INSTRUMENT DEVELOPMENT AND APPLICATION

Port Bunker Mapping

Hamburg Port Authority

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1 EXECUTIVE SUMMARY

The document is presenting the development and application of the "Port Bunker Mapping" instrument by DNV in collaboration with the Hamburg Port Authority (HPA). This tool aims to evaluate and visualize the feasibility of low-flashpoint (LF) fuel bunkering sites, including LNG, Methanol, Ammonia, and Hydrogen in Baltic Sea ports to support the transition to climate-neutral shipping. The study is part of the Interreg project H²Derivatives@BalticSeaPorts, involving multiple Baltic Sea port authorities, research organizations and industry players.

The instrument is designed to aid shipping companies, port authorities, and bunker suppliers in operational planning, communication, and analysis for alternative fuel bunkering. Focusing initially on the Port of Hamburg, the instrument will be generalized and enrolled to the Baltic area with plans for an interactive mapping application in the future

How to read this document

This document is organised into chapters based on two phases.

- Phase 1 covers the main work packages involved in developing the Instrument,
- Phase 2 focuses on workflow and subsequent application.

To help you navigate the document, references are included throughout to enable direct access to relevant sections. The symbol "→" indicates a reference to the criteria catalogue, which should be reviewed at the same time. The sections on terms and definitions, as well as the Table of Contents and Table of Figures, have been moved to the end of the document to enhance readability. The Appendix provides additional information, including materials used during development.

2 INTRODUCTION

The shift towards climate-neutral shipping requires a fundamental change in technology, affecting energy efficiency, alternative fuels and carbon capturing among others. The 2023 adopted IMO GHG strategy target (IMO, 2023) is to reduce carbon intensity by 2030 to 30% and becoming net-zero emissions by 2050 based on 2008 values.

A significant paving tile on this pathway is the implementation of alternative fuels, which not only changes how we design and operate ships but also entails a drastic paradigm change in global shipping. We need also to review existing organisation, regulations, infrastructure and technology all related to marine fuels.

Low-flashpoint fuels (LF-fuels) include Hydrogen derivates like Ammonia or Methanol. Methanol and Liquefied Natural Gas (LNG) have a special role as they represent a transitional technology reducing CO_2 and air emissions. Ammonia as Hydrogen carrier discloses the biggest potential as combustion yielding only Nitrogen and Water, neutral substances to climate balance. The introduction of alternative fuels drives progress across ports and harbours in terms of port infrastructure and operational standards.

Port Bunker Mapping stands for a project aimed at evaluating and visualizing the feasibility of different sites in a port for LF fuel bunkering. This study is embedded into the Interreg project *H² Derivatives @ Baltic Sea Ports*, a joint project which connects port authorities, research organizations, maritime fuel providers and energy suppliers in the Baltic Sea region, (Interreg, 2026). HPA is the lead organization for the Port Bunker Mapping and serves as the interface between DNV and Interreg. Project partners include the Port of Kiel, Port of Tallinn, Port of Klaipeda, and the Swedish IVL Research Institute among others.

The development of a Port Bunker Mapping instrument (Interreg WP1.3, 2026) addresses this challenge by developing a harmonised framework for liquid Hydrogen and its derivatives, Methanol and Ammonia.

The universal instrument presented in this study is embedding previous works and cumulated experience in application of Safety Analyses for LF fuel bunkering *LNG-Bebunkerung im Hamburger Hafen – Cruise Center Steinwerder, Risikobewertung und Sicherheitskonzept* (DNV, 2019), *Methanol-Bebunkerung im Hamburger Hafen – Cruise Center Steinwerder, Risikobewertung und Sicherheitskonzept* (DNV, 2023) and *LNG-und MeoH-Bebunkerung im Waltershofer Hafen – Terminals Burchardkai und Predöhlkai, Risikobewertung und Sicherheitskonzept* (DNV, 2025). The universal instrument at hand is a generic framework, supporting analysis, ranking, and showcase of established or future bunker locations. It is intended to serve as the foundation to support the development of the following applications:

- Shipping companies and vessel operators will receive an overview of terminals in a port where bunkering is possible (or not feasible) for their operational planning.
- A shared communication tool, including for use between port authorities, shipping companies/vessel operators, and bunker suppliers.
- An analysis tool for the expansion and further development of alternative fuels.

In the second phase of the Interreg project (Work Package 2), the instrument will subsequently be applied and tested in the Port of Hamburg. The final outcome of the project – but not in scope of this study – is an interactive map, helping all parties to quickly navigate and select suitable bunker sites for implementing reliable, robust and reproducible bunkering procedures.

In addition it is also dedicated to

- establish the basis for an approval for individual bunkering operations,
- ensure bunkering operations all statutory and regulatory requirements are fulfilled and to

- ensure that required safety measures are in place and responsibilities as well as information exchange is guaranteed,
- Give a visual overview for all stakeholders in the bunker market.

All relevant international standards as well as national and local requirements are taken into account. To date, many of them are still under development but referenced herein. In the document on hand the term *national* explicitly refers to Germany and Hamburg, and all national and local regulations are regarded in Phase 2: Instrument Application.

This study is meant to deliver a paving tile to the road of integrated LF fuel bunkering. However, detailed bunkering procedures – as e.g. Bunker Management Plans or Joint Plans of Bunkering Operations – remain the responsibility of the operator and ship personnel and are outside the scope of this project.

Scope of the DNV part in brief:

- Phase 1: development of the universal instrument and formulate mapping criteria,
  - include requirements for bunker operations Ship-to-Ship, Truck-to-Ship & Shore-to-Ship,
  - include requirements for bunker media LNG, MeOH, NH_3 und H_2,
- Phase 2: application of the port bunker mapping instrument to selected bunker sites,
  - include 110 berth locations for bunkering of LNG and MeOH in Hamburg Port area,
  - include map presentation.

3 PHASE 1: INSTRUMENT DEVELOPMENT

The IAPH initiated the *Port Readiness Leve for Marine Fuels* project (PRL-MF) to help ports to evaluate their preparedness for implementation and handling alternative marine fuels bunkering, (IAPH, 2024). PRL-MF provides a structured, practical way to assess and improve the readiness for alternative fuel bunkering – from early planning to full operational capability.

In the Interreg project *H² Derivatives @ Baltic Sea Ports* (Interreg, 2026), the PRL-MF is directly operationalize and linked to PRL-MF, cf. Table 12 PRL-MF outlined. One of the deliveries of this join project is the *Baltic Ports Bunkering Guidebook* (GASUM, 2026).

DNV and HPA got together for the universal Port Bunker Mapping Instrument to assess bunkering site suitability, establish criteria, support the approval processes, and support to generate bunker manuals. The Instrument is linked to PRL-MFs 4-6, development phase. I.e. it is aligned with but not completely covers

- the design and early planning stage (PRL-MF 4): the framework design and
- the preparation and early operational stage (PRL-MF 5): the framework design.

The framework testing and pilot demonstration (PRL-MF 6) is not covered in here.

3.1 Methodology

This chapter entails the instrument to build-up the case study application, finally called “Port Bunker Mapping”. All sections in here represent an important part of the development phase of the Instrument. As there is no predefined sequence of action, each section stands for its own and should be read simultaneously.

The methodical approach follows the given proposed implementation concept from (HPA, 2025). For the first phase “development of the instrument”, it includes identification of the top categories and sub-categories of concern (→ taxonomy), the related components and criteria to building up the relationships as well as a description of each component.

The methodology follows not any strict top-down or bottom-up approach. It is more to understand as a guidance to estimate the appropriate criteria, whatever is concern and in scope. Albeit in the end a most common approach is to proceed bottom-up beginning from a specific location for practicality.

