sign a responsible declaration stating the personnel capacitation according to their experience in LNG bunkering.

- **Bunkering operator hose watcher (BFO-HW):**

  STS mode

  - SCTW V/1-2 “Advanced Training for Liquefied Gas Tanker Cargo Operations” (IGC code).
  - STCW Advanced Training recommended for Personnel Categories A, B, C, D, E, F, G, H and any Crew member with responsibilities in Emergency Response.

  TTS mode (Truck Driver)

  - Sedigas certification “Técnicos de Plantas Satélite de GNL Alcance Tipo C”.
  - ADR qualification.

  PTS mode

  - Sedigas certification “Técnicos de Plantas Satélite de GNL Alcance Tipo A y B”.

Terminal representative (TO/COS)

- Shall be accredited at least as a Terminal Dock Operator in compliance with Royal Decree 145/89.

- **Receiving Ship Operator**

  - PIC of the receiving vessel (BFO-PIC) and hose watcher (BFO-HW) shall be qualified under "V/3 Advanced training on ships subject to IGF code".
  - Whole ship crew shall be qualified under "V/3 Basic training on ships subject to IGF code".

2.4. LNG Bunkering components and procedures [B1 C2-C3]

A joint LNG bunker management plan should be established for the involved parties (Receiving vessel, Bunkering Operator and Terminal/Port) to agree technically and commercially on procedure, safety, emergency response and other bunkering factors. This plan gathers all the information, certificates, procedures, and checklist(s) necessary for an effective and safe LNG Bunkering operation. The detailed content of the LNGBMP has been collected in [C 3.1.1].

For LNG bunkering components and procedures, PAs require LNGBMPs of the bunkering operators as a main document to evaluate:

1. **Compliance of equipment** employed in the bunkering operation with international standards or accreditation bodies. A detailed list of minimal components to check has been provided in [Annex 1.1.]

    - **Receiving vessel:** components approvals must be done according to IGF code.

    - **Bunkering Vessel**: should comply with the IGC code and accepted by the Flag of Registry and Port State.

    - **Truck:**
        - To be certified against ADR code and equipped with the equipment required by the code.
        - LNG tanks to be certified against ISO 1469-3 and ISO 2008-1.
        - LNG fuel and transfer systems (i.e. Valves, pressure regulators, LNG piping, fire detector, etc.) to be certified against ISO/DIS 12614-13.

    - **LNG Storage Tank:**
        - LNG pressure tanks and components to be certified against European Directive 2014/68.
        - LNG flat bottom storage tank and components to be certified against API 625/620 or NFPA 59A.

    - **LNG Bunkering transfer systems:** All the components of the transfer system shall be fabricated to meet the IGF/IGC codes as applicable, and the standards listed below:

        - Hoses : EN 1472-2 or EN 12434 or BS 4089
        - LNG dry connect, disconnect couplings: ISO 21593
        - Manifold flange: EN 1473-3/ISO 16904
        - Swivel joints: EN 1473-3/ISO 16904
        - Flanges: EN 1473-3/ASME B16.5
        - Bearings: EN 1473-3/ISO 16904
        - Breakaway coupling: EN 1473-3/ ISO 16904
        - Transfer arms: EN 1473-3/ISO 16904.

        - Bunkering operator should prove that all LNG transfer system are going to be adequately supported to operate without exceeding the load or bending limits established by the equipment manufactures and if needed they will provide the necessary support in conformity with ISO 16904 or EN 1474-3.
        - An insulation flange built to meet applicable requirements of the ISGOTT Safety Guide 5th Edition shall be provided in each transfer arm or hose. In case of TTS supply, the vehicle shall be grounded to an earthing point at the quay in conformity with national electrical codes.
        - Additionally, according to ISO 20519 the Bunkering Operator shall conduct or have a transfer system design analysis conducted by a competent organization to confirm and document the functionality of the system, the operating parameters for which the transfer

system is designed to operate and that generated loads or stresses in the transfer system do not exceed maximum allowable stress stated in EN-1474/ISO16904.

- **LNG Bunkering safety systems:**
  - All LNG transfer systems shall be fitted with an emergency release system (ERS) and connected to an emergency shutdown system (ESD). In the event that Trucks are not fitted with an ESD, the functionality of the ESD in way of monitoring, detecting leakages and initiating safe shutdown actions should be considered in the risk assessments (HAZID/HAZOPs) and reflected in the Emergency Response Procedure.
  - ESD and ERS link should be designed according to chapter 5.4 of ISO 20519 and applicable class rules.
  - The delivery facility and receiving vessels shall be fitted with an ESD link to ensure coordinated operation of both systems.
  - Other safety systems should be covered by applicable design code or class rules (ADR, IGF, IGC, etc.).

- **Communication system:**
  - Compliance with ATEX for the system operated in Hazardous Zone.
  - Bunkering operator must have spare equipment available.
  - Equipment for non-verbal communication should be robust and reliable.

- **Personal protective equipment and Fire protection:**
  - Personal protective equipment (PPE) shall be duplicated, have CE marking and be in in good working conditions.
  - Fire protection equipment required for TTS operation shall follow the provisions of the ADR code.
  - Fire protection equipment required for STS operation shall follow the provisions of the IGC code.
  - Fire protection equipment required Receiving Vessel shall follow the provisions of the IGF code.

The BFO should include a detailed maintenance plan with all the certification from Original Equipment Manufacturer (OEM) and a record of up to date maintenance of the equipment.

PA can include additional equipment requirements in the LNG BSS, to increase safety, quality or environmental performance.

PA can include a revision procedure in the LNG BSS, to confirm regularly that certification is in place.

2. Bunkering operator procedures and receiving vessel compatibility with bunkering system.

- **Compatibility assessment and bunkering procedures:** should be agreed between bunkering facility and receiving vessels, documenting their compatibility to perform bunkering operations jointly. An indication of the minimal content required for this compatibility assessment is detailed in [C 3.1.1]. and a detailed list of all relevance documents required to evaluate BFO vs RV compatibility (Equipment and procedures) has been collected in [Annex 1.2]. Additional consideration could be required when the supply is going to be performed on a Spanish national gas system LNG terminal.
  The bunkering procedures should detail all the actions and mitigation measures derived from the RA provided by the BFO.

A **Mooring plan** has to be established by the Bunkering Operator engaged in STS operations as described in [SGMF Safety Guidelines 6.2.5.6].

- **Communication** between the Bunkering Operator, Receiving Vessel and Terminal shall be maintained prior, during and after the bunkering operations. Communication procedures are to be described and documented by the Bunkering Operator. There should always be at least two reliable and independent means of communication available during bunkering operations. If communication fail, all bunkering operations should be suspended immediately. Signs for non-verbal communication are to be agreed before operations begin.

- **Operational checklists** should be implemented. The most recommended and commonly used around the globe are [IAPH checklists]. PAs should adopt these checklists as standard making it mandatory. In case other checklists or ways to manage all operations is proposed by any operator, a guide to evaluate alignment and equivalency with international standards and industry good practices is provided in [B1 C3.4].

- **Boil-off gas (BOG) handling procedures:** Bunkering Operators are to implement and identify an adequate set of measures to mitigate and prevent methane emissions. The avoidance of methane release to the atmosphere should be expressed by Bunkering Operators as an objective in a relevant Management System. Moreover, IGF code requires that the bunkering systems are arranged to not discharge any gas during filling of storage tanks.
  Venting to the atmosphere, either resulting from automated or manual action, through pressure relief valves (PRV) actuation, or through any other possible outlet from the LNG storage or bunkering system, should be only possible in case of emergency for safety reasons. An emergency venting of LNG vapours should be reported, quantified, and the reasons leading to the emergency venting to occur, understood and subject to analysis, sending a report to the PA.
  For bunkering of ships with atmospheric tanks (IMO type A, B or Membrane), a vapour return line should always be provided; this is not mandatory for type C tanks, however, bunkering operators should demonstrate that the Receiving Vessel can cope with pressure increase if the vapour line is not going to be provided. According to the EMSA, the purging operations of the remaining LNG must be carried out by dilution with nitrogen and in a way that no methane release occurs.

- **Non-Bunkering periods and movements inside the port**

  - Bunkering operators providing STS supply not engaged in bunkering operations should declare if they are going to remain in the port (docked or anchored), and provide the port with documentation that demonstrates the area chosen is safe and does not originate any unacceptable risk. The PA should grant or require a berth for LBV or LBB in their port which is provided with appropriate firefighting means for a LNG vessel and appropriate access control to the berth to avoid access to non-authorized persons, as the ISPS requires.
  - Bunkering operators providing TTS supply must use predetermined safe routes and parking areas (if provided). Should there be alternative safe routes and movements, these should be carried out in a sequence that avoids multiple suppliers' presence in agreed routes. Also, operators must declare the maximum holding time that trucks are designed to not venting.
  - At port, BFOs must design its operations to avoid any methane release to the atmosphere, special considerations have to be made when the bunkering means doesn't count with BOG management equipment.

The PA can include additional procedure requirements in the LNG BSS, in order to increase safety, quality or environmental performance.

2.5. Risk Assessment [B1 C5]

Risk assessments (RA) are required to evaluate the required control zones, safe operational envelopes, mitigation measures, emergency plans and SIMOPS suitability for a safe LNG bunkering operation.

ISO 20519 and ISO/TS 18863 makes RA mandatory for LNG bunkering services, and RAs can be conducted by a range of available techniques as detailed in [B1 C5].

The evaluation of risks for an LNG bunkering operation project is likely to be the most relevant document to be referred to, not only for permitting, but especially in the initial stages of concept or project development as an important tool to reassess the concept or project itself.

Risk Assessment studies are usually conducted by BFOs and can result in complex reports. PAs should have in place approval processes well mapped and structured for approval of Risk Assessments which are delivered to satisfy PA/competent authorities' requirements for LNG bunkering permitting location, licensing, and operation. **It is recommended that PAs hire technical experts to assist in the approval processes.**

Independency and transparency in Risk Assessment studies should be ensured throughout the whole process and can be achieved by:

- Requiring Risk Assessment studies to be developed by independent professionals in the field of LNG Risk & Safety, with recognized and demonstrable experience.

- Using Risk Criteria which has been taken either from existing legislative framework at national level or, alternatively, which has been imported from an existing published guidance, other country national risk criteria, industry guidance or standard (such as [EMSA guide Table 8.7], taken from ISO/TS 18683) .

- Ensuring that all assumptions and limitations are well addressed in the risk assessment report.

Assessment of risk will be made either following a qualitative approach (QualRA) using Hazid and Hazop analysis or quantitative (QRA) approach. In both cases, there are elements that can be considered fundamental drivers for an adequate feasibility evaluation derived from a risk assessment:

- Adequate representation of the LNG bunkering facility and operation in the risk assessment.
- HAZID team composition (experience, proven competency, number of participants).
- Number of different risk case scenarios considered (including the complete scope of operations).

Prior to license submission, it is highly recommended that PAs participate in RA preliminary meetings and workshops, to provide inputs in advance and help to define the scope of the analysis (if a QRA is needed this includes risk acceptance criteria, etc.). The next figure from EMSA guidelines provides a recommendation illustrating a general RA process flow:

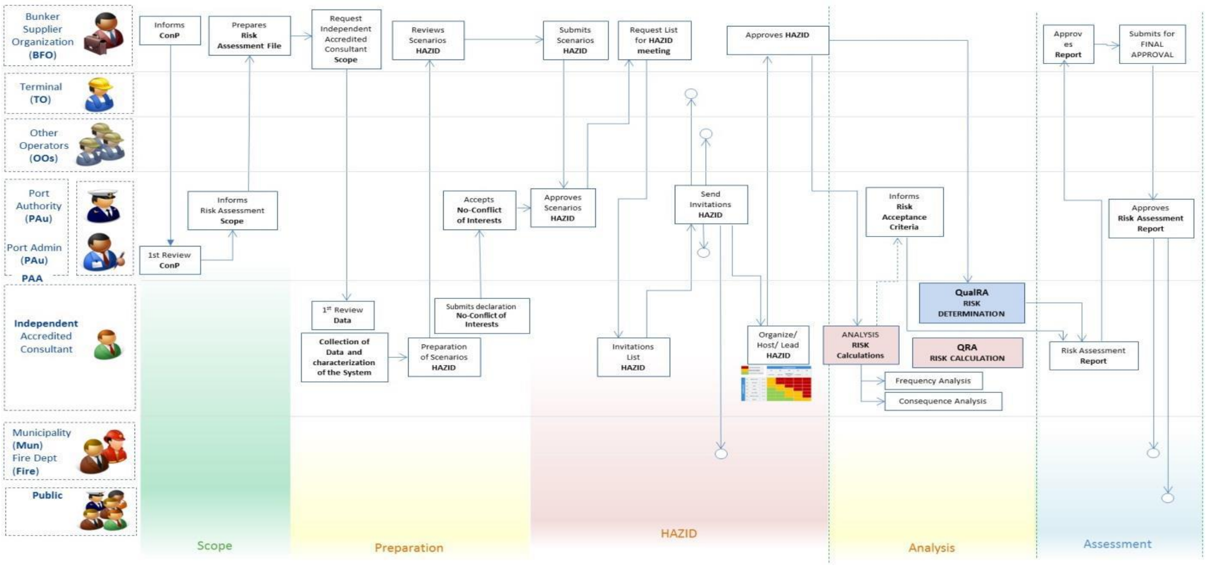

Figure 2.1 EMSA flow diagram for Risk analysis of bunkering operations

A PA can declare in the LNG BSS which RA techniques are mandated/recommended, being of particular importance to also declare the conditions under which a qualitative risk assessment (QualRA (HAZID+HAZOP)) is applicable and considered sufficient, or otherwise, a quantitative risk assessment (QRA) is required. Nevertheless, this declaration will act as a guide to bunkering operators as final decision should be taken by the PA on a project-basis having considered local factors, national regulations and previous knowledge.

According to EMSA guide, Quantitative Risk Assessment (QRA) is recommended when:

- Bunkering is not of a standard type (PTS, TTS or STS, in simple standard configuration, as defined in ISO/TS 18683);
- Design, arrangements and operations differ from the guidance given in ISO/TS 18683 or IACS Rec.142;
- Simultaneous Operations (SIMOPS) are planned to take place along with LNG bunkering in the Hazardous Zone.
- Automation elements are introduced to significantly reduce human intervention in operations (linked to system analysis).
- A reduction in a Safety Zone is intended, on the basis of consequence/ probabilistic data for the specific LNG bunkering location.
- Whenever a numerical calculation of Risk is required for verification of any given Risk Criteria.

An extended list of possible cases where the minimum QualRA prescribed in ISO/TS 18683 may not be enough for risk evaluation. The design of adequate risk mitigation measures is provided in [EMSA guide Table 8.9]. Additional information and considerations about the applicability of the different RA techniques to LNG bunkering has been collected in [B1 C5].

In the case of TTS licensing, the Bunkering Operator should also identify the hazards associated with Transportation within the port road system, addressing as a minimum:

- The safe road transportation of LNG within the specific Port's road access system.
- The number of LBTs required to complete specific TTS operations and the safe available parking facilities at the proposed quay where TTS will take place.
- That the potential truck operations impact to Simultaneous Operations (SIMOPS) has been addressed.

- Any issues of LBT traffic risks impacting outside the PAs boundary and communicate these to Competent Authorities for their review and approval.
- Appropriate emergency response procedures and communicate these to PAs for plans to be implemented involving any external emergency support (fire brigade, mobile cranes etc.)
- Ensure that the route of the trucks inside the port shall be decided in compliance with the road traffic rules established by the PA.

In case of Bunkering Operators employing novel, tailor-made or non-standard components in bunkering operations, a FMECA should be required to identify possible failures that could result in unacceptable levels of risks.

An agreed risk acceptance criterion for QualRAs and QRAs is required: There will only be a "Risk Assessment" if agreed Risk Criteria is available and that allows its use to evaluate calculated risk figures. **ISO/TS 18863 recommends a risk matrix table as showed below, included in Annex A of the standard, highlighting the proposed risk criteria for QualRA analysis.**

Consequence					Increasing probability			
Severity rating	**People**	**Assets**	**Environ-ment**	**Reputation**	**A**	**B**	**C**	**D**
					Has occurred in E&P industry	Has occurred in operating company	Occurred several times a year in operating company	Occurred several times a year in location
0	Zero injury	Zero damage	Zero effect	Zero impact				
1	Slight injury	Slight damage	Slight effect	Slight impact	**Manage for continued improvement**			
2	Minor injury	Minor damage	Minor effect	Limited impact				
3	Major injury	Local damage	Local effect	Considerable impact				
4	Single fatality	Major damage	Major effect	Major national impact	**Incorporate risk-reducing measures**		**Fail to meet screening criteria**	
5	Multiple fatalities	Extensive damage	Massive effect	Major international impact				

Figure 2.2 ISO/TS 18683 Risk proposed criteria for deterministic approaches

The risk analysis shall primarily be carried out with respect to consequences for people, but the PA can require that risk to assets, environment and reputation shall also be addressed.

Whenever a QRA is required, a numeric threshold criterion using Individual Risk (IR) is recommended by ISO/TS 18683:

Figure 2.3 ISO/TS 18683 Risk proposed criteria for numeric approaches

	Acceptance criteria	Comment
Individual risk 1st party personnel	AIR < 10^{-5}	Applies to crew and bunkering personnel
Individual risk 2nd party personnel	AIR < $5 \cdot 10^{-6}$	Port personnel
Individual risk 3rd party personnel	AIR < 10^{-6}	General public without involvement in the activity

In the absence of relevant directly applicable risk acceptance criteria, the BFO, RV o Port Authority may propose relevant risk criteria to be adopted. As a good practice approach, where better procedure is not available, the risk criteria should be subject to approval by the Port Authority. In approving the risk criteria, Port Authority should liaise in close cooperation with other relevant competent authorities (i.e. Harbour Master) involved in prevention of major accidents, or with responsibilities on civil and port protection.

It is possible, and recommended, that PAs get expert professional advice on the definition of risk acceptance criteria.

It is recommended that a transparent and homogenous general risk criterion is adopted, or that the criteria is agreed on a project-basis.

2.6. Control Zones [B1 C5.4]

Determination of Control Zones may be port-specific, ship-specific, berth-specific, involving different conditioning factors, of technical or operational nature. Several factors are determinant to the size and shape of the different Control Zones. Examples of such factors will be the bunkering arrangement, weather condition, bunkering parameters or potential SIMOPs considered.

PAs can apply conservative zoning derived from their own HAZID studies although EMSA recommends these to be proposed by operators and evaluated and approved by PAs.

Evaluation of control zones should be done by BFOs along with risk assessments (RA) and approval of Hazardous and Safety zones should be done by the PA during evaluation submission (It is recommended to hire expert technical assistance).

A set of recommendations for verifying Bunkering Operator safety zones calculations has been collected in [C 3.2.3]. Recommended roles in Risk Analysis should be:

Table 2.1 EMSA Adaptation of recommended roles in Risk Analysis

	Calculate/Determine	Plan	Approve	Implement	Control
Hazardous Zone	**BFO/RSO**	**N/A**	**PA for the bunkering interface** (Hazardous Zones on the ship side approved as per Ship Certification/Flag approval)	**RSO/BFO**	**BFO/PA**
Safety Zone	**BFO/RSO**	**BFO/PA**	**PA**	**BFO,** with PAA support	**BFO/PA**
Security Zone	**BFO/PA**	**BFO/PA**	**BFO/PA** (internal approval procedure)	**BFO/PA**	**BFO/PA**

2.6.1. Hazardous Zones [B1 C 5.4.1] [EMSA]

It is important that PAs grant the approval of the hazardous zones as they will dictate the specification for electrical equipment (equipment in this area has to be ATEX certified) and also define the areas where other hazards may be present (such as asphyxiation through oxygen depletion or low temperature / cryogenic).

- The standard references to calculate Hazardous Zone are:
  - IEC 60079-10-1:2015 Part 10-1 for the transfer system
  - IGF Code 12.5 for receiving vessel
  - IGC Code 1.2.24. for bunkering vessel/barge

- Hazardous Zones must be defined for all components of the LNG bunkering supply chain by their respective owners, being the responsibility of Bunkering Operators to check and confirm the compatibility of the multiples Hazardous Zones between them.

- It is to be ensured that any equipment or personnel do not place ignition sources within the Hazardous Zones.

- In the absence of a mandatory calculation methodology for the hazardous zones applicable to LNG bunkering, and in view of the challenges inherent to performing calculations following IEC 60079-10-1 methodology, **a good practice approach may be established through the adoption of IGF/IGC Code Hazardous Areas reference**.

Having in mind the limitations recognized to the methodology prescribed by IEC 60079-10-1, alternative computational calculation methods (i.e. CFD) are possible and often looked for to define the actual extent of Hazardous Zones.

A recommendation to evaluate Hazardous Zones proposed by Bunkering Operators and its calculations - according to IGF/IGC codes[1]- during license granting has been provided in [C 3.2.3.1]**.**

2.6.2. Safety Zones [B1 C5.4.2] [EMSA]:

The safety zone is temporary in nature, only present during bunkering and may extend beyond the physical assets involved in the supply.

Safety zone proposals from the Bunkering Operators have to be approved by PAs and should take into consideration:

- Standard References for use: ISO/TS 18863 and ISO 20519.

- The Safety Zone should never be smaller than Hazardous Zone, Port Specific requirements or National Standards/Safety regulations potentially applicable.

- The terminal owner should review, agree, and accept the safety distance and mitigations strategies provided by the Bunkering Operator as result of a RA. Review of the proposal will assess the suitability of the proposed bunkering area based on terminal equipment, operational procedures and proximity of staff and the public.

- Once the area has been defined, the BFO or TO should provide a means of limiting access to the area to authorized staff through the use of fences/barriers and/or appropriately trained security staff. Limiting the ship traffic when Safety zone invades the waters of the port will have to be approved by the Harbour Master, that could propose some alternative measures in order to not affect the port traffic while keeping the operation safe, i.e. towage or pilotage requirements.

- Prior to operations, a confirmation of LNG bunkering parameters and safeguards considered in the definition of the Safety Zone must be carried out.

[1] IGC/IGF recommendations are based on IEC 60079

Applicable safety zones could be established in three different ways:

1. **As a result of own PA preliminary risk assessment** using deterministic approach: this could be reassessed by Bunkering Operators with specific analysis that demonstrates any new proposed distances are safe.

   [B1 C8.3] provides a guide for preliminary calculation of safety zones that could be used as first reference, indicating that:

   - **For LNG Bunker Trucks** with a 5 bar-g tank working pressure, the safety zone distance should be **60m radius from truck cold box.** If LNG pumps are fitted and the tank is kept at saturated pressure condition, safety zone can be reduced to 25m. Remotely operated valves should reduce safety zone radius to 35m.

   - **For LNG Bunkers Barges/Vessel with type C tank** the safety zone distance should **be 30 m radius from either side of the flexible hose system** (based on an instantaneous release of 0.133 m^3 of LNG following a hose rupture, i.e. a hose of 30 m and 75mm diameter). Size and length of the hoses will determine how much LNG could be released, so strongly influences the size of safety zones. Geographical features (sloping position) and average weather conditions (wind strength, direction), strongly influence the safety distance.

   - **For LNG Bunkers Barges/Vessel with type B or prismatic tank (usually bigger than type C tanks vessels)** the safety zone distance should be **50 m radius from either side of the flexible hose system** (based on an instantaneous release of 0.37 m^3 of LNG following a hose rupture, i.e. a hose of 30 m and 125mm diameter).

   - **For LNG Storage tanks, 25m radius, or up to 50 m radius** considering the application of ISO20519 Annex B requirements.

2. **Deterministic approach**: as a result of QualRA analysis performed by Bunkering Operators.

   - This methodology is **based on the calculation of the distance to the LFL (Low flammable limit) for a maximum credible release conservatively defined as part of the HAZID**. The maximum credible release needs to consider:

     - Properties of the LNG, reflecting release conditions.
       Size of the hole, reflecting the installed equipment and validated failure data. If validated failure data is not available, conservative assumptions shall be made;
     - Roughness of the surface over which the vapour/gas disperses, (i.e. land or water)
     - Release height and dispersion elevation;
     - Outflow conditions;
     - Release rate, release orientation, available inventory.
     - Evaporation/flashing of LNG reflecting LNG properties and heat transfer from ground/water.
     - Heavy gas dispersion.
     - Structures and physical features that that could significantly increase or decrease dispersion distances. Large objects, such as buildings and ships, and topography, such as cliffs and sloping ground, can constrain or direct dispersion.
     - Weather conditions at the bunkering location; wind speed, humidity, air temperature and the temperature of the surface upon which the fuel could leak.

   - ISO 20519 provides two curves for a simplified safety zones calculation, one in case of a release of trapped volume in bunkering connections and other for continuous release from broken instrument connections. The origin and considerations for calculations are not well explained and, in some cases, can result in relatively large distances or are not well representative of possible bunkering arrangements according to EMSA.

- A more precise calculation methodology has been developed by SGMF: The calculation model called BASIL is used to estimate the size of the Safety Zone based on the extent of the gas cloud to 100% LFL [SGMF Controlled zones BASIL model]. This methodology allows Safety Zone dimensions to be conservatively estimated for a wide range of bunkering configurations, flow rates and locations. This method is an alternative to be based on graphs like the ones provided in ISO 20519 and adopting a probabilistic calculation (Risk-Based approach**)** [SGMF Basil introduction].

3. **Probabilistic approach**: according to ISO 20519, QRA analysis can be used if deterministic approach results in too large distances. A QRA is a systematic and comprehensive methodology to evaluate risks associated with the LNG bunkering system during its operation. In a QRA the risk is characterised by two quantities - the severity of the adverse consequence(s) that can potentially result given a failure e.g. an LNG leakage event and by the likelihood of occurrence of the given adverse consequence(s) of the same LNG leakage. It should be noted that historical data available is limited, so quality of this kind of analysis could be compromised. Computational fluid dynamics models (CFD) can determine more realistic or representative patterns for LNG vapour cloud dispersion. When the determination of a Safety Zone is supported by computational calculations, PAs must give special consideration to representativeness of the model, not only for the local conditions (boundary conditions, wind, temperature) but also to the LNG bunkering operation parameters (flow rate, transfer pressure, bunkering line location. Giving special consideration to:

   - Calculation Codes: as Integral, Box/Top-Hat or the most widely used CFD
   - Technical competence of the analyst responsible
   - Boundary conditions
   - Local conditions model: should be chosen in agreement with the PA
   - Location of interest
   - Bunkering conditions, such as temperature, transfer rates, pressures, etc.
   - Release scenarios
   - Grid detail and convergence of the CFD calculations, to provide a measured quality of calculations.

A set of recommendations to evaluate the determination of the safety zones during license granting has been provided in [C 3.2.3]**.**

2.6.3. Monitoring and Security Zone [B1 C5.4.3] **[EMSA]:**

As ISO 20519 and ISO/TS 18683 indicate, a monitoring and security zone should be implemented as a means of protecting safety zones from invasion, ignition sources and other potentials dangers.

BFO shall propose a Security Zone considering the elements to be present at the time of the bunkering operation. Responsible organization for the port area (Port Authority or Terminal Operator) must validate the proposal and provide the required means to the BFO to be implemented and protected.

Calculation methodologies are not available to define this area, so **PAs/TOs should determine the security zone reflecting their situational awareness of the port area and based on the local knowledge provided by the operator** on the proposed safety zone.

At least the following activities should be considered:

- Ships at berth in nearby position.
- Surrounding road traffic, industrial plants, factories and public facilities, including restaurants, shopping centers and other commercial activities.
- Vehicle movement inside the port area.
- Drones.
- Cranes and other loading/unloading operations.
- Construction and maintenance works.
- Works on electricity distribution/junction boxes.
- Utilities and telecommunication activities and infrastructure.

The Security Zone should not be inferior to the safety zone.

Security Zones should be enforced by either physical barriers or by communications with all the points of contact/responsible coordinators involved in the port activities to monitor, ensuring early warning and alarm dissemination in the event of any problems with the operation.

The LNG BSS should specify the communication procedure in place and what is required by the Bunkering Operator to comply with it.

Marine Exclusion Zone

- The establishment of marine exclusion zones is a competence of the Harbour Master, that will determine it if the measures proposed by the BFO are enough for a safe operation and does not affect the surrounding marine traffic. The Harbour Master could propose alternative measures in order to minimize the risks and the marine traffic disturbances i.e specific pilotage and towage requirements. Marine Zones and additional safety measures should be enforced by communications with all the points of contact/responsible coordinators involved in the port activities to monitor, ensuring early warning and alarm dissemination in the event of any problems with the operation.

- Bunkering activities should be clearly signposted, and its location should be known by other ships passing nearby.