Port Bunker Mapping as well as the elaboration of a Bunker Manual (DNV, 2025) is based on the same requirements and fit the same generic approach:

- Elaboration of boundary conditions
- Performing Safety Analyses
- Performing Validation.

Bunkering operations involve numerous considerations, many of which are not addressed here in detail. E.g. from the regulatory standpoint, only high-level requirements are covered. Here the operator (facilitator of planning, risk assessment, bunkering etc.) is obliged to address the whole entity of details. The Instrument addresses the major aspects in the sense of a guard rail and furthermore linking the subsequent procedure.

The Port Bunker Mapping Instrument was developed under premise of giving support and guidance as mentioned. Some aspects herein are proprietary and linked to Hamburg Port boundary conditions. Other ways of applicating the Instrument are considerable and feasible.

So e.g. the *ISO 20519:2021 – Ships and Marine Technology – Specification for Bunkering LNG-fuelled Ships*, the reference guideline to perform risk assessments also for other LF fuels, points out different ways to perform; and even the validation and permission-giving process can be different. The Instrument is mainly following the methods of ISO 20519 but applying it to other LF fuels.

Regarding the process of bunkering, a wide range of aspects and safety measures is addressed:

Management:

- Bunker manual
- Joint bunker plan
- Control zones (hazardous/toxic, safety and security zone)

Procedures

- Compatibility check
- Pre-bunker / post-bunker meeting
- Hose handling, connection, testing, transfer, purging, inerting
- Executing SIMOPS

Technology

- Communication systems (radio/phone)
- Monitoring equipment (leakage detection, gas sensors)
- Control Systems (SSL, ESD, VSD)
- Safety equipment (DDC/QCDC, PERC, double-walled hoses, drip tray, water curtain, recondensation kits, PPE)

We do not step into the details but will point out in which category the individual parts are belonging.

3.2 Criteria catalogue

The criteria catalogue is the main part of Phase 1: Instrument development. In this section, the criteria are written out clearly. There are several different categories that need to be reviewed together and thus we have added cross references where necessary. As it is the philosophy of the Port Bunker Mapping to present human-readable content to easily work on, the criteria are designed not overly complicated. Section Taxonomy in the Appendix gives an overview of how the categories relate to each other and explains the terms.

The criteria catalogues are ordered and written in the form of checklists. They were made to date to the best of our knowledge and belief. However they might be incomplete or may not completely reflect the needs and requirements of a specific port. It is then required to adapt them to the port specific boundaries.

The criteria are ordered in a list of tables, in which – for simplification – the regards are ordered only in

- top categories,
- subcategories and
- requirements / description.

The top categorisation entails a risk, a risk of building up hierarchy where no such is. As this limitation is well known and addressed in , all the latter categories and sub-categories contain links to the adjacent categories to keep up with ontology approach.

The top categories denote the entity, and the subcategories belong to the properties or in GIS context: attributes. At those properties again different questions emerge. The “Coverage” keyword lists alle the do’s. Where the “Derived” keyword list everything what to look at next or being conditional if’s. The main structure is covering subcriteria related to

- law, rule and guideline requirements
- GIS position, navigation, accessibility requirements
- SIMOPS requirements
- Weather and other requirements, among others.

To bring order into criteria catalogue it is helpful to regard a structure of top categories. Any of those top categories are essential and belong to the overall Safety Analysis process at different hierarchical levels, see 4.1 Workflow. At this point is it helpful to list the top categories and concerning sub-categories briefly. For better understanding, the Safety Analysis level is referenced.

A complete table of categorized requirements is drafted in Appendix 7.7.

The top categories are

Location-based criteria (Land: directly affecting site selection)

- Regulations (International / European law, regional law, guidelines)
- Accessibility (TTS/CTS…) and ISPS,
- SIMOPS

Specific GIS Information is required for location-based criteria. For any object of bunker location e.g. as berth sites, terminals etc, a dedicated information needs to be stored in a GIS shape layer. The required GIS information in generic WKT format as follows:

- Shape, a closed polygon covering the extend and to estimate the minimum distance to, e.g. closed polygon((lat0, lon0, elev0), (lat1, lon1, elev1), …, (lat(n), lon(n), elev(n)), (lat0, lon0, elev0)), for n – vertices.
- Center (point(lon, lat, elev)), for addressing in a map tool for instance

Additional location specific parameters, e.g. for berth: berth length; for harbour: effective water depth is very helpful to make the work easy, but it can be added later. The implementation is matter of the GIS application and may be proprietary.

Location-based criteria (Marine: directly affecting site selection)

- Regulations (International / European law, regional law, guidelines)
- Accessibility
- SIMOPS

Bunker case criteria (directly affecting site selection)

- bunker technology
- bunker parameter
- SIMOPS

Vessel criteria (affecting the use case and the business case directly)

- Regulations, classification, certificates
- Technical capabilities, equipment
- SIMOPS

Operation-based criteria (indirectly affecting site selection)

- SIMOPS
- Crossing traffic

Climate and weather criteria

Then climate and weather criteria will be assessed during bunker approach. Statistics climate, sea state and weather data will be considered also in Phase 1 but on a higher level.

Proximity closest point

The proximity assessment is important to evaluate the safety distance to critical infrastructure, using the estimated Safety Zone from the latter QRA part of the Safety Analysis.

The Infrastructure is not taken as a specific top category but as a property in the criteria catalogue. We ask for the existence of such in the near vicinity. Infrastructure splits off in

- “normal infrastructure” to protect (bridges, locks, roads) and
- Critical infrastructure to protect (power plants, chemical production facilities, hospitals, schools…).

The GIS information of infrastructure is essential and needs to be implemented in the GIS system of choice. It requires as shown for location-based criteria as well:

- Shape, a closed polygon covering the extend and to estimate the minimum distance to, e.g. closed polygon((lat0, lon0, elev0), (lat1, lon1, elev1), …, (lat0, lon0, elev0)), vertices n+1
- Center (point(lon, lat, elev)).

3.2.1 Location-based categories

Location based criteria cover all information related to a specific geo location, whether it is land or in marine environment.

From that classification up it is deriving the categories marine and land, which additionally cover different requirements e.g. for navigation or SIMOPS, which are a part of → Operation-based criteria as well. Those “invoked” categories may require additional attention because they are linked to the below ones.

The subsequently listed category proximity is a derived category, as it requires the consideration of other objects, here nearby critical infrastructure for instance.

The criteria lists are to be applied to any kind of marine location category, whether it be berth’s or port waters. The same regarding the land categories.

Remark that some but at least one top category is overlapping: berth’s location is according to its nature a transition between land and water and so belonging to both.