- The LNG BSS should specify the communication procedure in place and what is required by the Bunkering Operator to comply with it.

2.7. Operational Envelopes

Operational envelopes refer to a limited range of parameters in which operations will result in safe and acceptable equipment performance. These envelopes are assessed by Bunkering Operators during RA process along with control zones calculation. Operation envelopes are usually referring to environmental and weather conditions.

Any bunkering operation should not start or resume if local conditions are not matching operational envelopes.

A communication procedure between the PA and Bunkering Operator must be established in order to keep the personnel involved in the operation informed about local conditions that may result in changes to the operational envelopes that could affect the LNG bunkering operations.

The PA or the Harbour Master can establish general or location-based operational restrictions in the LNG BSS, based on local weather conditions (i.e., visibility, wind, storms, etc.).

2.8. Simultaneous Operations (SIMOPS) [B1 C5.7]

Bunkering Operators should assess SIMOPS specifically and individually and submit a report describing it. The minimum content of this report is described in [C 3.1.3]**.**

Bunkering Operators should demonstrate that SIMOP risks levels are in compliance with risk criteria established by the PA [C 2.5].

- **The most relevant reference to be considered regarding the SIMOPS RA evaluation is the LGC NCOE Field Notice 01-2017** *Recommended Process For Analyzing Risk Of Simultaneous Operations (SIMOPS) During Liquefied Natural Gas (LNG) Bunkering*, detailed in [B1 C5.7]**.** [EMSA] **further elaborated this recommendation in its chapter 11.5.2 to 11.5.4 differentiating by Control Zones where SIMOPS can take place**, also detailed in [B1 C5.7].

  Both documents agreed that SIMOPS assessment should be carried out in consideration of which control zones are going to be used. **QRA analysis would only be necessary if SIMOPS are going to occur in any of the Hazardous Zones**. If SIMOPS is going to happen in the safety zone, a specific HAZID could be enough. Nevertheless, ISO 18683 still requires a QRA analysis if passengers are going to be embarked or disembarked during bunkering operation.

LNG Bunkering SIMOPS must be performed in agreement of all parties involved.

Compliance with Article 24 of Law 31/1995 and RD 171/2004 regarding coordination of business activities should be taken on account.

The PA can declare in the LNG BSS which SIMOPS are allowed in advance and which require further analysis. A list of SIMOPS to assess is provided by **[EMSA].**

[EMSA] recommend to establish a SIMOPS supervisor in order to release PICs of bunkering operation from the responsibility of SIMOPS overview, coordination and alarm dissemination.

2.9. Emergency Response [B1 C6]

- Every party must have a procedure for notification of incidents, accidents, or emergencies. According to the LNG supply mode, the following procedures are recommended:
  - For TTS operations, the ADR regulation specifies in 1.8.5 the requirements for notification/reporting of incidents.
  - For LNG terminals, the SEVESO directive specifies the information required for incident reporting [EMSA].
  - For ships, both receiving and supplying data must be sent to the module "Marine Causalities and Incidents" from IMO GISIS.
  - Directive 2009/18/EC establish a requirement to provide information about marine causalities at European level through the EMCIP (European Marine Casualty Information Platform).
  - **It is recommended that ports develop an internal procedure to collect incident reports (a model form is provided by** [SGMF gas a marine fuel safety guidelines].
- **The Bunkering Operator must have an Internal Emergency Response Plan (ERP) integrated in its Joint Bunkering Management Plan** for the measures to be taken within the LNG bunkering Facility or whenever the LNG bunkering operation takes place, from the moment authorization has been granted, to its conclusion. A description of the minimum content required of the ERP is given in [C 3.1.1].
  - This plan must be in accordance with the risk scenarios associated with the LNG bunkering operation.
  - BFO must perform a Consequences analysis study (EAC) according to article 2.3.2 of the RD 1196/2003 in order to zoning the area in case of emergency and help to define the strategies that will shape the Emergency Plan.
  - The internal emergency plan must integrate the emergency procedures of receiving ship's Safety Management System (ISM) in accordance with the requirements of the IGF code.
  - In case of STS supply, the internal emergency plan must integrate the emergency procedures of bunkering ship's Safety Management System (ISM) in accordance with the requirements of the IGC code.
  - In case of TTS supply, the Bunkering Operator should present a contingency plan.

    The internal emergency plan must contemplate the Terminal emergency response plan if the operation is performed in a third-party managed terminal or the PA emergency response plan other wise.
  - The internal emergency plans provided for in the context of new LNG bunkering projects/facilities must be drawn up in consultation with the personnel working inside the establishment, including long-term relevant subcontracted personnel.
  - Operators and the general public of concern are to be given early opportunity to give their opinion on external emergency plans when they are being established or substantially modified.

- In case of TTS or STS supply, Bunkering Operators' ERPs are to be integrated with Port or Terminal ERPs (*Plan de autoprotección*), as RD 393/2017 indicates.

2.10. Preselected locations for LNG bunkering [B1 C8]

Concurrently with other competent authorities with responsibilities for land planning, use, classification and administration, **PAs could perform an analysis to consider the need to integrate/exclude possible LNG bunkering locations into the spatial planning of the port as referred to in** [B1 C8].

Although preselected locations exist at the port, Bunkering Operators should refer to all the provisions and documentation referred to in Chapter 2 and 3. No operation will begin without the specific authorization.

Excluded locations cannot be used to perform any bunkering operation.

2.11. Management System (Safety, Quality, Environment)

Compliance with ISO 20519 requires the Bunkering Operator to list conformance with ISO 20519 as a management objective in their systems. Management systems that can be used are: ISO 9001, ISO 14001, ISM, ISO/TS 29001 and API Spec Q1.

The PA should require Operators to demonstrate that an adequate set of measures to mitigate the release of natural gas to the atmosphere are in place, adequately identified in their LNG Bunkering Management Plan. The avoidance of methane release to the atmosphere should be expressed by the BFO as an objective in a relevant Quality Management System.

3. LNG Bunkering License

As previously mentioned, the BFO must hold a License including specific authorizations related to the specific operations (typically for each specific trio: bunkering physical assets, receiving vessel and port terminal). Licenses will have timeframes of years and will detail the commercial and administrative conditions that operators must fulfill - outside of the scope of this guideline-. **Without prejudice to these conditions, each specific operation must be authorized. To obtain the authorization the BFO will submit the documentation related to the operation that will prove compliance with the PA LNG BSS. Authorizations will be valid for a specific Trio providing conditions don't change.**

This chapter describes the required Documental Folders that the BFO should send to the PA to get an Authorization for a specific Trio - section 3.1 - and provides guidelines to the PA for the evaluation of the submission - section 3.2 -.

3.1. Documental Folders

The LNG BSS requirements should be fully adopted by BFOs in an integrated and coordinated way. In order to prove this, BFOs are required to send a series of documents, including:

- **Folder 1 "Joint Bunkering Management Plan"**: describing equipment, procedures and compatibility assessments of the Trio, roles and responsibilities and a comprehensive emergency response plan (ERP) that includes all parties involved in the LNG bunkering operation.

- **Folder 2 "Risk Analysis collection"**: including at least a HAZID and HAZOP analysis focused on the LNG bunkering transfer system, and when the situation requires it, a QRA and/or FMECA.

  Folder 3 "SIMOPS": whenever a SIMOP is going to be performed during LNG Bunkering, a specific individual assessment of every SIMOP is to be carried out.

- **Folder 4 "Management Systems"**: evidence of compliance with requirements of ISO 20519 should be provided by BFOs.

The minimum content that each folder should contain is described in subsequent paragraphs.

3.1.1. Joint Bunkering management plan

This folder should include:

1. **List of equipment together with:**

   - the standards they are certified against.
   - the accredited bodies that issue the certification on behalf of administrations / authorities, recognised organisations.
   - A detailed maintenance plan of the equipment involved in the service.
   - [Annex 1.1] provided a list of the main equipment and its required certificates.

2. **Compatibility assessment, procedures and operational checklists**:

   a) **Compatibility assessment and bunkering procedure:**

   - Pre-bunkering, compatibility assessment procedures, including mooring plan.
   - Hazardous Zone, Safety zone, security area implementation, test of ESD and safety systems and notification of authority procedures. Calculation details will be provided in Risk Analysis Folder
   - Bunkering connection, inerting then natural gas purging procedures.
   - LNG filling/transfer procedures (start-main- topping up to filling limit sequence).
   - LNG stripping, inerting and disconnection procedures.
   - Procedures to prevent the release of natural gas to the atmosphere.
   - Procedure to implement control zones.
   - Mitigations plan resulting from risk analysis.
   - Reporting on the LNG quality.

   A detailed list of all relevant documents required to evaluate BFO vs RSO compatibility (Equipment and Procedures) has been collected in [Annex 1.2].

   b) **Operational checklists** to be used: it is recommended to adopt [IAPH checklists], but in some situations alternative checklists cuse can be requested. APs will find a list of recommendations to evaluate this alternative checklists in [B1 C 3.4].

   c) **Communication procedure:** agreed communication channels should be detailed and tested before operations.

   d) **Boil-off Handling measures** should be summarized and detailed, according to following groups recommended by EMSA:

      1. **Management,** i.e. minimization of trapped volume inventory, adjustment of operation rates between BFO and RSO, LNG holding times, Vapour return piping specifications or any vapour management system employed such as Re-liquefaction, gas consumption or pressure accumulation.
      2. **Planning:** the specified LNG holding times and operation rates are to be in accordance with demand patterns expected. Waiting time pre-bunkering is to be minimized.
      3. **Purging and inerting** procedure should aim to avoid the venting of mixtures of inert gas and natural gas.

e) **Non-bunkering periods:**

- **For bunkering vessels and barges,** the bunkering operator must specify where the vessel is intended to be located when it is not in operation. If the vessel/barge is going to stay within the port premises, its location should be specified, and associated risks evaluated for the location to be considered safe. Berths used must be provided with at least appropriate firefighting means for a LNG vessel and with appropriate access control to the berth, to avoid access to non-authorized persons, as required by the ISPS code.
- **For tank trucks,** predetermined alternative routes and parking areas are to be specified.

3. **A description of the Roles and Responsibilities according to LNG BSS following the format in Table 3.1:**

Table 3.1 Table for Roles and Responsibilities declaration

Name and company role	Company	Bunkering operative role	Qualifications

Evidence of appropriate qualification should be provided, attached to each person included in the matrix, according to LNG BSS 2.3 specifications.

4. Emergency Response Plan (ERP)

a) Bunkering operator must provide a comprehensive Emergency Response Plan involving both terminal and receiving vessel and integrating their different emergency plans:

- Receiving vessel's ISM must have an Emergency Plan in accordance with the requirements of the IGF Code.
- Bunkering vessel's ISM must have an Emergency Plan in accordance with the requirements of the IGC Code.
- LNG Trucks service operators must have a contingency plan.
- Terminal emergency plan should be adapted to include LNG bunkering operations.

These plans must outline as minimum:

- Fire-fighting equipment required and procedure for mobilizing it
- Procedure for mobilize first aid, hospitals and ambulances
- Evacuation of personnel and third parties
- Communication to authorities and third parties involved

At least the following should be included in the Emergency Response Plan (ERP):

- Names or positions of persons authorized to set emergency procedures in motion and the person in charge of and coordinating the on-site mitigation action.
- Name or position of the person with responsibility for liaising with the authority responsible for the external emergency plans.
- For foreseeable conditions or events which could be significant in bringing about a major accident, a description of the action which should be taken to control the conditions or events and to limit their consequences, including a description of the safety equipment and the resources available.
- Arrangements for limiting the risks to persons on site including how warnings are to be given and the actions persons are expected to take on receipt of a warning.
- Arrangements for providing early warning of the incident to the authority responsible for setting the external emergency plan in motion. The type of information which should be contained in an initial warning and the arrangements for the provision of more detailed information as it becomes available. Where necessary, arrangements for training staff in the duties they will be expected to perform and, as appropriate, coordinating this with off-site emergency services.
- Arrangements for providing assistance with off-site mitigation action.
- An Emergency Response Plan should be prepared to address cryogenic hazards, potential cold burn injuries to personnel and firefighting techniques for controlling, mitigating and elimination of a gas cloud fire, jet fire and/or a LNG pool fire.

The minimum emergency situations to cover in the Internal Emergency Plan are described in [C 3.2.5]

b) **The integration with the ERP of the PA or the TO, BFOs in STS and TTS supply must include:**

- Names or positions of persons authorized to set emergency procedures in motion and of persons authorized to take charge of and coordinate off-site action.
- Arrangements for receiving early warning of incidents, alerts, and call-out procedures.
- Arrangements for coordinating resources necessary to implement the external emergency plan.
- Arrangements for providing assistance with on-site mitigation action.
- Arrangements for off-site mitigation action, including responses to major-accident scenarios as set out in the safety report and considering possible domino effects, including those having an impact on the environment.
- Arrangements for providing the public and any neighboring establishments or sites with specific information relating to the accident and the behavior which should be adopted.

After the approval of the Authorization, in subsequences operation when the BFO is uncertain of any changes on the previous documented conditions, is entitled to request the abovementioned documentation at any time before the operation. Failure of the RV to comply with this request will allow the BFO to cancel the operation.

3.1.2. Risk analysis collection

1. **When it is decided that just a QualRA is needed (**having considered local factors, national regulations, and previous knowledge) the bunkering operator should provide a report including:

   a) **SCOPE**: Definition of study basis and familiarization with the design and planned operation of the bunkering facility:

   - Description and layout of the bunkering installation including all Concept Project drawings and intended receiving ship's characteristics.
   - All technological elements envisaged for safety control (such as alarms or other relevant features).
   - Description of other simultaneous activities and stakeholders and third parties in the area.
   - Description of all systems and components with regard to their function, design, operational procedures and relevant operational experience.
   - Description of operations and operational limitations.
   - Organization of the bunkering activities with clear definitions of roles and responsibilities for the ship crew and bunkering personnel.
   - Identification of authority stakeholders.
   - Acceptance criteria for the project aligned with the LNG BSS requirements -Figure 2.2-.

b) **HAZID** [ISO/TS 18683 7.2.3]: HAZID review with the purpose of identifying hazards and assess the risks using a risk matrix. The HAZID shall also identify risk reducing measures for all hazards representing medium or high risks. The HAZID should consider accidental spills and consider/identify technical and operational safeguards. The HAZID shall also determine maximum credible release scenarios as a basis for the determination of the safety zones.