Table 1 Marine category

Category	**Subcategory**	**Description**
Marine	General	The water-side category, covering all spatial and navigational limits for accessibility by BSV and RV respectively. Coverage: – Id – Name – Geo object category, e.g. waters, berth locations – Topologic relationships , e.g "berth bounds to harbour" – Description, if possible
	Regulatory	Laws and regulations applicable to the location. Coverage: – International law (e.g. IMO / SOLAS…) – Regional law (e.g. ADN…) – Local law (e.g. GGBVOHH, spec. navigation rules) – ISPS control level 1 Derived: – rules derived by → operational criteria, e.g. rules which emerge applicable by doing, e.g. water-site or vessel-side SIMOPS
	Bathymetry	The charted water depth at the location. Coverage: – Charted water depth – Draught limitations by means of other regulations Derived: – keel clearance and design draught requires cross validation with → vessel criteria – charted water depth requires regular updates from topographic survey
	Location	The location in RCS coordinates, covering its centre and extend. Coverage: – centre – shape – cartographic properties (colour, texture, boundary, etc.)
	Navigation	Category to cover accessibility of BSV and RV, e.g. room for manoeuvring, turning cycle, passing by traffic etc. Coverage: – space for manoeuvring (if applicable) – turning cycle (if applicable) – navigational constraints (derived from → bathymetry, nearby → infrastructure or similar) – passage width regarding cross traffic for aspired Ship-to-Ship transfer

		Derived: – crossing vessel traffic → port-side SIMOPS See also → Operation-based criteria Navigation access water-side / land-side
	Proximity	Proximity to existing infrastructure, e.g. residential area. This criterion needs to be evaluated in common with → infrastructure objects. Derived: – critical infrastructure (chem. Plants, power plants…) – transportation infrastructure (water locks, bridges, roads…) – residential area (homes, schools, business infrastructure…) – recreational area (nature reservates, protected biomes, protected species…) See also → proximity criteria
	SIMOPS	Expected SIMOPS access by waterways and vessel. Derived: – port-side SIMOPS – vessel-side SIMOPS – bunkering SIMOPS See also → operation-based criteria
	Weather	This is a requirement. Weather model, statistical climate data, statistical sea state. Note that current weather is part of the pre-bunker assessment. See → Climate and Weather criteria. Note that a specific place normally receives the climate at harbour site. That it is exposed in a special way is unlikely but to consider.
	Time limitations	Are there limitations for day- night-time regarding noise emission or similar?
	Miscellaneous	Miscellaneous requirements, if any.

Table 2 Land category

Category	Subcategory	Description
Land	General	The land-side category, covering the geo location and all spatial and accessibility limits by road. Coverage: – Id – Name – Category, e.g. terminal, berth location – Topologic relationships , e.g "terminal has berth" – Description, if possible

	Regulatory	Laws and regulations applicable to the location. This covers licenses and permissions as well for what the location is cleared. Coverage: – International law (e.g. IMO/SOLAS…) – Regional law (e.g. ADR…) – Local law (e.g. GGBVOHH, spec. terminal rules) – ISPS control level 1 Derived: – rules derived by operational criteria, e.g. rules which emerge applicable by doing, e.g. terminal-side or vessel-side SIMOPS
	Location	The location in RCS coordinates, covering centre and extend. Coverage: – centre – shape – cartographic properties (colour, texture, boundary…)
	Accessibility	Accessibility by road, ISPS level, other terminal traffic among others Coverage: – space for required onshore facilities – space for manoeuvring DG truck (if applicable) – accessibility by road given for DG truck – accessibility (derived from nearby →infrastructure or similar) Derived: – crossing terminal traffic See also → operation-based criteria
	Proximity	Proximity to existing infrastructure, e.g. residential area. This criterion needs to be evaluated in common with → infrastructure objects. Derived: – critical infrastructure (chem. Plants, power plants…) – transportation infrastructure (water locks, bridges, roads, …) – residential area (homes, schools business infrastructure…) – recreational area (nature reservates, protected biomes, protected species…) See also → risk-based criteria
	SIMOPS	Expected SIMOPS access by road and vessel. Derived: – terminal-side SIMOPS – vessel-side SIMOPS – Onshore Power Supply See also → operation-based criteria
	Weather	This is a requirement. Weather model, statistical climate, sea state and weather data

		See → Climate and Weather criteria. Note that a specific place normally receives the climate at harbour site. That it is exposed in a special way is unlikely but to consider.
	Miscellaneous	Miscellaneous requirements, if any.

3.2.2 Bunker Case criteria

A Bunker Case is an aggregate bunker procedure, for which the Bunker Setup to be used (like a template) and all parameters have to be applied. Beyond the Bunker Setup, the parameters include the bunker volume, bunker rate and other procedural parameters, safety equipment, ship type and data of the receiving vessel and specific bunker location, see Figure 3-2. It makes used of the predefined Bunker Setup, a constitution of bunker equipment, bunker fluid and bunker procedure disregard of a specific location and time as shown in Figure 3-1.

This simplification became apparent as appropriate for performing a Bunker Safety Analysis in an efficient way. As the requirements for location of a distinct category (site selection / evaluation) and Bunker Setup (regulations, operations) are not conflicting or overlapping, the easiest approach is to assess a Bunker Setup first and – on demand – inherit the setup to apply to the dedicated Bunker Case. This ensures that assessment work is not done twice and transparency is preserved. In terms of decision-making this is important, that the ancestry (were it was derived from) and the rationale (chain of arguments supporting the derivation) becomes evident.

Hence, a Bunker Setup becomes the least common denominator of any procedure and its permission-granting assessment. This means that a setup acts as the basis for the Safety Zone determination among others.

The below figures gain some insight into the simplified structure.

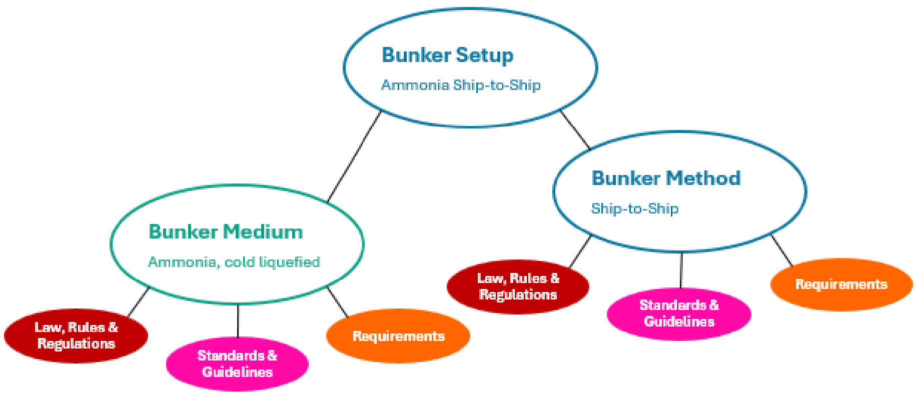

Figure 3-1 Bunker Setup, simplified

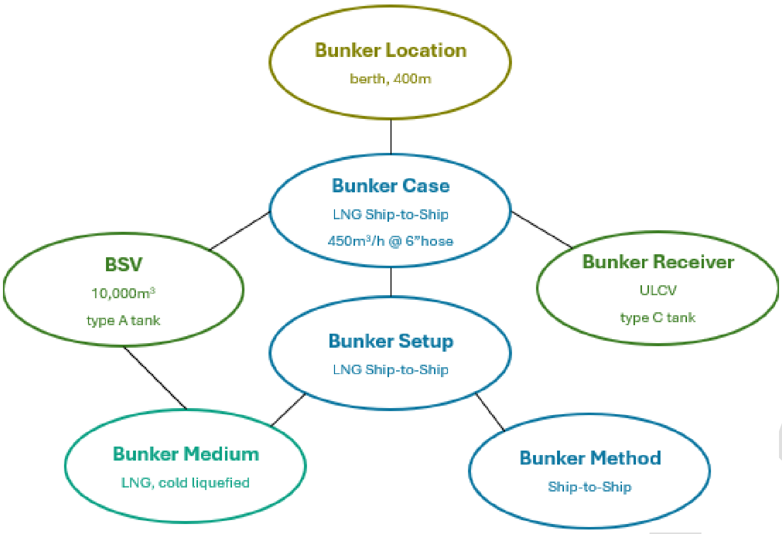

Figure 3-2 Bunker Case, even more simplified, with examples

Table 3 Bunker setup criteria

Category	**Subcategory**	**Description**
Setup	General	A constitution of bunker equipment, bunker fluid and bunker procedure (operation), free of time and location. This setup is the basis for the Safety Zone determination. Coverage: – Id – Category (Setup) name – Description is essential, including references to bunker fluid documentation / safety sheet and guidelines to bunker procedure – A brief description of the transfer technology
	Regulatory	Laws and regulations applicable to the setup. Coverage: – International law (e.g. IMO / SOLAS…) – Regional law (e.g. EMSA…) – Guidelines (e.g. SIGTTO; SGMF, …)
	Transfer properties	All properties which describe the process boundaries making it unique. Coverage: – bunker fluid properties – bunker fluid (e.g. LNG, cold liquefied) – techn. limits: max. bunker volume (e.g. small / large, 2000m³) – techn. limits: max. bunker rate (e.g. 450m³/h
	Transfer equipment	All equipment required for bunkering. Coverage: – Bunker transfer equipment (hoses, PERC., hose handling crane…) – Safety Equipment (ESD, VSD, sensors, drip tray…) – PPE