Minimum content as adapted from ISO/TS18683:

- Study basis including description of design, operations, and assumptions being made.
- Description of the working process including participants in the workshops.
- Summary of the identified hazards and the risk assessment.
- Identification of the Risk Matrices with the full risk screening developed in the HAZID.
- Clarification on the risk ranking categories used.
- Release scenario to serve as a basis for determination of the safety zone (maximum or credible release scenario).
- Determined safety distances.
- Definition of the security zones.
- A proposal of meteorological condition limits for the LNG bunkering taking into account the location of the bunker site, to the PA for approval.
- Summary of follow up actions.
- Detailed records from the workshop.

For a more detailed assessment of a Hazid Report, [EMSA Table 8.6] **describes the methodology and content of the HAZID report.**

A recommendation for evaluating submitted HAZID Reports is provided in [C 3.2.2.1].

c) **HAZOP** [IACS Rec. 142 Annex I]**:** A HAZOP looks at how the existing LNG bunkering transfer system responds to the various failure scenarios and adds mitigations or actions to eventualities that have been identified. All process operations, equipment and their reactions need to be considered.

At least the following should be analyzed:

- Connection
- Inerting of relevant pipe sections
- Cooling down
- Transfer start
- Transfer at nominal flow
- Transfer stop including topping-up
- Draining
- Inerting for disconnection
- Disconnection
- Fatigue, stress, and human errors

[IACS Rec. 142 Annex I] provides a minimum list of cases that a HAZOP should review.

A recommendation for evaluating a submitted HAZOP is provided in [C 3.2.2.1]**.**

Both HAZID and HAZOP processes will produce a list of recommendations and an action plan that must be included in the Joint Bunkering Management Plan submitted by the BFO. These action plans will address each recommendation developed and provides a means for tracking the hazards for assessment and implementation.

d) CONTROL ZONES: Bunkering Operator safety zones proposal should address at least:

- Identification of Control Zones in suitable diagrams/plans, where the whole LNG bunkering system is represented including surrounding infrastructure elements.
- Areas in the vicinity of the Safety Zone should also be clearly identified, in particular, the existence of hazardous Zones, populated areas, potential ignition sources and gas trapping points.
- Other Safety Zones approved, maybe as a result of preliminary site location conducted by the PA.
- Supporting report of the calculations performed, indicating the methodology and assumptions considered.
- Elements required for Safety Zone signaling and access control.

2. If a QRA is needed (i.e., SIMOPS in Hazardous Zones or more accurate calculation of control zones), the Bunkering Operator should provide at least:

a) **SCOPE**: Definition of study basis and familiarization with the design and planned operation of the bunkering facility.

b) **HAZID+HAZOP**: HAZID review with the purpose of identifying hazards and assessing the risks using a risk matrix. The HAZID shall also identify risk reducing measures for all hazards representing medium or high risks. The HAZID should consider accidental spills and consider/identify technical and operational safeguards. The HAZID shall also determine maximum credible release scenarios as a basis for the determination of the safety zones.

c) Consequence modelling: The consequence assessment shall be carried out using recognized consequence modelling tools that are capable of determining the resulting effects and their impact on personnel, equipment and structures. These tools are normally validated by experimental test data appropriate for the size and conditions of the hazard to be evaluated.

d) **Frequency analysis:** The following are common techniques and tools available for frequency assessment:

- Analysis of historical incident data
- Fault tree analysis
- Event tree analysis

The selected technique will depend on the availability of historic data and statistics, but few data are available for LNG specific failure frequencies.

e) **Risk assessment:** using individual and societal risk criteria, risk analysis results must be in accordance with risk criteria established.

f) **SAFETY ZONE**: with same content as described for QualRA analysis but using a probabilistic approach.

g) **REPORT**:

QRA Report should contain all elements for a HAZID report and, in addition:

- Identification of the most critical scenarios.
- Approach followed.
- Software used for consequence modelling.

- Identification and experience of the analyst, including evidence of company-specific validation procedures.
- Assumptions used for modelling.
- Simplifications used in computational model.
- Failure statistics.
- Reliability data.
- Human error type and frequency data.
- Software used for any probability event failure scenario calculation.
- Risk Calculations.
- Risk contours on adequate aerial images for the area of interest.
- Identification of any operation-specific elements taken into consideration for the modelling.
- Safeguards considered and due justification for any risk attenuation which either hasn't derived from.

A recommendation for evaluating submitted QRA is provided in [C 3.2.2]**.**

3. **Failure Mode and Effects Consequence Analysis (FMECA)** [B1 C 5.3] **could be required if some of the components are not certificated by existing standard rules (i.e. MTTS ad-hoc solutions).**

   A recommendation for evaluating submitted FMECA is provided in [C3.2.2].

4. **Verification of LNG truck movements safety inside the port, addressing at least the content included in** [B1 C 5.6]**.**

3.1.3. SIMOPS

Bunkering Operators should assess SIMOPS specifically and individually, detailing in a report at least:

1. **Definition of the SIMOPS**, what assumptions are made and the risk criteria it should be judged against. The minimum amount of information required is included in [SGMF SIMOPS Guidelines].

2. **Identification of hazards of potential interactions between the operation and LNG bunkering** and the control measures that exist or could be considered, using HAZID methodologies (if SIMOP is assessed during planning phase this can be included in the HAZID report of the assembled RAs).

3. **Assessment of risks,** estimating the risks with QRA methodologies and reviewing these against risk acceptance criteria established in the LNG BSS or industry good practice, using the QRA methodology described above (if SIMOP is assessed during planning phase this can be included in the report of the assembled RAs).

4. **Acceptance of all parties involved**: When developing SIMOPS, the organization responsible (PA or TO) for the location - public wharfs, anchorage or terminal where the bunkering occurs, must be involved in the risk assessment. The location should review local factors to make sure the proposed bunkering plan does not include any risks that the terminal operator would find unacceptable. All three parties should agree that the SIMOP proposed is acceptable, otherwise, SIMOPS should not be allowed.

5. **Organization and control systems**: a summary of who is in charge of the SIMOP (PIC SIMOP), how the parties involved interact and communicate and how they are managed.

6. **Contingency plans**: a summary of how an incident will be handled and where necessary, evidence of consultations with emergency response organizations and adaptations required to the Emergency Response Plan must be provided.

3.1.4. Management system (quality and environmental)

The BFO which has a quality management system based the upon requirements of ISO 9001 (or equivalent- ISO 14001, ISM, ISO 29001 or API Spec Q1), must submit the respective documentation of their quality system properly audited and being compliant with requirements of ISO 20159, Section 7.

3.2. Evaluation of submissions

Once BFOs have submitted all the documentation required to get an authorization, PAs should review it and accurately assess if the bunkering operation proposed is compliant with the LNG BSS and regulatory framework. **It is a recommendation of this guidelines that a specific technical team is established within the PA to be in charge of this process and provide responsiveness to BFOs. It is also recommended to hire external technical assistance to evaluate submissions.**

This chapter provides a set of recommendations to guide the PAs technical evaluation team on which aspects to emphasize when an Authorization submission has to be reviewed.

3.2.1. Verifying the content of Joint Bunkering management Plan

- **Verifying the equipment list**

  The Bunkering Operator should provide a list of equipment and their certification declaring the accreditation body for every item on the list. PAs should check if the list of components and certifications are in accordance with tables provided in [Annex 1.1]. PAs could check this with its own means or by asking for a responsible declaration from an external company on the certification provided by the BFO.

- **Verifying compatibility assessment and procedures**

  [Annex 1.2] collects the required checks to perform a compatibility assessment between Bunkering Operator and Receiving Vessel. PAs should check that this analysis has been performed and results are acceptable.

- **Communication procedures:** The PA should check that communication procedures and equipment are clearly specified and agreed between all parties.

- **It is recommended to adopt IAPH checklists without any modification.** Checklists proposed should be agreed by all parties involved. In case of custom checklists, [BI C 3.4] provide a set of recommendations to evaluate if checklist proposed are valid for LNG bunkering.

- **Boil-off gas handling:** The PA should check that potential release situations are assessed (and mitigation measures are proposed) according to [EMSA] proposed structure. Mitigation measures should be:

  - **Relevant**: related to the actual project and adapted to the different stages of the process.
  - **Enforceable:** the PA should be able to confirm actual practice of the measures presented, both technical and operational.
  - **Safe:** no potential unsafe operation or condition should arise, and all scenarios should be assessed in the risk analyses.
  - **Quantifiable:** the amount of methane not sent to the atmosphere is possible to quantify.

- **Non-Bunkering periods:**

  For STS: The PA should check that the proposed wharf/anchor area is safe, taking into consideration:

  - Exposure to maritime traffic.

- Exposure to terminal operations: there should be no activities that can generate sources of heat, flames or any source of ignition in a radius of 100 meters.
- Appropriate access, means of firefighting for LNG and supply of cooling water in order to facilitate the safe and effective intervention of emergency services.
- Mooring equipment is suited for the ship.
- ISPS code compliance.

For TTS: The PA shall agree on a movement and parking plan for trucks inside the port, taking into consideration:

- Truck routes are through areas/zones of less traffic and operational activity.
- Alternatives routes are assessed.
- Compliance with port traffic rules.

- **Evaluation of personnel assigned to the operation:**

  Certifications should be updated and valid, according to chapter 2.3.1 specifications.

3.2.2. Verifying Risk Assessments

3.2.2.1. Verifying the HAZID (Hazard Identification)

The fundamental goal behind the HAZID is to identify the causes of accidents before they occur so they can be eliminated or mitigated in terms of design changes and/or operational response.

In **evaluating the format and features of a HAZID report,** the port authority should verify the following:

- Completeness and consistency in describing the hazards. The Port Authority should confirm that the LNG bunkering system described in the HAZID reflects the actual component, equipment and control that will be used by the bunkering supplier and the receiving ship.

- Where LNG Bunkering Trucks are employed, evaluate that the LNG tank, components, equipment and system are designed, constructed and tested against established safety standards (e.g. ISO, API, NFPA certification).

- That there is a diversity of LNG experience and expertise in the HAZID participants. The HAZID should include inputs from the bunkering provider, chief engineer (receiving ship), component/equipment Original Equipment Maker (OEM) expert, fire-safety engineers and emergency response specialists.

- It should reflect and reference documented LNG accidents involving bulk transportation and transfers.

- There is a qualitative evaluation of the significance (criticality) of each hazard based on a well-defined criteria (i.e. developed risk criteria matrix).

- The hazards are organised in terms of significance and the most critical are identified for further analysis (e.g. some hazards require simulation modelling of large releases, FMECA of safety critical components, etc.).

- For each hazard there are prevention and/or mitigation measures for eliminating and reducing the risk. This should include the assignment of responsibilities involving design changes, operational procedures, etc.

- Documentation and supporting evidence that the prevention and/or mitigation measures are reflected in the bunkering system and operation.

In terms of the HAZID technical content, as a minimum, the Port Authority should confirm the completeness and correctness of different hazards relevant to inadvertent LNG release/leakage, including adverse events such as loss of containment, accidental ignition and fire/explosion. **The list below is a representative checklist derived from a collection of Lloyd's Register HAZID reports on LNG bunkering and LNG fuelled ships.**

The bunkering site HAZID must consider at least:

- Impact from collisions (i.e. third-party vehicle/vessel collision with bunkering truck, ship)
- Dropped objects.
- Inability to properly set-up, configure the emergency release system
- Severe misalignment of LNG transfer system affecting the quick connect, disconnect component.
- Severe winds, wind loading onsite
- Adverse weather conditions (excessive summer, winter temperatures, strong wind conditions)
- Transient weather such as storms, lighting strike event
- External fire, explosion independent of the bunkering operation (if applicable)
- Earthquake (if applicable)
- Behaviour of large LNG release given topological features, proximity to general public

Receiving Ship LNG Tank(s) and Bunkering Vessel LNG Tank(s):

- Fire in LNG tank space generating excessive heat in the tank vicinity that initiates the tank safety relief valves
- Fire affecting localised sections of LNG tank resulting in tank failure.
- Overfilling LNG tank (e.g. faulty/incorrectly set HL/HHL alarms, tank level control failure, level sensor failure).
- Loss of insulation effectiveness (i.e. large drop in overall insulation performance)
- Loss of vacuum insulation
- Ingress and build-up of contaminants (e.g. N2, O2, etc.)
- Excessive BOG, vapour generation during the bunkering process.
- Tank pressure control failure.
- Loss of purging capability (inert gas system, inert gas bottle failure)

Receiving Ship and Bunkering Vessel, LNG Bunkering System:

- Leakage of internal pipe(s) in double wall arrangement, including pressurization of the annular space in case of vacuum insulation.
- Emergency shutdown ESD of LNG bunkering and thermal expansion of trapped LNG in isolated pipe sections.
- Remote isolation valve control failure (i.e. control valves failing safe to closed position)
- Adverse thermal stresses from incorrect cool-down operations
- Adverse, cyclic variations of operating pressure during bunkering
- Vibration
- Excessive expansion, contraction of pipes and pipe components
- Occasional, persistent bending of flexible hoses
- Incorrect support arrangement of QCDC, flexible hoses at manifold.

Bunkering Truck (Single Truck, Multiple Truck Arrangements):

- Fire generating excessive heat initiating the safety relief valve of the LNG tank(s).
- Localised, high intensity fire resulting in tank failure.
- Ingress / build-up of contaminants (e.g. N2, O2) O2 is particularly dangerous
- Loss of insulation effectiveness (both annular vacuum space tank and multi-layer insulation tank design)
- Abrupt loss of vacuum in annular vacuum space tank design
- Loss of N2 purging system
- Bunkering pressure control failure exceeding bunkering operational pressure
- Thermal expansion of liquid in isolated piping sections in the truck cabinet
- Failure of pressure build up unit (PBU)
- Failure of LNG transfer pump (cavitation, dry running)
- Failure of truck braking system resulting in movement of truck during bunkering.
- Degradation (wear and tear) or failure of bearing on truck rotating axle
- Presence of corrosive conditions underneath cryogenic insulation ("under lagging corrosion")
- Incorrect material selection, use of wrong spares during component and equipment maintenance and servicing.
- Failure of earthing/grounding, accumulation of static electricity.
- Incorrect electrical components and equipment (i.e. violation of hazardous area classification zoning requirements).
- Usage of cryogenic flexible hoses beyond the recommended cycles (operational hours) of the OEM
- Poor, flawed maintenance practices on truck LNG components and equipment.
- Thermal expansion / contraction stress

Human factors:

- Missing or unclear written instructions and protocols
- Procedures not followed, not existing or not correct
- Lack of commissioning procedure, normal start-up, operational and shutdown procedures
- Lack of Safety Management System
- Inadequate education/training of bunkering personnel
- Inadequate or ineffective isolation practices for maintenance
- Overriding, ignoring alarms and indications of control, monitoring and safety systems
- Poor change management
- Inadequate, poor maintenance practices (e.g. no maintenance identified, not scheduled or not completed)
- Maintenance error (i.e. lack of knowledge, experience of maintenance technician).