	Requirements	Which requirements to fulfil in order to use this setup in bunkering. Coverage: – Safety Analysis – Estimation of minimum safety distances, performing consequence-based or risk-based calculations – Training and training documentation
	Miscellaneous	Miscellaneous requirements, if any.

Table 4 Bunker case criteria

Category	Subcategory	Description
Case	General	An aggregate bunker procedure including the Bunker Setup, BSV, RV and a specific location. (Note that the Bunker Case does not entail a specific time. It is to come in at 4.1.12 Assessment during Approach) Coverage: – Id – Case name – Description is essential, including references to bunker fluid and guidelines to bunker procedure – including which vessel BSV / RV? – using which Setup?
	Regulatory	Laws and regulations applicable to the Case, if not yet defined in Setup. Coverage: – International law (e.g. IMO / SOLAS…) – Regional law (e.g. EMSA…) – Guidelines (e.g. SIGTTO; SGMF…) – Local law (e.g. GGBVOHH, spec. terminal rules) Note that the above rules & regulations are mentioned here for completeness. Applying the process systematically enables the inheritance of such rules in an easy way from → Setup, → Location, etc. and thus may not need to be operationalized here.
	Setup	The reference to the transfer procedure → Bunker Setup, free of location and time.
	Location	The reference to the location where the process is pursued, → Location-based categories
	Bunker Supplier	→ Vessel criteria BSV
	Bunker Receiver	→ Vessel criteria RV
	Requirements	Which requirements to fulfil in order to perform this specific bunker case? Coverage: – Regulatory: Safety Analysis – Procedural demands: who has priority in ESD line (lead bunkering)?

		– Required training and training documentation
	Miscellaneous	Miscellaneous requirements, if any.

3.2.3 Vessel criteria

Vessel-based cover regulations, classification, certificates as well as technical capabilities, equipment and SIMOPS.

This category applies to bunker supply vessel as well as for receiving vessels.

Table 5 Vessel criteria

Category	**Subcategory**	**Description**
Vessel	General	Coverage: – Id – Vessel type, IMO and name – Description is essential, list of main particulars and cargo hold properties including references to bunker fluid (BSV+RV) → – Bunker Case criteria including references to guidelines of applicable bunker procedures → – Operation-based criteria
	Regulatory	Laws and regulations applicable to the setup. Coverage: – International law (e.g. IMO / SOLAS…) – Regional law (e.g. EMSA…) – Guidelines (e.g. ISO, SGMF, …)
	SIMOPS	→ Operation-based criteria SIMOPS vessel-side
	Requirements	Which requirements to fulfil in order to connect this vessel in a bunker process? Coverage: – Navigational: pilot requirement – Transfer equipment – Technical safety equipment – Operational safety measures – Training and crew skills
	Miscellaneous	Miscellaneous requirements, if any.

3.2.4 Operation-based criteria

Operation-based criteria encompass all activities undertaken before, during, and after bunkering—covering both access and navigational aspects—as well as those related to simultaneous operations (SIMOPS). Risks associated with access and navigation, such as grounding or collisions on the marine or land side, are well recognised and should be addressed within the Individual Qualitative Risk Assessment.

The primary emphasis is placed on ensuring the safe execution of the bunker operation. For both terminal and ship operators, there is a commercial need to perform loading and bunkering processes efficiently. Consequently, simultaneous operations during bunkering (SIMOPS) are often necessary. However, SIMOPS demand careful evaluation of the relevant operational criteria listed below.

Further clarification regarding SIMOPS is essential, as these activities significantly impact subsequent procedures. Different types of SIMOPS may require distinct criteria and, therefore, a tailored individual approach to Safety Analysis. In addition to passenger ship to boarding and de-boarding, SIMOPS also encompass various other tasks pertinent to the vessel types under consideration:

- PAX embarking / disembarking / luggage
- Container loading operations, lashing / unlashing
- Bulk cargo operations, cranes, belt conveyor, …
- Gas carrier operations, jetty connection, …
- Rolling cargo operations, ramp movement, …
- Bunkering fuel / operating fluids / spares / provisions etc,
- garbage and wastewater disposal
- Maintenance and regular repair
- Boarding customs, coast guard, authorities, personnel etc.
- Terminal traffic: trucks / van carrier etc.
- Onshore Power Supply

To date, SIMOPS are considered to be a requirement of the Receiving Vessel, rather than any other party (such as the Terminal or BSV). These operations are carried out both on the terminal side and the water side. The following criteria apply not only to bunker operations but also to any other operation, including SIMOPS.

Table 6 Operations category

Category	Subcategory	Description
Operation	General	The procedural category, covering all the operations related to bunkering, disregard whether they are performed before, after or simultaneously to bunkering. Coverage: – Id – Name – Category / Setup, e.g. Ship-to-Ship bunkering

		– Description is essential, including references, invoking or follow up procedures
	Regulatory	Laws and regulations applicable to the operation. Coverage: – International law (e.g. IMO / SOLAS…) – Regional law (e.g. EMSA…) – Local law and regulations (e.g. by terminal operator) – Guidelines (e.g. SIGTTO, SGMF, …) – ISPS control level 1 Derived: – rules derived by location-based criteria, e.g. rules which emerge applicable by doing the operation at the respective location
	Navigation, Accessibility water-side	Coverage: – Is accessibility required and given for water-based operations? – Does marine offloading facility (MOF) exist for the transfer of equipment?
	Navigation, Accessibility shore-side	Coverage: – Is accessibility required and given for land-based operations? – Is road transport of equipment operable?
	SIMOPS general	Coverage: – Which type of SIMOPS operation? – Who is demanding? (RV, Terminal) – Does it tangent the Safety Zone? – Does it comprise ignition sources?
	SIMOPS onshore power supply	Coverage: – Does it tangent the Safety Zone? – Does it comprise ignition sources? – Is vessel or bunkering power supply backed up by UPS? – Was Power outage / shortage ever reported in the past during OPS use?
	Weather limits	Coverage: – What are the weather limits (wind speed, precipitation)? – What are the sea state limits (current, wave heights, wave direction)? Derived: – Weather assessment as part of the pre-bunkering See also → climate and weather criteria.
	Miscellaneous	Miscellaneous requirements, if any.