3.2.2.2. Verifying the HAZOP (Hazard and Operability) Analysis

The HAZOP is a systematic, detailed review of the bunkering that seeks to identify the causes and consequences of deviations from the bunkering system design intent and ideal (exemplar) bunkering operations. In the context of LNG bunkering approvals, the HAZOP is conducted following a HAZID and the final (agreed) bunkering system design between the Receiving Vessel, LNG bunker facility (LBT, LBV, LBB, onshore tank) and terminal.

In evaluating the format and features of a HAZOP report, the port authority should verify the following:

- That there is a diversity of LNG design, safety and operating experience in the HAZOP participants.
- It should reflect the detailed P&ID (process and instrument diagram), control and ESD (emergency shutdown) diagrams and operational, functional documentation of the LNG bunkering system – starting from the bunkering asset system to the Receiving Vessel's LNG system and tank.
- The design intent, functionality, capability and expected performance of the LNG bunkering system.
- Given that there are discrete unique operations involved with bunkering (e.g. connection of hoses, purging of pipes, etc.) where the process is not at a steady state (i.e. in contrast to the actual LNG transfer), the HAZOP should cover the discrete time intervals during each process.
- Deviations from the design intent, exemplars using guide words such as "no/not/none, more, less, part of, reverse, other than, high, low" applied against parameters such as temperature, pressure, flow and LNG properties.
- Identification of the causes (pre-cursors) leading to the deviations.
- Manifestation of the deviations (i.e. observable symptoms) in terms of the sensors, parameters and information available on the bunkering system. In terms of LNG bunkering system these parameters include flow, pressure, temperature, level and LNG composition -if it is possible-.
- Possible consequences of the deviation(s) as they occur.
- Control and safety functions (e.g. exceedance of set threshold triggering a safety response) that are initiated to minimise the hazard associated with the deviation(s).
- Where the deviation(s) are not addressed by control design and safety functions – specific operational actions that mitigate the consequences of the hazards from the deviations.
- Reflecting the operational, recovery actions detailed by the HAZOP into the contents of the emergency response procedure.

Table 3.2 shows a real working example of a HAZOP Worksheet completed during the risk assessment workshop of a LNG bunkering operation study. It is shown here for awareness and as a reference for the level of detail expected as output from a HAZOP study.

Table 3.2 Example: excerpt from a HAZOP Worksheet for LNG bunkering study

Node: 1. HV101 (ESD Valve) To HV350A To Hose to V56 up to V57 ESD Valve.
Deviation: 6. High Pressure
Design Conditions/Parameters: Drawings / References:
Type: Equipment ID:

Cause	Consequence	Effective Safeguards	Recommendations	Action By	Status
1. HP build up in ship's tank due to heat ingress	1. Small pressure differential between tanks with reduction in bunker flow	1. Ship will initiate top spray within the tank to reduce vapour pressure.	7. Cause & effect matrix and also Safety Checklists to address scenarios and eliminate potential relief of gas within port by either Viking or AGA. This is a Port Authority requirement which needs to be met at all times.	Wartsila/STX	Open
		2. Ship may also relief to the second tank.	8. AGA system/operations to address effective damping during back over pressure event in order to eliminate any potential relief of gas adjacent or within the bunkering manifold of the Viking ship.	Wartsila/AGA	Open
		3. At 7 bar tank pressure, Viking [illegible]	[illegible]	STX/Wartsila	Open

Node: 1. HV101 (ESD Valve) To HV350A To Hose to V56 up to V57 ESD Valve.
Deviation: 7. Low Temperature
Design Conditions/Parameters: Drawings / References:
Type: Equipment ID:

Cause	Consequence	Effective Safeguards	Recommendations	Action By	Status
1. Not an issue.					

Node: 1. HV101 (ESD Valve) To HV350A To Hose to V56 up to V57 ESD Valve.
Deviation: 8. High Temperature
Design Conditions/Parameters: Drawings / References:
Type: Equipment ID:

Cause	Consequence	Effective Safeguards	Recommendations	Action By	Status
1. Potential thermal impact of cold bunkering LNG on warm Viking piping system.	1. Long term material effects relating to very frequent bunkering operations. Impact on flanges and valves on gas fuel system. Potential for fractures resulting in leakage. Hose stress/cracking/loss of integrity	1. Efficient cool down of fuel gas and bunkering system prior to full flow bunkering will be required.	10. Refer to Deviation 2, Low Flow. It is noted that the most reduced cool down time will clearly depend on how cold the Viking line between V36 & V57 can be maintained. Operation Manual to address.	STX/ Wartsila	Opem
		2. Efficient cool down also means that cool down requirements for hose, dry coupling and breakaway coupling have to be met. It is a requirement that hose and safety valve connection will always take place with the system fully inerted.	11. AGA to advice cooling rate and the time required to cool down all equipment downstream of HV350A and how this can be safely done after connection. Viking Operating Manual to be updated to include slow start bunkering procedure.	AGA/Wartsila/STX	Open
		3. AGA has undertaken a HAZID/HAZOP of their own operations involving an independent third party.	12. AGA to communicate with hose manufacturer and provide details with regards to Gutteling 6 inch hose cool down requirements.	AGA	Open

3.2.2.3. Verifying the Quantitative Risk Assessment

EMSA Guidance on LNG bunkering defines a QRA as "a well-known and widely accepted methodology to quantify safety risks. It is an approach to determine risk levels associated with accidental Loss of Containment events (e.g. LNG spills, large gas releases)". **Eventually, while there is growing maturity in the development and acceptance of QRA in the Marine and Offshore industries, there remains specific challenges in using a QRA to analyse and justify the safety of LNG bunkering operation (i.e. lack of historical data).**

Applying a QRA to LNG bunkering operations quantifies the risks from hazardous events such as loss of LNG containment LOC (large spill event), fire events etc., and involves a thorough consequence analysis associated with the hazard and the quantification of the frequency at which different faults and failures are expected to materialise. The resulting risk is then analysed against recognised risk criteria in finalising the LNG bunkering design and operation. Figure 3.1 below shows a typical workflow when conducting QRA studies for LNG bunkering operations.

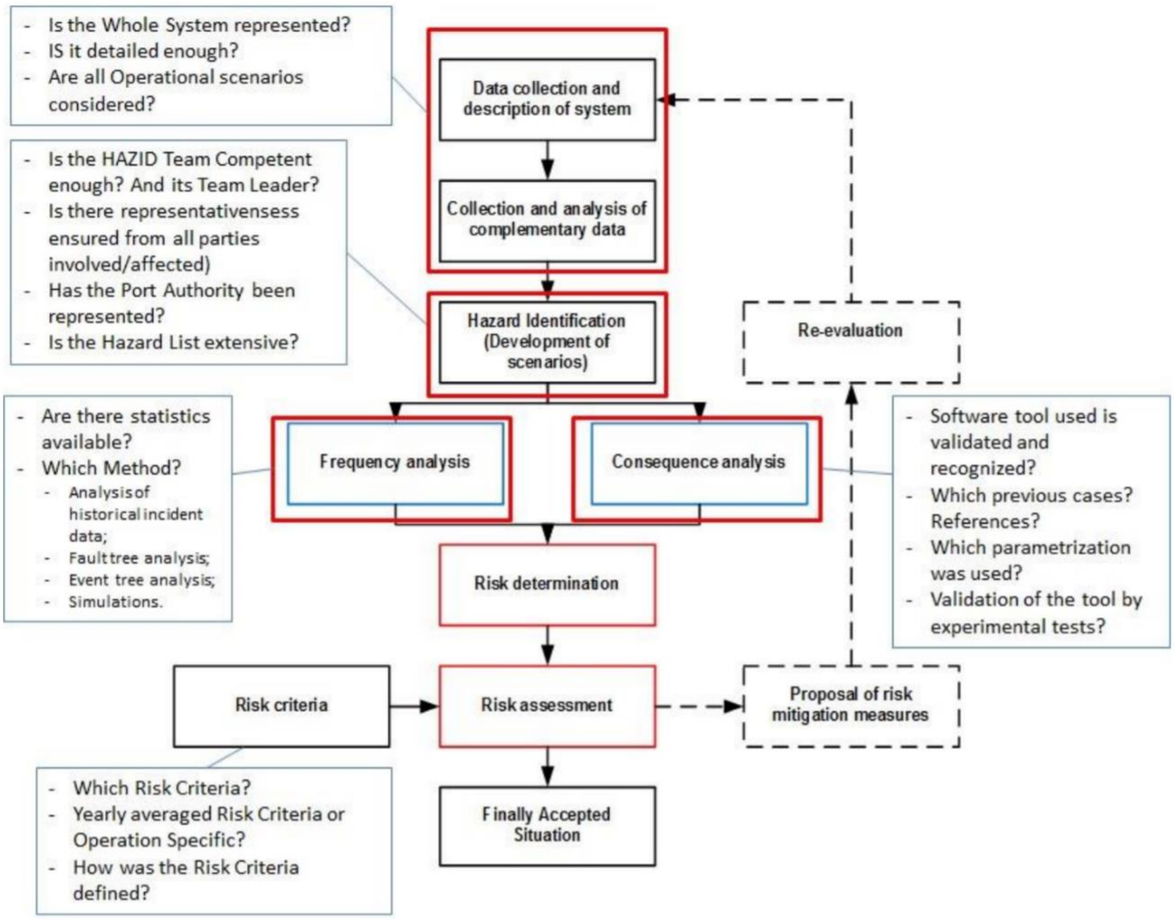

Figure 3.1 QRA workflow for LNG bunkering operation analysis

Distinct features of a QRA that the Port Authority should verify include:

- Consideration of complex fault-failure interactions and multi-disciplinary(domain) information integration.
- Reduction of selected LOC risks through quantified risk-based decisions (i.e. reducing the length of the hose, adding gas detectors at strategic positions, improving monitoring and safety response, etc.)
- Demonstration that risk levels are reduced As Low As Reasonably Practicable (ALARP).
- Direct influence on the technical and practical content of the emergency response procedures.
- Quantitative comparison of different options (e.g. type of ERS, instrument penetrations, etc.) in evaluating the safety of LNG bunkering system and operating procedures.

Misuse of QRA and incorrect content that the Port Authority should recognize and actively challenge include:

- Ignoring, neglecting deterministic arguments – for example release rates and supporting context prescribed in ISO/TS 18683.

- Misusing, incorrectly developing the risk criteria i.e. the appropriate risk criteria, Frequency vs Number of fatalities curve, etc. fit for LNG bunkering.

- Using inaccurate, unrealistic data - specifically the failure statistics of components and equipment.

- Arguing that everything is safe because a calculated risk level is lower than a numerical criterion (threshold) without providing context and supporting justification.

- Manipulating results to justify the desired decisions e.g. reducing the safety zone distance via inaccurate representation of failure frequencies.

- Purposely diverting attention from proven, achievable precautionary and preventative design and operational measures.

- Complete lack, exclusion of human factors. A QRA is typically dominated by electrical, mechanical, structural faults and failures leading to the LOC event. This rigid and focused approach on hardware failures do not reflect actual operations and emergency conditions.

- For LNG components, equipment and operation in general, there are sparse data on initiating events such as component failures.

3.2.2.4. Verifying the FMEA, FMECA (Failure Modes and Effects Criticality Analysis)

In evaluating the format and features of a FMEA, FMECA report the port authority should verify the following:

- Conformance of the FMEA to widely recognised standards such as IEC 60812.

- Consistency in the granularity of replaceable part(s), elementary function. For equipment, component FMEA/FMECA the PA should require submission of certificates on the compliance of replaceable parts and basic functions according to the Official Equipment Manufacturer operational and maintenance manual.

- That OEM design engineer, production and servicing engineers, independent facilitators and experts were involved in the FMECA study.

- There is an evaluation of the criticality of each failure line item based on a well-defined criterion (i.e. risk criteria matrix).

- The providence of the frequency (occurrence) estimation (i.e. the reliability data for individual parts) came from recognised failure and reliability databases.

- The failures are organised in terms of criticality and that major, catastrophic risks are eliminated or mitigated by existing design features and operational requirements (e.g. increased inspection, servicing frequency).

- Documentation and supporting evidence that the design measures and/or operational mitigations are reflected in the component and equipment.

In terms of the FMEA/FMECA technical content, as a minimum, it should be reviewed for completeness of the parts and functions of the equipment being evaluated, based on the granularity described by the OEM in the operating and maintenance manuals. Unlike a

HAZID/HAZOP where it is possible to anonymize and list a generic set of hazards from failures, errors, faults and accidents, the detailed nature of an FMEA, FMECA makes it challenging to develop a review guide that is generic enough and yet applies to the model/type of the target component.

3.2.3. Verifying determination of control zones

3.2.3.1. Verifying the Hazardous Zone Distances (i.e. permanent zones that should be free of sources of ignition)

The following elements should be checked for approval of Hazardous Zones by PAs:

1. Identification of all Hazardous Areas in suitable diagrams/plans where the whole LNG bunkering system is represented. Zones 1 and 2 should be clearly identified and related to the following elements in the bunkering system:

    a) Bunkering manifolds, their flanged connections or containment coamings
    b) Flanged connections along the bunkering line
    c) Venting lines, GCUs
    d) ERC
    e) QC/DC bunkering connectors
    f) Any flanged connection along the bunkering transfer system
    g) Bunkering articulated arms, in particular, where swivel LNG piping joints are present, mechanical elbows and other articulated connections.

2. Identification of the references for each Hazardous Zone presented. One or more of the references below should be presented:

    a) IEC 60079-10-1, indicating which assumptions were followed for the definition of the Hazardous Zone extent.
    b) IGF/IGC Code, making reference to the code, in particular indicating pressure and temperature windows defined for the bunkering. This is relevant to check compatible physical pressure-temperature conditions between LNG delivered and LNG system of the RSO.
    c) Other Codes, if national/regional standards have been followed, other than IEC/EN related.
    d) CFD, signed by the responsible person for the calculations, the code used, assumptions followed, verification & validation procedures, including convergence of model, mesh refinement location and boundary conditions.

3. LNG Bunkering Management Plan, to be checked for reference to Hazardous Zones, in particular, provisions for its establishment and control.

Only if a projected Hazardous Zone is proposed, along with effective measures for its control, should it be considered realistic. Sign, labelling and warning signs are some of the physical measures possible. Also, confirmation keys, unlocked following Ex-proof verification can be considered.

The Table 3.3 below shows the minimum distances that apply to the Hazardous zone, according to IGF/IGC code, to be checked for each specific bunker location (note that the bunkering provider should also account for the Receiving Vessel's HAZID).

Table 3.3 Applicable Hazardous zone according to IGF/IGC Code

Bunkering Component	Zone	LNG Fuelled Vessel	LNG bunkering Barge	LNG bunkering Truck
1. Tank Relief Vent Termination	1,2	- At least Breadth/3 or 6m in vertical height - At least 10 meters away from non-hazardous areas	- At least Breadth/3 or 6m in vertical height -At least 25m away from other areas	- At least 10 meters away from non-hazardous areas
2. Ventilation outlets (i.e. termination of HAZ spaces)	1	- At least 3m from the outlet in all directions	-At least 3m from the outlet in all directions	-Not Applicable
	2	-At least 1.5 m on top of the zone 1 requirement (1.5+3= 4.5m total)	-At least 1.5 m on top of the zone 1 requirement (1.5+3= 4.5m total)	-Not Applicable
3. Bunker manifold valves and flange connections	2	- At least 3m away from non-hazardous areas	- At least 3m away from non-hazardous areas	- At least 3m away from non-hazardous areas
4. Quick connect, disconnect couplings	1	At least 3m from the coupling in all directions		
	2	At least 1.5 m on top of the zone 1 requirement (1.5+3 = 4.5m total)		
5. Emergency release coupling	2	At least 3m away from non-hazardous areas		
6. Flexible hoses (flange connection, coupling end)	2	- At least 3m away from non-hazardous areas	- At least 3m away from non-hazardous areas	- At least 3m away from non-hazardous areas

3.2.3.2. Verifying the Safety Zone Distance (i.e. distance based on the worst credible release and gas dispersion)

a) Reviewing a Safety Zone Derived using a Deterministic Approach (HAZID)

A deterministic safety zone distance is derived from LNG leakage modelling (i.e. modelling a LOC event) which consists of two distinct stages – first the immediate LNG leakage behaviour then secondly, its characteristics during pool spread and dispersion. Immediately after leakage the LNG behaviour is dominated by the conditions of the bunkering operation (i.e. working pressure and temperature of saturated LNG), release geometry and orientation in addition to features of the infrastructure coming into direct contact with the LNG release (e.g. protection via stainless steel drip trays, pool formation at concrete etc.). In the latter stages of the modelling i.e. downstream dispersion, as the influence of the initial release condition decays, the prevailing atmospheric conditions (e.g. ambient temperature, wind direction/strength, etc.) becomes increasingly important in influencing the vapour dispersion behaviour.

1. Reviewing the Assumptions, Escalation and Mitigating Factors in "Deterministic Safety Zone Distance Modelling"

The following Table 3.4 presents the two modelling phases of this methodology, the phenomena studied at each phase and lists the assumptions that should be considered in order to perform the analysis and accept the results.

Table 3.4 Deterministic Safety Zone Distance Modelling - Assumptions

Modelling Phase	Phenomena	Assumptions and Parametric/Sensitivity Analysis
1. Immediate LNG Leakage Stage (Source Term)	Bunkering (transfer) working conditions	Apply "design conditions" for conservatism
	Release geometry, duration and rate	Finite, trapped volume release or continuous release via instrumentation diameter
	Release orientation	Vertical, horizontal, angled release
	LNG Release type	-Jet release (liquid or two phase) downstream of pump and/or pressure build-up unit -Pool release
	Interaction with immediate infrastructure	-Heat transfer characteristics of material upon immediate contact (concrete, stainless steel, sea water, etc.) -types of pool formation (geometry) -types of pool spread
	System protection, containment features	-ESD, ERS capabilities -Spillage coaming/containment
	LNG leakage spread	- Surface roughness, flat, sloping, water curtain, etc.
2. Dispersion Stage	Vapour cloud formation	- LNG vapour stratification - Effect of water spray (steel thermal protection)
	Ambient condition and atmospheric stability	- Varying the air – LNG vapour mixing phenomena -Considering buoyancy - Varying wind speeds and direction
	Interactions with surrounding terrain and physical infrastructure	- Representation of obstacles like cranes, container stacks, tanks, buildings (including air intakes),

2. General – Software Modelling tools

The following is a list of validation checks that Port Authorities could perform in order to make sure that the software modelling tools are adequate and have been properly implemented.

Details of the modelling (not just the results) should be documented and made available for assessment

Fundamentally, the modelling result (i.e. dispersion distance to LFL, ½ LFL) must be reproducible. This means that given similar assumptions and boundary conditions (i.e. LNG working temperature, pressure, surface contact, wind conditions, etc.) two unique/independent modelling methods must produce similar results. In case the models yield completely different results, then both must be evaluated and compared in order to technically understand then resolve the differences. This requires a structured documentation of the elementary functions within each modelling tool alongside the assumptions and boundary conditions employed.

The modelling software has been peer reviewed and evaluated

The modelling software should be able to correctly represent the different phenomena concerning the different phases of the LNG leakage, surface contact, pooling and eventual dispersion. This means that experts from the LNG industry, physics modelling, LNG testing, etc. domains have in the past been allowed to review and scrutinize the different aspects of the modelling software. It is recommended that the Port Authority and the LNG modelling Subject Matter Experts consult the [UKHSE RR789] "LNG source term models for hazard analysis – A review of the state-of-the-art and an approach to model assessment" for the details on how to technically conduct a peer review. The UKHSE guide lists and describes the different commercial modelling software in detail including their advantages and shortcomings.

3. Immediate LNG Leakage Stage (i.e. the Source Term)

The modelling employs a credible description of the initial LNG leakage (i.e. the source term)

The conditions representing the LNG bunkering operation should be credible in terms of working pressure, temperature, flow rates and LNG properties. The correct and accurate specification of these parameters strongly influences the fidelity of the model irrespective of the modelling software applied. If there are doubts, uncertainties in defining the working conditions prior to LNG release, conservative assumptions should be made i.e. using the design temperature, pressure, flow rates of the LNG transfer system.

Other important assumptions to be scrutinized include the size of the leakage area where ISO 18683 recommends a full break of the line releasing a finite volume of trapped LNG or a continuous release through failure of a 25mm instrument penetration. The release height and orientation should also be evaluated as these govern the immediate LNG leakage behavior as it comes into contact with the ground or some other protective arrangement.

The modelling accounts for the LNG leakage behavior during contact with the immediate environment

The representation of the immediate LNG leakage characteristics is as important (if not more) as the dispersion modelling itself. The real-world arrangement and configuration of the LNG bunkering system should be accounted for such as stainless-steel drip trays, concrete structure, seawater ambient properties, etc. that will influence the initial behavior of leakage. For instance, LNG spillage on concrete is typically approximated as a boiling pool that travels/spreads in a certain direction. As the pool spreads, the LNG continues to encounter warm ground which results in consistently high boiling rates. In contrast, an LNG leakage restrained by a large enough drip tray (i.e. some form of dike) will be restrained cooling the immediate vicinity, thus restricting the heat transfer rates and the boiling rate.

4. Dispersion Stage

The modelling accounts for the effects of the wind direction and speed

Intuitively higher wind speeds will transport the resulting vapour cloud more rapidly in the downwind direction. Similarly, highly turbulent atmospheric conditions will work to dilute the vapour cloud more rapidly. The relative importance of these environmental effects on the gas cloud concentration (LFL-HFL limits) as a function of downwind distance can be technically complicated, as the wind speed varies with height and there is also gravity driven turbulence even in the absence of wind (as discussed in paragraph 4). Accounting for all these phenomena to be reflected in the model using realistic features and constraints in the vicinity of the port designated for LNG bunkering is critical.

The modelling accounts for the effects of aerodynamic surface roughness

The aerodynamic roughness is a property of the air flow, which relates wind speed at a given height to turbulent transport. It is one of the factors affecting the relative rates of transportation and dilution of the vapour cloud.

The modelling represents the effects of atmospheric stability on dispersion

Turbulent transport in the atmosphere is affected by more than just the wind speed and the surface roughness. Another important factor is atmospheric stability. If air near the ground is colder than air above (i.e. a stable atmosphere), mixing is suppressed as the vertical density gradient acts to damp out vertical movement and mixing of air. Conversely, warmer, less dense air near the ground (i.e. unstable atmosphere) will result in enhanced vertical mixing. Thus, for any given wind speed and roughness length, both the vertical wind-speed profile and the turbulence intensity, will depend on atmospheric stability.

The modelling accounts for both heavy gas and passive dispersion

The most important quantity which distinguishes heavy gas dispersion from passive dispersion is typically the Richardson number g′h/(u*)2. Here g′ is the acceleration due to gravity multiplied by the relative density difference and so for a vapour cloud of great enough height h, in an atmosphere of small enough friction velocity u*, the gas cloud can still be 'heavy' when it dilutes to LFL and below. Conversely, a smaller cloud of the same gas in a more turbulent atmosphere can disperse effectively passively even while it is relatively concentrated.

The modelling factors the effects of buoyancy on dilution

A heavy gas cloud suppresses any vertical mixing due to atmospheric turbulence because of the strong stable density gradient. In the early stages of the leakage, much of the turbulence that affects the air-gas vapour mixing can be generated by the effects of the gravity driven spreading motion. Meaning the stronger the gravity current, the stronger the turbulence generation. In contrast with atmospheric turbulence, mixing via gravity does not suffer the same suppression as that powered by atmospheric turbulence. The consequence being that the spreading significantly affects the dilution near the source and its dynamics should be represented in the model.

The modelling should represent the surrounding infrastructure at sufficient fidelity

In the event of physical infrastructure (e.g. container stacks, cranes, passenger terminals, buildings, etc.) obstructing the dispersion of the gas cloud, a detailed geometry model will be important in the estimation of the safety zone. Furthermore, having detailed geometry represented, has the additional benefit of estimating the thermal heat transfer from the gas cloud cryogenic pool towards the structure to analyse other secondary/tertiary effects of the cryogenic temperature e.g. analysing possibility of infrastructural damage.

Table 3.5 LR Safety Zone Distance Matrix using integral models – including Sensitivity/Parametric Analysis

	Release		Flammable Extent - Horizontal Distance (m) by Stability Class and Wind Speed (m/s)																	
	Elevation	Orientation	A1	C5	F2	A1	C5	F2	A1	C5	F2	A1	C5	F2	A1	C5	F2	A1	C5	F2
Continuous Release from 13 mm Ø Hole - 100 mm Ø Hose/Line	1 m	D	20	16	102	22	19	115	23	19	120	24	20	123	25	21	131			
		V	5	4	6	4	4	5	4	4	5	4	4	5	3	4	4			
		H	41	32	64	47	36	67	50	38	64	53	40	62	58	42	59			
	3 m	D	20	16	102	22	19	115	23	19	120	24	20	123	25	21	131			
		V	5	5	6	5	5	5	4	5	5	4	4	5	4	4	4			
		H	47	13	40	55	19	45	59	21	47	62	23	50	67	26	55			
	5 m	D	20	16	102	22	19	115	23	19	120	24	20	123	25	21	131			
		V	5	5	6	5	5	5	4	5	5	4	5	5	4	5	4			
		H	48	12	38	56	13	45	59	14	47	62	14	50	66	15	54			
		release rate	1.27 kg/s			1.64 kg/s			NA			1.94 kg/s			2.19 kg/s					
		operating pressure	3 barg			5 barg			6 barg			7 barg			9 barg					
		release onto	water			water			water			water			water					
	1 m	D	19	13	93	21	14	102				22	15	109	23	16	115			
		V	5	4	6	4	4	5				4	4	5	3	4	4			
		H	41	32	62	47	36	58				53	39	57	57	41	57			
	3 m	D	19	13	93	21	14	102				22	15	109	23	16	115			
		V	5	5	6	5	5	5				4	4	5	4	4	4			
		H	47	13	40	56	19	46				62	23	51	67	26	55			
	5 m	D	19	13	93	21	14	102				22	15	109	23	16	115			
		V	5	5	6	5	5	5				4	5	5	4	5	4			
		H	48	12	39	56	13	46				62	14	51	66	15	55			
		release rate	1.27 kg/s			1.64 kg/s			NA			1.94 kg/s			2.19 kg/s					
		operating pressure	3 barg			5 barg			6 barg			7 barg			9 barg					
		release onto	concrete			concrete			concrete			concrete			concrete					

Notes
A1 - a hot still day with no cloud cover. C5 - daytime with partial cloud cover and a moderate wind.
F2 - a clear night with low wind speed and little or no cloud cover. D - downwards. V - vertical/upwards.
H - horizontal impinged releases.
74% relative humidity. LNG 100% methane, density of 420.3 kg/m3. Surface roughness: parameter, 0.1 land; height, 5 mm water.
Operating temperature -160 degC. Lower Flammable Limt - 44,000 ppm (v/v).
Distances reported to lower flammable limt (5% methane in air - 44,000 ppm (v/v)) regardless of height from grade.
Calculation used PHAST default ‘averaging time’ of 18.75 s to determine gas concentrations. Generally, the longer the ‘averaging time’ the shorter the dispersion extent. Within a reasonable range of ‘averaging time’ it is judged that the extent would not change significantly, but no investigation of this parameter was made.

b) Verifying the Safety Zone using a QRA (Quantitative Risk Assessment) approach

The standard ISO/TS 18683 uses a location specific individual risk LSIR criteria (i.e. a risk contour) as an alternative to the "deterministic" safety zone distance. The risk contour represents the tolerable risk a group of people (e.g. bunker operators, crew, general public, etc.) against large LNG releases and other hazards considered in the QRA. This mean that the contours represent the geographical variation of the risk for an individual (i.e. bunkering operator, passenger etc.) who will be in the vicinity of the LNG bunkering for 24 hours per day, 365 days per year.

Given that the figures represent a continuous exposure and are not representative of LNG bunkering operations which are infrequent and completed in a very short time duration, the criteria requires some normalisation to the intent and context (nature) of the intended LNG bunkering operations. Meaning the resulting risk if not normalised to the actual bunkering operation, can be extremely small (i.e. as the frequency is averaged over the year rather than the cumulative, realistic bunkering hours) resulting in very little protection (i.e. additional design safeguards, emergency response) should a large leakage occur.