3.2.5 Climate and weather criteria

Table 7 Climate and weather criteria

Category	**Subcategory**	**Description**
Climate	General	Coverage: – Id – Name it: Middle European Moderate Climate – Description, if possible

	Climate Model	Statistical Climate Model
		
		Coverage:
		– Weather models (e.g. for use in safety distance calculations),
		– including
		    – steadiness,
		    – main wind directions,
		    – wind speeds over a year

	Sea State	Statistical Sea State Model (WMO) Coverage: – tidal changes – Wave atlas (seasonal averaged height, period, and direction) – Persistent or changing currents (e.g. in estuary)

	Weather	The actual weather and sea state
		
		Coverage:
		– Weather forecast from trustworthy source acc. best practise
		– Including
		    – Wind
		    – Temperature, humidity, dew point
		    – Precipitation
		    – Tide,
		    – Waves,
		    – Currents,
		    – Ice coverage

	Requirements	Location needs to be defined in order to forecast. This is linked to Land and Marine Category → Location-based categories.
	Miscellaneous	Miscellaneous requirements, if any.

3.2.6 Proximity – Closest Point

The proximity assessment is important to evaluate the safety distance to critical infrastructure, using the estimated Safety Zone from the latter QRA part of the Safety Analysis. Generally, proximity refers to the state of being near in space, time, or relationship. In here only the spatial aspect is meant, namely the distance between geo objects in topography. For this purpose the Euclidean minimum distance has to be estimated. It is done by accumulating (measuring) any pair of points on the RCS ETRS89 / UTM (the Euclidean tangential system to the geodetic coordinate system):

$$d(A,B) = \min_{a \in A, b \in B} \|a - b\|$$

with A, B – shapes (objects) and a, b – entity of infinitely dense point vectors on the rim of A or B resp. Note that using only the rim instead of the surface is an appropriate simplification. This approach becomes valid under the pre-assumption that A and B are disjunct, they do not overlap or include each other, nor they entail holes.

Closest Point of Proximity point (CPP) is a phrase conceived for this purpose. It describes the shortest geodetic distance in RCS between two spatial objects in 2D-plane. If any required minimum safety distance is undercut by CPP, a violation exists and can be detected.

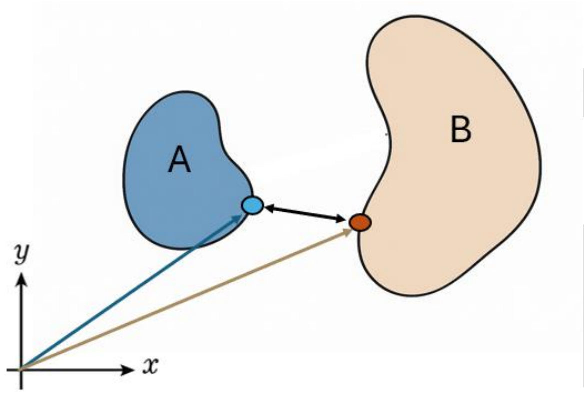

Figure 3-3 Closest Point of Proximity (CPP)

Table 8 Proximity requirements

Category	**Subcategory**	**Description**
Proximity	General	The closest distance to adjacent – residential area, – leisure area, – military bases, – storages holding inflammable goods or explosives, – sensitive production facilities, – airports or air corridors, – heritage (archaeological) sites, – nature reservates / ecological protection zone, among other locations not mentioned here.
	Requirements	Coverage: – geographic studies to assess infrastructure (find, list, categorize, digitalize, publish) – Evaluation of Safety Distances

		Note that the estimation of Safety Distances is implied in the Safety Analysis process to assess a Bunker Case.
	Miscellaneous	Miscellaneous requirements, if any.

3.3 Selection of potential bunker sites

Side selection is an essential prerequisite on the way of understanding and evaluating of risks. Although it is not the concern of this report it is mentioned here for completeness. The sites must be assessed and has to satisfy several criteria, including strategic and operational feasibility, operational and environmental constraints and accessibility by different means among others.

The following considerations must be regarded during and after site selection:

- shortlisting potential sites based on a set of conditions that are required or beneficial to develop the pilot for bunker transfer at early stage,
- a quantitative evaluation using a decision-making system to select and rank the suitable sites for pilot bunkering,

it is important that all steps undergo a validation, whether simultaneously or in a latter phase before or during approval. The Safety Analysis and the alignment with stakeholders and relevant permission-giving authorities ensure the site suitability.

A site pre-selection was conducted by HPA to identify the most feasible sites for a LF fuel bunkering, deviating from the proposed workflow, see also 4.1 Workflow. Ideally, this is part of Part 2, the application of the Instrument. The selection methodology to date was under development, but certain criteria as well as decision-making were applied.

To ensure a selected site is appropriate for bunkering, it must meet the following requirements:

- sufficient space landside to develop the required onshore facilities
- accessible for the type and size of vessels recommended for pilot bunkering operations, supported by adequate sea access, space and water depth
- allowance for safe operations by having sufficient distance from the safety zone to critical infrastructure

The following would also be beneficial:

- the development potential to scale beyond the pilot phase for future commercial operations
- the presence of potential downstream users and onshore chemical storage area
- ability to accommodate both SHTS and STS transfer operations

The above considerations should initiate discussions with industry stakeholders which assist the site selection. Site operators' buy-in is crucial, and their input is valuable for future talks.

HPA's selection strategy is outlined in the following and may differ depending on local situation. The criteria for sorting out were:

- tanker port / not a tanker port (local regulatory criterion),
- size restrictions for STS, width & draft of bunkering vessels, as these tend to get larger,
- changes in area and repurposing of port areas, e.g. Steinwerder Süd or conversions for residential development
- HPA's own berths which have not been used for bunkering so far
- berths for ships that do not bunker at berth. In Hamburg, these are internal harbour ships, e.g., barges, which bunker at a fixed bunkering station.

- berths for which Risk Analysis‘ or Risk Assessments have been conducted (e.g. CC3, Waltershof)
- waiting berths (Warteliegeplätze)

The following aspects may rather be optional, or it should be discussed whether they should be excluded across the board:

- location: directly in front of a lock and bridge, directly in front of residential buildings and public hot spots (e.g., Elbphilharmonie)
- weighing effort vs. benefit → berths that are only rarely used during the year and have so far not been used for bunkering at all.

3.3.1 Site Evaluation

The site evaluation is the primary step in application of the Instrument. It is based on a scoring system, qualitatively and quantitatively ranking pre-selected sites and shortlist only the suitable ones for bunker development. The responsibility is at the particular Port Authority, which defines the corner stones, instructs and supports the institute assigned with facilitating the evaluation.

A thorough site evaluation guideline is given in (SIGGTO, 1997) for LNG. It points out that the overarching goal is the minimization of the risk by adapting the frequency or mitigating the consequences. Those risks can be of different kind: environmental, navigational, technical or procedural to name a few. The evaluation is supposed to be the data population phase to get there. It is particularly governed by the following considerations:

- The pre-selection has been done based on high-level considerations. The most suitable bunker sites were selected from a bird’s perspective. If there are counter-indications appearing in between; site is neglected. This requires basic knowledge about aspired bunker setup as well as bunker medium and transfer procedure, as they affect local criteria.
- The site evaluation is based on a deeper look. Proceed on operating the catalogue for marine-based and land-based criteria one-by-one until all questions have been answered. This can be done in a process of self-assessment or by 3rd party.
- Additionally: do further requirements exist? Do records of the real distances to infrastructure exist? They will be needed in the next step.

For deriving the answer, the criteria catalogue should be assessed one by one, as shown in 3.2. If one of the questions is not evaluated with a positive answer, at least one shortcoming exists and it can not be closed with a positive result. The current implementation requires all responses to be positive to go ahead. But it is considerable, that specific criteria might be an easy-win and hence the answer “No, but it needs adaptations to develop bunkering” can be stated. A list of follow-up actions to address needs should be provided here.

The final response of the site evaluation is the binary score given by the instrument: whether green – bunkering permittable within the boundaries of the instrument or red – not possible. The instrument enables this process to be carried out in a straightforward manner. The scoring system is described in section 3.4 Scoring System.

A subsequent site validation, preferably done by a 3rd party is not mandatory for process assurance. But it is highly likely that the approving authority requires any kind of validation. To achieve a good collaboration, the validation can be done in a latter phase, e.g in 4.1.7 Individual Qualitative Risk Assessment. Also the bunker partners need to validate if they can implement all requirements. The approval body may need to validate based on the available information.

3.4 Scoring System

The final response to the site selection phase is the binary score given by the instrument: the strict binary answer whether

- Green – Yes, bunkering permittable within the boundaries of the instrument or
- Red – No, not possible. The Red colour means also eliminating the site from further evaluation.

The colour-code does not reflects potential risks, limitations or additional costs that may be associated with each site, only giving a binary statement. Also in the criteria catalogue all criteria in question are equally weighted. A more sophisticated weighting system could be recommended – especially with respect to further site development using the development potential of bunker sites. A traffic light colour

- Yellow – Needs adaptations to develop bunkering

could be beneficial here in combination with a numeric score. if a question is not evaluated with a positive answer, namely at least one shortcoming exists, site scoring can not be closed with a positive result. It is considerable, that specific criteria might be an easy-win and hence the answer “No, but it needs adaptations to develop bunkering” can be stated. A list of follow-up actions to address needs and to improve the score must be provided in this case.

The traffic light analysis and penalty point system was inspired by the “Singapore Ampel” and adapted, see (DNV, 2023).

Table 9 Scoring proposal

Green	**Yes**, possible	Bunkering feasible within the requirements made in the Bunker Manual.
Yellow (not in scope)	**No**, shortcomings	Needs adaptations to develop bunkering. A list of required actions needs to be given.
Red	**Not feasible**, permitted	Major counter indications exist. No bunkering within the limits of the Bunker Manual.

3.5 Safety Analysis

We suggest choice of one of methods in *ISO 20519:2021 – Ships and Marine Technology – Specification for Bunkering LNG-fuelled Ships* (ISO, 2021), the reference guideline to perform risk assessments also for other LF fuels. The document reads:

> If the risk assessment is being performed to meet a requirement set by national or local authorities that have jurisdiction over the safety and security where the bunkering operation take place, the assessment methodology used should conform to the requirements set by the authorities.

It shows up different ways to perform, and we cannot prescribe a dedicated method as we do not know the local boundary conditions. In the following a suitable approach is pointed out, which was – with success – carried out in (DNV, 2019), (DNV, 2023) and (DNV, 2025).

3.5.1 Safety Philosophy

Risks are assessed with regard to the probability of occurrence and the consequence / extent of damage of an event. The combination of probability and consequence creates the risk. Low risks are accepted; high risks are viewed as unacceptable and must be eliminated through appropriate measures.

The Safety Philosophy defines for medium risks the ALARP principle: As Low As Reasonably Practicable. I.e., for an evaluated medium risk a reduction of the risk using appropriate measures is required as long as the expense for the measures to take can be reasonably justified and the implementation of the measures are practicable, see figure below emphasizing this principle.

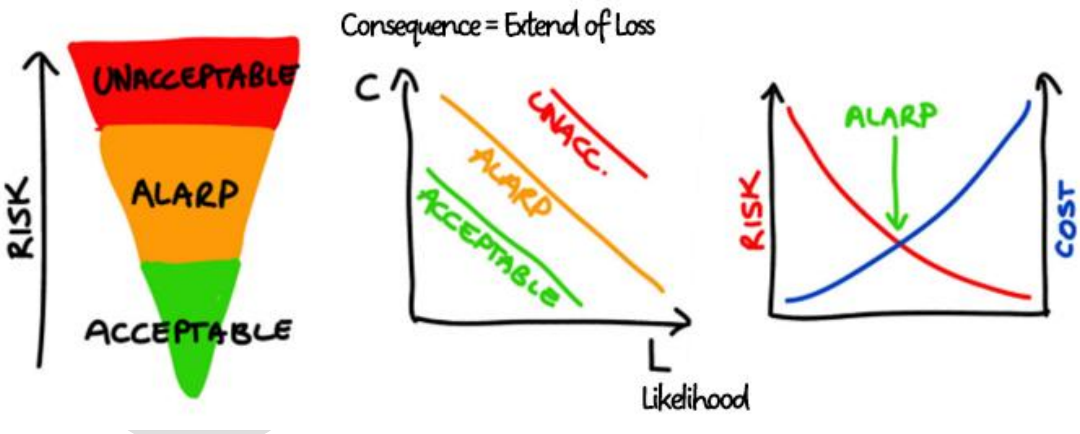

Figure 3-4 Safety philosophy: ALARP

The Evaluation of the risks, the probability of occurrence and consequences / severity of effects is based on the risk matrix, shown below.

Their metrics are based on the scales proposed in

- ISO/TS 16901:2022 *Guidance on performing risk assessment in the design of onshore LNG installations including the ship/shore interface* and
- ISO/TS 17776:2016 *Petroleum and natural gas industries — Offshore production installations — Major accident hazard management during the design of new installations*

and accepted as best practise for HPA projects.

3.5.2 Qualitative Risk Analysis – HAZID

To keep pace with the complexity come along with innovative technologies, tool is required to systematically list technology- and operational connected hazards in a detailed, structured, and methodical way.

The HAZID is one of certain options of performing a Qualitative Risk Assessment, (ISO 16909, 2022). It represents a technique used for early identification of potential, with a specific concept, design, operation, or activity associated hazards and threats. Its goal is to assess and control or mitigate the identified hazards to ensure the required safety level is met per internationally recognized standard requirements.

It is also suited to the identification of non-process related hazards such as ship collision, dropped objects, extreme weather, SIMOPS etc. The effect or possible consequence of an inadvertent incident is itemized and the potential causes determined.

A HAZID is usually supported by a facilitator and held in form a workshop, connecting representatives and specialists with domain knowledge and experience. The below figure shows the methodology of a HAZID workshop:

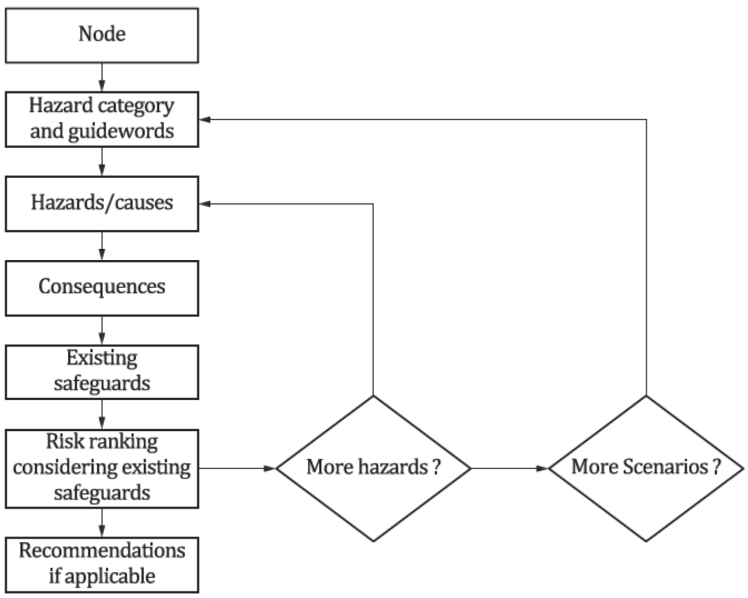

Figure 3-5 HAZID methodology

The Bunker HAZID, as a specific type of HAZID, warrants further discussion due to its particular relevance in this context. The Bunker HAZID goes along with the following topics:

- identification and evaluation of risks related to bunkering of LF fuelled vessels at a specific bunker site,
    - identification of relevant risks,
    - qualitative evaluation of the occurrence probability (likelihood),
    - qualitative evaluation of the consequences (severity),
- identification of preventive (operational and technical) measures for risk reduction,

- identification of mitigative measures,
- conducting a risk ranking and
- building-up the basis for further evaluations.