3.2.3.3. Reviewing the Monitoring Security Zone

It is proposed jointly by the BFO and PA taking in consideration elements provided by all parties involved in the operation.

The Port Authority should consider permanent structures, vessels and active port locations within 50 m or less of the calculated safety zone as part of the monitoring/security area. These will include but are not limited to:

- Leisure and shopping facilities such as restaurants and shops in passenger terminals.
- Administrative buildings and warehouses where third party port personnel can be present during periods of bunkering operation.
- Other vessels berthed adjacent to the bunkering location.
- Cranes and other port fixtures.
- Roads being used for container/bulk liquid/ commodities loading and unloading operations.
- Marine, ship navigation zones.
- Electricity and communication infrastructure.

3.2.3.4. Reviewing the Marine Zone

In general, the Marine Zone determination is performed by the PA and the Harbour Master, although these studies could also be performed by the BFO with external assistence under PA and Harbour Master supervision.

Carried out in order to undertake a detailed examination of maritime operations and identify potential issues associated with the supply from LBV and LBB approaching the Port for operations at the proposed sites. The aim is to establish the navigational critical scenarios required to be verified by real time Manoeuvring Simulations performed in compliance with IMO, Classification Societies and SIGTTO recommendations as applicable.

Typical verification studies could include the following operations as a guide, although each PA would determine the kind of verification studies that need to be performed in order to satisfy other Port traffic commercial operation requirements, while securing the safe transfer of LNG to Receiving Ships and the navigation of LNGC, LBV and LBB within Port:

- LBV Port approach and piloting procedures and exemptions
- Maritime Operations – LBV berthing at Terminal
- Maritime Operations – LBV / LBB ships operation within Port at designated areas
- Maritime Operations – LNG bunkering operations at designated areas
- Maritime Operations – Port Emergency Responses

In performing the above scenario studies, Port Authorities and Harbour Master could verify that the relevant standards are considered. As a minimum, it is recommenced to follow the requirements set by the Society of International Gas Tankers and Terminal Operators (SIGTTO) standards and the International Navigation Association (PIANC) standards.

In addition, Port Authorities and Harbour Master could verify that the maneuvering Simulation Studies are performed by a recognized / accredited organization. Such organization could typically perform the following studies for the case where LNG bunkering Vessels / Barges are entering the Port for access to a Gas Terminal or Jetty where loading and discharging LNG would take place:

- Determine the maximum size of the required type of LNGC that can be safely operated in the approach entry manoeuvre to the proposed LNG storage terminal site at Port for LNG unloading operations.
- Determine the maximum size of vessel able to approach and berth at the terminal jetty to be directly bunkered - LNG bunker feeder/barge to be loaded.
- Determine potential traffic congestion impact within the port due to the LNGC and bunkering vessel traffic.
- Determine the maximum size of the required type of vessels that can be safely operated in the berthing manoeuvre to their respective terminal quay inside the Port.
- Determine the number and size of tugs required for berthing operations of the largest size of planned visiting vessel.
- Consequences of the typical failure events for vessel Port entry and manoeuvring operations.
- Determine under which assumptions a pilotage exemption could be awarded

Other specific Port requirements might need to be considered within the scope of the Manoeuvring Simulation Studies on a case-by-case basis for each Port.

3.2.4. Verifying SIMOPS assessment

SIMOPS assessment should follow a 2-step approach (planning and implementation phase) as it indicates in **[SGMF guidelines for SIMOPS] and** [EMSA]**. Instead, these guidelines recommend that along with notification, the PA requires from the BFO, a SIMOP all parties declaration agreeing that supply conditions are going to be in accordance with SIMOPS Authorization.**

During the planning phase (license submission or authorization[2]) regular SIMOPS are identified and included in the RA as a way to evaluate SIMOPS risks and assess the required contingency measures. Steps of the planning phase according to SGMF guidelines should be:

1. **SIMOPS description, being the minimum amount of information required:**

    - Overview:
    - Description of the work activity
    - LNG Bunkering procedure
    - Roles and responsibilities: the number of personnel involved and whether they are employees or contractors supervised by employees, who is the SIMOPS supervisor and how the rest of roles interact and communicate.
    - The proximity of the work activity to the safety zone and hazardous zones
    - Whether any special equipment is required that may present a hazard
    - Whether staff involved in LNG bunkering also need to be involved in this activity
    - Whether the ESD system has been developed to cover this activity
    - Whether common control can be achieved and how communication is handled
    - Whether escape routes are affected by the SIMOPS activity
    - Whether the activity is consistent with the port plan for bunkering
    - Special mitigation measures

2. **Hazards of SIMOPS should be clearly specified (to be included in the RA)**: identification of potential interactions between the operation and LNG bunkering, the hazards resulting from this and the control measures that exist or could be considered.

3. **Risks should be assessed with the recommended methodology (QualRA or QRA depending the situation),** reviewing these against PA criteria/industry good practices to decide what barriers/mitigations may be required to reduce risks.

    Analysis 2 and 3 should be done along with the RA of the bunkering operation, if SIMOPS has not been evaluated prior to license submission, a new authorization should be provided, and the RA must be updated to consider the SIMOP.
    Only a QualRA would be required if SIMOPS are not going to take place in Hazardous Zones.

4. **Acceptance of all parties involved in the SIMOP:** The port/terminal operator should review local factors to determine that the SIMOP and LNG bunkering operation proposed does not include any risks that the terminal operator will find unacceptable. All three parties should agree that the SIMOP proposed risk level is acceptable, what mitigation measures exist and the roles of everyone involved. If a single party disagrees, the SIMOPS should not be allowed.

[2] Explained in next chapter, licenses contains authorizations addressing BFO,RSO and terminal joint specific conditions

5. **Approbation of the SIMOPS by the PA:** The PA must evaluate if SIMOP assessment has been properly performed according to the prescriptions established by the PA in the LNG BSS, that risk levels are acceptable according to the PA risk criteria and all parties involved agree on operation conditions. If SIMOP are recurrent, this process just happens once, but during the notification procedure the PA must check that the conditions considered match the actual conditions before they authorize the operation.

3.2.5. Verifying the content of the internal Emergency Response Plan (ERP)

The Port Authority or designated body would check that the internal ERP contents, as a minimum, will include the following emergency procedures that should be documented and shared by all parties involved:

- Protocol to deal with loss of manoeuvrability/power during berthing. Clear instructions should be provided to effect vessel control and avoid potential traffic impact on port operations. Including coordination with the Port Authority (harbour master) in requesting additional tug support.

- In the event of vessel collision, existing emergency response procedures developed for the Receiving Vessel's Master (ISM) should be employed. These procedures should be updated to address potential LNG leakage. Near term bunkering operations should be immediately suspended by the Port Authority and its resumption subject to an investigation.

- Instructions for mooring line failures should follow the existing safety management procedures for the Receiving Vessel's Master. Clear instructions should be provided to inspect and confirm the integrity of the connected LNG bunkering system, with the option of initiating an ESD II protocol should the operating window of the supporting arrangement be exceeded.

- Instructions for loss of power – both in bunker facility and the Receiving Vessel. In the event of partial or complete loss of power (i.e. vessel blackout), ESD I protocols should be initiated and followed making sure that the bunkering flow is stopped and the system isolated in a safe state.

- Vapour relief as a result of receiving tank overpressure. Instructions to initiate an ESD I, including investigation of the source of the defect/failure that led to the tank over-pressurisation and its rectification prior to re-starting the bunkering operations.

- In the event of LNG and / or vapour release during bunkering operation, an ESD I protocol should be initiated automatically (via gas detection) or manually via designated personnel. Procedures for the investigation, analysis and rectification of the source of the leakage shall be executed.

- Inadvertent ignition following a leakage event. Depending on the size and gravity of the leakage event a manual ESD II should be initiated and fire-fighting protocols should be applied. This will involve remote shutdown and isolation of both bunker facility and receiving vessel LNG systems, boundary cooling of fire-exposed LNG tank and piping and where possible, extinguishing the gas fire.

4. Overseeing LNG operations

The third stage in the LNG service deployment at the port, after planning the framework and licensing operators, is to oversee the operations, assuring they are performed as planned and as conditions of the license. This chapter deals with the tasks that the port must carry out daily in relation to LNG bunkering services.

4.1. Managing Notifications

As described in section [C 2.2], the third requirement to perform a bunkering operation is the notification from the BFO to the PA. The PA will have decided which department will receive the notification, the advance notice, and the content of the notification. At this state, the officer in charge would verify all the following conditions are met, otherwise, he would deny the operation.

Notifications must be made in advance as established by the LNG BSS. The following conditions would be verified, and all should be met:

1) The operation is fully covered under an existing active authorization under the operator's license.
   A good practice will be to provide the officer receiving the notifications with a summary of the current authorizations to check the notification. The information managed by the officer validating a notification would be clear and straight forward with no room for discrepancies. Should the BFO plan to change any of the authorized conditions, it should not use the notification channel but request an authorization change as described in the next section.

2) The operation will be carried out under the operational envelope laid down in the authorization.
   Weather and sea conditions for the hours ahead will be checked to assure conditions are met.

3) The planned traffic conditions do not prevent the safe execution of the service.
   Port movements, dredging, maintenance works or any other incompatible activities with the bunkering operations would be checked.

4) In case of SIMOPS: PA approval, detail of specials measures to be considered and personnel appointed to SIMOPS related communications.

The port will have established on the LNG BSS the conditions of response to the notification: confirmation required or accepted by default.

4.2. Change Management Procedure

Authorizations were initially approved as part of the Licensing process supported by all documentation required as described in section 3.1 of this guide, where the documentation folder content was detailed.

Therefore, adding a new Authorization to the License would require the same package of documentation, PA validation and formal approval.

The BFO should contact the PA whenever a planned operation exceeds the scope of its active Authorizations or needs to apply significant changes that recommend triggering the Change Management Procedure.

Based on the nature of the changes, the PA would opt either to update or extend an existing Authorization or issue a new one.

The specific risk assessment and associated Joint Bunkering Management Plan supporting an Authorization shall be re-visited when the study scenario assessed during the risk assessment deviates in at least one of the following:

- Different receiving vessel
- Different receiving vessel systems
- Different location
- Different bunkering mode
- Modification of operational procedures
- Introduction of SIMOPS operations
- Modification to bunkering equipment.

It is the BFOs responsibility to notify and trigger the change management procedures when any of the above situations occur, and always prior to the operation as their Authorization would not be supporting such operation. Notice that even slight changes could be considered a deviation are required to trigger the procedure if it alters the assumptions used in the risk assessment. Nevertheless, replacing of equipment with equivalent characteristics and certificates is not considered a relevant change, neither are personnel substitution with equivalent certifications and training, although these changes must be registered in the BFO management system.

It is advisable that the PA set a maximum valid period to the risk assessments supporting Authorizations. The recommended renewal period is 3 years and failure to comply with this obligation would set the Authorization on-hold.

All the above-mentioned causes are derived from operational changes introduced by any of the three parties involved in operations. PA's themselves can also be a source of change when introducing variations in the LNG BSS that affect active Authorizations. Normally, these changes would pursue improvements in safety by taking advantage of the latest technological advances or correcting aspects of risk based on best practices and international recommendations. When triggering these changes, PAs would decide when they need to be implemented, either immediately or postponed for existing Authorizations until their renewal.

The process described above addresses changes on Authorizations, however, it is also important to note that PAs could introduce changes in the administrative or economic terms of the Licenses that might alter the conditions of the provision of the service for all operators as happens with other port services.

4.3. Supervising

PAs will work with three main tools to supervise the LNG bunkering operations, once License and Authorizations have been awarded:

- **Audit of Management System**: as described in Chapter 2.11, BFOs must prove compliance with ISO 20519, listing conformance with the standard and declaring the avoidance of methane releases as a management objective in their systems. Audit of management systems will provide verifiable compliance. It is recommended request to the BFO a report including the external audits results of the BFO Management system every year..

- **Obligatory submission of information:** License holders are required to submit periodical information about the LNG bunkering activity to the PAs. It is recommended that BFOs submit periodically the following information:

    - Properly complimented and signed operational checklists used in the operations.
    - Copy of Bunker Delivery Notes issued by the BFO, according to ISO 23306:2020 or any model that stakeholders involved in the supply agree to employ
    - A report of any incident or accident that occurred during operations.
    - An activity report including supply volumes, receiving vessels, duration, and any other parameter that PAs can find useful to supervise the activity.
    - A specific report detailing situations where venting was inevitable.

- **On-site inspections:** with or without independent expert assistance, PAs can perform pre, during or post inspections of every aspect regulated on the LNG bunkering specifications to check that compliance is in place. **These on-site inspections are highly recommended in cases of a first operation to give the BFO the opportunity to prove the correct implementation of procedures, checklists, communications, and mitigation measures approved in the Authorization**.