3.5.3 General Qualitative Risk Assessment (general HAZID)

This part is to be used in multiple risk assessments. It does not cover a specific location nor specific time. If the outcome of a General Qualitative Risk Assessment supports a bunker process and its parameters, it can be used as a template. The outcome is a generic Bunker Management Plan or Bunker Manual for a specified fuel and bunker procedure.

General Qualitative Risk Assessment covers :

- Rules & Guidelines (international / regional),
- climate / tide / currents,
- nautical conditions and port facilities,
- bunker fluid and properties,
- bunker mode and process parameters (time limitations, pressure, bunker rate, bunker equipment, etc.),
- BSV specific conditions (size, type, certificates, etc.),
- ship (RV) specific conditions (size, type, cargo, certificates),
- SIMOPS (general & BSV),
- Identification of possible accidents and evaluation of their consequences and
- Safety measures.

3.5.4 Individual Qualitative Risk Assessment (location-based HAZID)

The Individual Qualitative Risk Assessment is location-specific but does not entail a time for bunkering. It can be understood as as continuation of the above General Qualitative Risk Assessment wit stepping deeper into question arising with the location, see Location-based categories for detail.

The Individual Qualitative Risk Assessment covers

- local conditions (range, proximity, population, presence of persons),
- type of goods,
- local traffic,
- SIMOPS (RV & terminal),
- mooring concept,
- Identification of possible accidents and evaluation of their consequences and

– Safety measures.

The outcome of the Individual Qualitative Risk Assessment is the Bunker Management Plan or Bunker Manual, adapted for the specified location and the Joint Plan of Bunker Operation (JPBO).

The dedicated bunker permission issued by the respective approving body in the next stage verification process.

Specific in Hamburg Port area this is achieved by the GGBVOHH Einzelausnahmegenehmigung (individual certificate of exemption – issued by WSP (Harbour Police).

3.5.4.1 Safety Zone Assessment – Quantitative Risk Assessment (QRA)

The identification of hazards based on zoning concept, risk definitions (occurrence and likelihood) has been done in the Individual Qualitative Risk Assessment above (cf. QRA), given for an individual location. There also the risk levels were defined, which now form the basis for the quantification of safety distances.

There are no prescribed tools to use but implementation of best industry practice is recommended. To name here:

- BASiL (Bunkering Area Safety information LNG) as an automated gas dispersion tool from (SGMF, 2026) or
- SAFETI & PHAST, a software for quantitative risk analysis (DNV, 2026) among others.

The quantification of hazards can be carried out by evaluating the results of the HAZID using PHAST. PHAST can be set up to perform dispersion calculations for a batch of individual scenarios. It determines the maximum spread of potentially ignitable or toxic gas clouds. This is basis for the so-called deterministic or consequence-based approach in QRA.

In addition, SAFETI – the sibling of PHAST – enables probabilistic assessments of hazard risk. For this purpose, the before in PHAST defined leakage scenarios are taken and linked together with corresponding leakage frequencies from an implemented database. SAFETI then calculates the overall risk and presents it in the form of risk contours, see Figure below. This approach is the so-called risk-based approach.

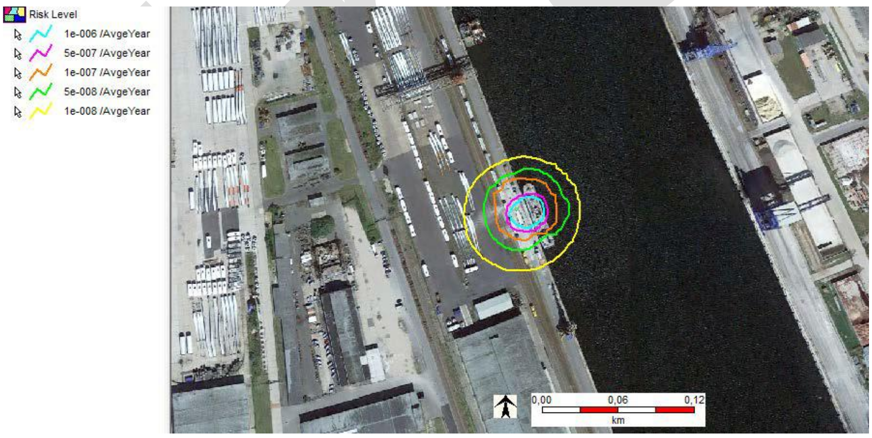

Figure 3-6 Risk contours from SAFETI for a bunker site with a given set of release scenarios

3.5.4.2 Control Zones

The concept for defining the control zones generally follows the philosophy in ISO 20519. A zoning concept entails a proper segregation of zones in order to identify different responsibilities and to take appropriate response measure in case of an incident. Hierarchically ordered it is aspired to have no overlapping zones. It can be understood as an onion model, where innermost zones with stricter requirements are a subset of the next outermost one. Exemptions here are the “No-cargo-operations” Zone which is defined for a dedicated purpose to avoid dropping objects, the marine zone which only extends waterside and the Security Zone which has specific requirements (monitoring / preventing SIMOPS) and hence may overlay across the other zones.

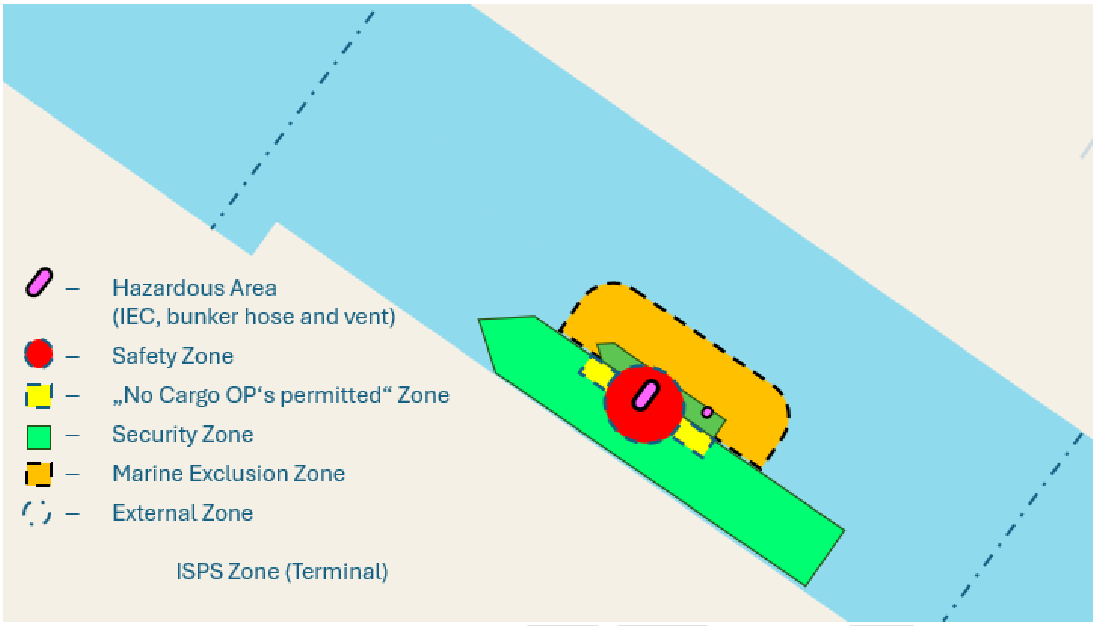

Figure 3-7 Control zones as defined in the HAZID

Hazardous Area

The Hazardous Area is a 3D zone where the presence of a toxic, combustible and / or explosive atmosphere is expected to occur frequently. In such quantities that special precautions are required to protect the safety of workers, third-party personnel and materials. The zone is defined in accordance with the International Standard for the Classification of Hazardous Areas, IEC EN 60079-10-1, (ANSI / IEC, 2015).