[ANNEX I] Joint LNGBMP Detailed Content

1.1. Equipment

1.1.1. Verifying equipment and components of LBTs (TTS)

Type of Information	Applicable Standards, Class Rules, Regulations	Role: Class, Accredited Bodies	Role: Recommendation to PA
1. LNG Trailer and Truck LNG bunkering systems	-ADR EU agreement International Carriage of Dangerous Goods by Road -ISO Standards	Evaluation done by recognised accreditation Body (e.g. TUV, UL) -Classification Society via their Type Approval Scheme	Verify the records of the independent review, testing of the LNG tank and bunkering system undertaken by independent, accredited bodies and classification societies
1.1 LNG tank	ISO 1496-3 – 1 Tank Containers for Liquids, Gas		
	ISO 20088-1 cryogenic spillage resistance of insulation materials		
1.2 LNG fuel and transfer system	ISO/DIS 12614 Road Vehicles LNG system components		
Performance and general test methods	ISO/DIS 12614-2		
Check valves	ISO/DIS 12614-3		
Manual valves	ISO/DIS 12614-4		
Tank Pressure gauges	ISO/DIS 12614-5		
Overpressure regulator	ISO/DIS 12614-6		
Pressure relief valve	ISO/DIS 12614-7		
Excess flow valve	ISO/DIS 12614-8		
Gas-tight housing and ventilation hose	ISO/DIS 12614-9		
LNG and vapour piping	ISO/DIS 12614-10		
Fittings	ISO/DIS 12614-11		
Pressure control regulator	ISO/DIS 12614-13		
Diff. pressure LNG level gauge	ISO/DIS 12614-14		
Capacitance level gauge	ISO/DIS 12614-15		
Heat exchanger (vapouriser, pressure build up unit)	ISO/DIS 12614-16		
Fire Detector	ISO/DIS 12614-17		
Gas Detector	ISO/DIS 12614-17		
Temperature Sensor	ISO/DIS 12614-18		

1.1.2. Verifying equipment and components of LBV and LBB

Type of Information	Applicable Standards, Class Rules, Regulations	Role	
		Class, Accredited Bodies	Recommendation to PA
2. LNG Bunkering Barge, Vessel	Class Rules for Carriage of Liquefied Gases in Bulk, International Gas Carrier Code IGC	Component approvals done by Classification Society via Type Approval Scheme. -System review via design appraisal. -Sizing, capacity verification work using empirical requirements in Rules -Witnessing and evaluating different verification and validation tests	Verify the records (design appraisal, class certificate, test records) of the work done by Classification Societies
2.1 LNG Fuel Storage Tank	Class Rules, IGC Chapters 4, 6		
LNG tank insulation	Class Rules, IGC Chapters 4 and 9		
LNG tank double barrier	Class Rules, IGC Chapter 4		
Pressure Relief Valve(s)	Class Rules, IGC Chapters 8, 15 ISO 18154		
Vent Termination	Class Rules, IGC Chapter 8		
2.2. LNG Fuel Transfer System			
LNG Pumps (Supply, Spray/recirculating)	Class Rules, IGC Chapters 5,7		
Vapour Compressors	Class Rules, IGC Chapters 5,7		
Reliquefaction System	Class Rules, IGC Chapter 7		
Thermal Oxidisers	Class Rules, IGC Chapter 7		
Vacuum protection	Class Rules, IGC Chapter 8		
Inert gas system	Class Rules, IGC Chapter 8		
Heat Exchangers (Pressure Build-up Units, Vapourisers)	Class Rules, IGC Chapter 7		
Isolation Valves (Manual, Remote Operated)	Class Rules, IGC Chapters 5,7		
Relief Valves	Class Rules, IGC Chapter 5		
Pressure Sensors	Class Rules, IGC Chapter 13		
Temperature Sensors	Class Rules, IGC Chapter 13		
Tank level indicators	Class Rules, IGC Chapter 13		
Fittings	Class Rules, IGC Chapters 4,5,7		
LNG and vapour piping	Class Rules, IGC Chapters 5,7		
Gas Detectors	Class Rules, IGC Chapter 13		
Spill temperature detectors	Class Rules, IGC Chapter 13		
Fire Detection	Class Rules, IGC Chapter 11		
Fire Fighting	Class Rules, IGC Chapter 11		
ESD safety system	Class Rules, IGC Chapters 6,18		
Hazardous Area Classification	Class Rules, IGC Chapters 3,18		

1.1.3. Verifying equipment and components of LNG Storage Tank

		Role	
Type of Information	**Applicable Standards, Class Rules, Regulations**	**Accredited Bodies**	**Recommendation to PA**
3. LNG Storage Tank (Pipe to Ship LNG bunkering)	ISO standards, North American standards such as NFPA 59A, API 625/620	Component, equipment approvals may be done by recognised accreditation bodies such as TUV.	LNG Tank, LNG transfer system safety review could be performed by the Port Authority working in conjunction with other national, regional authorities and recognised LNG safety SMEs -given that fixed LNG tank installations will be mostly greater than 50 tonnes (110m3) and likely to exceed 200 tonnes (440 m3) the safety review of such installations should cover the requirements in the Seveso III directive.
3.1 LNG Fuel Storage Tank	ISO/AWI TR 18624 LNG Storage Tank Design and Testing Standard NFPA 59A Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG) API 625/620 Tank Systems for Refrigerated Liquefied Gas Storage		
LNG tank insulation			
LNG tank double barrier			
Pressure Relief Valve(s)			
Vent Termination			
3.2. LNG Fuel Transfer System			
LNG Pumps (Supply, Spray/re-circulating)	NFPA 59A		
Vapour Compressors	NFPA 59A		
Reliquefaction System	NFPA 59A		
Thermal Oxidisers	NFPA 59A		
Recondensers	NFPA 59A		
Vacuum protection	NFPA 59A		
Inert gas system	NFPA 59A		
Heat Exchangers (Pressure Build-up Units, Vapourisers)	NFPA 59A		
Isolation Valves (Manual, Remote Operated)	NFPA 59A, API 625/620		
Relief Valves	NFPA 59 ISO 21013 Pressure-relief cryogenic service		
Pressure Sensors	NFPA 59A, API 625/620		
Temperature Sensors	NFPA 59A, API 625/620		
Tank level indicators	NFPA 59A, API 625/620		
Fittings	NFPA 59A, API 625/620		
LNG and vapour piping	NFPA 59A, API 625/620		
Gas Detectors	NFPA 59A,		
Fire Detection	NFPA 59A		
Spill temperature detectors	NFPA 59A, API 625/620		
Fire Fighting	NFPA 59 A		
ESD safety system	NFPA 59A,		
Hazardous Area Classification	IEC 60079:10		

1.1.4. Verifying equipment and components of Gas-fuelled Ships / Receiving Vessels

Type of Information	Applicable Standards, Class Rules, Regulations	Role	
		Class, Accredited Bodies	Recommendation to PA
1. **Gas Fuelled Ship (Receiving LNG Ship)**	Class Rules for Ships using Gases as a Fuel, IGF		
4.1 LNG Fuel Storage Tank	Class Rules, IGF Chapter 6		
LNG tank insulation	Class Rules, IGF Chapter 6		
LNG tank double barrier	Class Rules, IGF Chapter 6		
Pressure Relief Valve(s)	Class Rules, IGF Chapter 6 ISO 18154		
Vent Termination	Class Rules, IGF Chapters 6,12		
4.2. LNG Fuel Receiving System			
LNG Pumps (Supply, Spray/recirculating)	Class Rules, IGF Chapter 9	-Component approvals done by Classification Society via Type Approval Scheme. -System review via design appraisal. -Sizing, capacity verification work using empirical requirements in Rules -Witnessing and evaluating different verification and validation tests	Verify the records (design appraisal, class certificate, test records) of the work done by classification societies
Vapour Compressors	Class Rules, IGF Chapter 9		
Reliquefaction System	Class Rules, IGF Chapter 6		
Thermal Oxidisers	Class Rules, IGF Chapter 6		
Inert gas system	Class Rules, IGF Chapters 6,8		
Heat Exchangers (Pressure Build-up Units, Vapourisers)	Class Rules, IGF Chapter 6		
Isolation Valves (Manual, Remote Operated)	Class Rules, IGF Chapters 6,7,8		
Relief Valves	Class Rules, IGF Chapter 6		
Pressure Sensors	Class Rules, IGF Chapters 6,15		
Temperature Sensors	Class Rules, IGF Chapter 6,8,15		
Tank level indicators	Class Rules, IGC Chapter 13		
Fittings	Class Rules, IGF Chapter 6		
LNG and vapour piping	Class Rules, IGC Chapters 5,7		
Gas Detectors	Class Rules, IGC Chapter 13		
Spill temperature detectors	Class Rules, IGC Chapter 13		
ESD safety system	Class Rules, IGC Chapters 6,18		
Hazardous Area Classification	Class Rules, IGC Chapters 3,18		

1.1.5. Verifying equipment and components of LNG bunkering transfer and safety systems

Type of Information	Applicable Standards, Class Rules, Regulations, Guidelines	Role	
		Class, Accredited Bodies	Port Authority recommendation
5. LNG Transfer (Bunkering) and Safety System	Class Rules, ISO 20519, IEC, NFPA standards		
5.1 Transfer components			
Cryogenic Hose	EN 1474-2, EN 12434		
Manifold flange	EN 1474-3		
Dry coupling, Quick connect, disconnect coupling	ISO 18683 ISO 21593		
Loading arm	EN 1474-3		
Swivel joint	EN 1474-3		
Bearing	EN 1474-3		
Integration of LNG Transfer components, equipment	Classification Rules IGC Code SIGTTO guides, technical notices SGMF guides EN 1474 EN ISO 28460 NFPA 59A	Component approvals done by Classification Society via Type Approval Scheme.	
5.2 Safety components		-Component, equipment approvals may be done by recognised accreditation bodies such as TUV. -System review via Class Society design appraisal.	Verify the records (design appraisal, class certificate, test records) of the work done by classification societies and accreditation bodies
Nitrogen purging	Class Rules, IGC, IGF Code		
Emergency shutdown valves	Class Rules, IGC, IGF Code		
Emergency Release Coupling	EN ISO 20519		
Pressure Relief Valves	Class Rules, IGC, IGF Code		
Powered Emergency Release Coupling (PERC)	**Proprietary designs - FMECA should be required if the PERC is not reviewed by class or other accredited bodies.		
Gas Detection	Class Rules, IGC, IGF Code		
Fire Detection	Class Rules, IGC, IGF Code		
Emergency shutdown system	EN ISO 20519, SIGTTO		
Hazardous Area Classification	Class Rules, IGC, IGF Code, EN 60079:10		
Fire Fighting	IGC Code IGF Code ISO 7203-1,2,3 NFPA 59A		

1.2. Procedures and Receiving vessel compatibility

1.2.1. Pre-bunkering, compatibility assessment procedures, including cool down of gas fuelled ship

- Compatibility checklist of mechanical and electrical connections between the Receiving Vessel manifold and the transfer system employed by the bunkering provider.
- Compatibility checklist for the LNG transfer control and safety (ESD) systems.
- Checklist for carrying out the cooling down of the receiving LNG tank and its LNG bunkering piping.
- Mooring plan and proposed fender system.
- Arrival draught, freeboard of the Receiving Vessel including the height of the bunker station above the waterline.
- Estimation of the height difference between the LNG supply and receiving manifolds for configuration of the LNG transfer system.
- Assessment of the prevailing local weather conditions.
- Identification and confirmation of availability of LNG bunkering personnel.

1.2.2. Safety zone, security area implementation, test of ESD and safety systems and notification of authority procedures

- Checklist confirming the correct safety zone based on the worst leakage scenario. This should include aggravating (e.g. sloping land) and mitigating features (e.g. drip trays, bunds).
- Instructions and checklist on the implementation of the security zone including the setting of barriers and assignment of security personnel.
- Checklists and up-to-date records of periodic inspection and testing of gas detectors, fire detectors and system alarms (i.e. in-line with OEM servicing manuals).
- Instructions to test the release mechanism of the powered emergency release coupling PERC including its link with the emergency shutdown ESD system. The test procedures should confirm that the release coupling and its initiation of the ESD are operational.
- Inventory list of personnel protective equipment (PPE) for all bunkering personnel.
- Agreed protocol involving notification of port authorities including consent that confirms if the bunkering operation can proceed.

1.2.3. Bunkering connection, inerting then natural gas purging procedures

- Instructions and checklist to complete multiple piping connections for liquid (LNG), saturated vapour (BOG) and inert gas.
- Instructions to verify the inerted condition of the LNG and vapour pipe. This will include checking the moisture and oxygen content in the transfer system.
- Warnings and caution prescribing the maximum amount of oxygen and moisture that can be tolerated in the system. Alternatively, instructions prescribing the minimum amount of inerting required by the system.
- Instructions to introduce natural gas (saturated vapour) to displace the inert gas and maintain the fuel quality in the receiving ship. This may be in the form of a purging time period.
- Procedures on how to safely dispose of the inert gas (N2) and gas-vapour mixture. This can be achieved using thermal oxidisers (i.e. gas combustion units) or compressing back the mixture to the BFO tanks. If any equipment is involved, the OEM operating instructions should be included in the procedure.

1.2.4. LNG filling/transfer procedures (start-main- topping up to filling limit sequence)

- Instructions to activate and operate the transfer equipment. Normally the LNG transfer will be achieved using a submerged centrifugal LNG pump. If this is the case, the pump OEM operating manual should be integrated into the procedure.
- If LNG transfer is achieved using a pressure build-up unit, clear instructions should be available on how to configure the valves that allow the LNG flow through the heat exchanger including the mechanism for heat exchange.
- Instructions to operate (open / close) both the receiving ship and bunkering asset LNG and vapour isolation valves.
- Operating instructions on how the LNG transfer system will be ramped up towards the design transfer rate.
- Checklist on the instrument (sensor) set points including normal bands and abnormal thresholds during the start-up – full flow – topping up phases of transfer operation.
- Instructions on carrying out bottom filling and top spraying operations (i.e. managing conditions in the receiving tank during bunkering).
- Instructions on how to slow down the transfer rate (i.e. topping up) before approaching the tank filling limit.
- Explanation and context behind the different high-level alarms and the required filling limit.

- Warning not to exceed the filling limit including operational instructions on how to remove excess LNG in the event that the filling limit threshold is breached.

1.2.5. Reviewing the LNG stripping, inerting and disconnection procedures

- Instructions on how to perform liquid line (LNG piping) stripping, including the operation of isolation valves and transfer equipment.
- Consequently, at the end of the line stripping procedure, there should be instructions to introduce nitrogen to displace the remaining gas vapour in both LNG and vapour piping prior to disconnection.
- There should be clear instructions on the length of the nitrogen purging period or consumption amount to make sure that the LNG and vapour lines are free of gas vapour.
- Instructions on de-activating the emergency release coupling.
- Procedure to disconnect the dry connect/disconnect coupling and safely stow the cryogenic hoses and supporting arrangements.

1.2.6. Reporting on the LNG quality

The predominant quality criterion considered by dual fuel engine and gas engine manufacturers is the gas's methane content which is used to derive lower or net calorific value (lower heating value) and methane number. Lower or net heating value defines how much gas is needed to get a full engine output. The lower the heating value the more gas one needs during combustion to generate the same power. Also weathering/ageing of LNG can cause a change in the composition of LNG. This results from the LNG supply chain, where the LNG will be continuously warmed by any small heat input entering from the surroundings, vaporizing it and producing vapor (boil off).

As the boiling points of different components within the LNG range widely, from -196 °C to +36 °C those constituents that have the lowest boiling points such as nitrogen and methane boil-off first, changing the initial composition and properties of the LNG.

Methane number predicts the gas' tendency to cause knocking in the engine during combustion. Methane number depends very much on gas quality and the more of the heavier hydrocarbon gasses (such as ethane, propane, butane) are concentrated in the gas, the lower the Methane number will be. Lower compression ratio in the engine can be used to compensate for low methane number, but this will come with a performance penalty in the form of lower efficiency output of the engine and corresponding higher emissions such as NOx and CO_2.