Safety Zone

The Safety Zone is a 3D zone during bunkering around the transfer system (or other relevant hazard source), determined from the result of a leak or emergency discharge or vapor return occurring. SIMOPS and passing traffic may be prohibited or strictly controlled to maintain safety. Purpose is avoiding the ingress of ignition sources and avoiding risk exposure of / to people.

In order to establish the Safety Zone size, the (EMSA, 2018) guidance refers to both deterministic and risk-based / probabilistic approaches.

- **Deterministic approach**
  Analytical approach based on first principle (mathematical) equations. For several release scenarios, defined in the bunkering HAZID, worst-case scenarios are derived as the maximum possible release distances, satisfying the exposure thresholds required by regulations. Subsequently the Safety Zone is then defined as the enveloping radius encountering for each of the calculated distances around the Hazardous Area.

- **Probabilistic approach**
  The most representative Safety Zone distances can be determined by a probabilistic (risk-based) approach. This may allow for establishing of rather smaller zones if the risk to potentially exposed populations can be

demonstrated to be acceptable. This approach includes the assumption of the statistical evidence of the likelihood of occurrence. Here, a well-defined maximum LSIR is taken for practicality.

See Ammonia Bunkering as well *in Hamburg Port – Terminals Cruise Center Steinwerder, Waltershofer Hafen and O'Swaldkai, Risik Analysis & Safety Concept* (DNV, 2026) for details.

"No-cargo-operations" zone

This zone with the unspecific name is a construction to prevent from falling objects onto the BSV's deck by permitting cargo operations. It was introduced in (DNV, 2025) in order to take account for required SIMOPS at the container terminals in Waltershofer Hafen; as there are container loading operations, container bridge movements and lashing / unlashing operations. The zone extend was derived form the best-practise approach of a large container shipping company and in depth discussed in (DNV, 2025). A paradigmatic picture is given below.

Monitoring Zone and Security Zone

An area around the bunker transfer system (or other relevant hazard source) that needs to be monitored as a precautionary measure to prevent interference with the hazardous operation or facility, i.e., the bunkering operation. Unlike the Hazardous Zones and Safety Zone, which are determined by the probability of the presence of an explosive atmosphere in the respective control zones and the need to mitigate the risk of ignition and escalation of the accident, the Security Zone addresses the external factors.

The following activities (external to the Safety Zone) should be monitored within the Security Zone:

- other ships, either passing or at berth.
- surrounding road traffic / vehicle movements and industrial activities,
- cranes and other loading / unloading operations,
- construction and maintenance activities and
- drones.

The Security Zone is the responsibility of the Port Authority, reflecting the situational awareness of the port area in any given moment, (EMSA, 2018).

Marine Exclusion Zone

The Marine Exclusion Zone is a zone of sufficient size to prevent passing shipping from impacting the hazardous facilities, namely the BSV and the receiving vessel. It is closely linked to the above Monitoring and Security Zone with the additional requirement to protect against any vessel / shipping impact potential. It is not necessarily a uniform zone but has unconditionally to satisfy the 30m Safety Zone radius required by (GGBVOHH, 2025).

In addition, the Marine Exclusion Zone takes account for special barriers / safeguards, technical conditions (e.g. ship types, pilot boats, tugs); and which traffic control is implemented or practically feasible in this area.

This Zone must be reasonably defined by the Nautische Zentrale in cooperation with the terminal operator, the bunker suppliers and bunker receivers.

External Zone

The External Zone (or Assessment Zone) is the outermost zone which serves to identify, inform and prepare third parties and the public for the potential for releases and appropriate responses in case of exposure. While the Safety Zone – in effect – provides the immediate separation of the bunkering facility from other facilities and activities within the port, some jurisdictions may require the establishment of an External Zone to provide a certain risk-level and separation to off-site / external populations, see Figure 3-7. The External Zone is determined by local regulatory requirements.

3.5.4.3 Evaluation of Safety Distances

After the QRA has been performed, yielding the extend of risk contours defining the Safety Zone it is required to evaluate the clearance for safety distances to infrastructure objects. This can only be done in a geo information system, see Open GIS data formats and toolboxes, manual approach would be too tedious here.

If the measure CPP (Proximity – Closest Point) can state a sufficient clear distance from critical infrastructure, this step can be closed with success. Other wise the process stops here with RED, not feasible or it has to return to former steps to evaluate the potential of improvement[1].

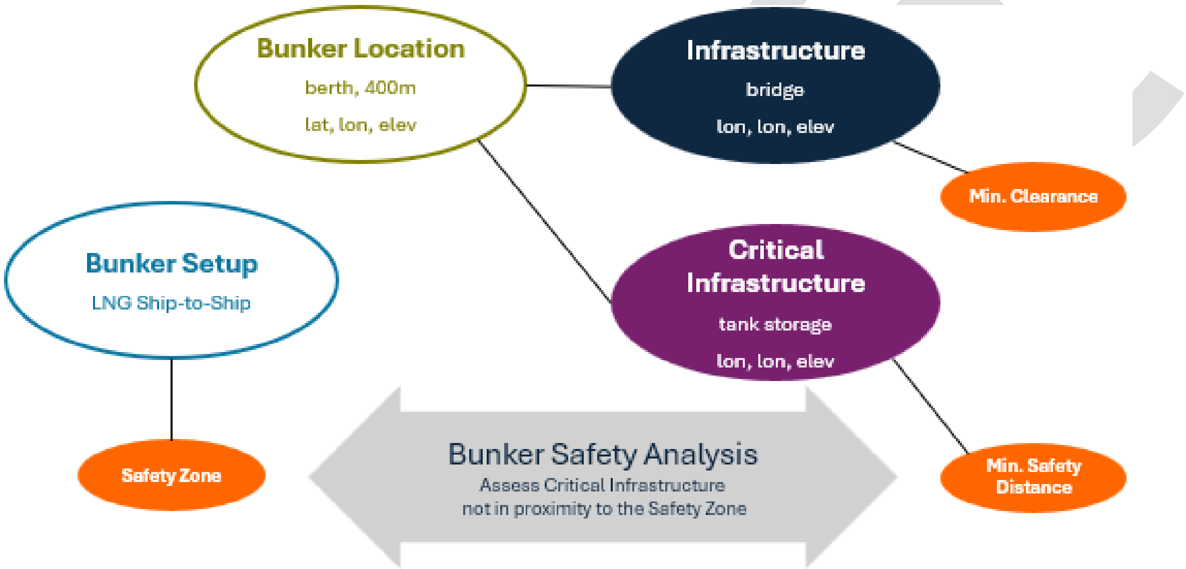

Figure 3-8 Evaluation of Safety distance after estimation of Safety Zone

[1] Note that in a project continuation this might by a YELLOW flag: "Needs adaptations to develop bunkering. A list of required actions needs to be given."

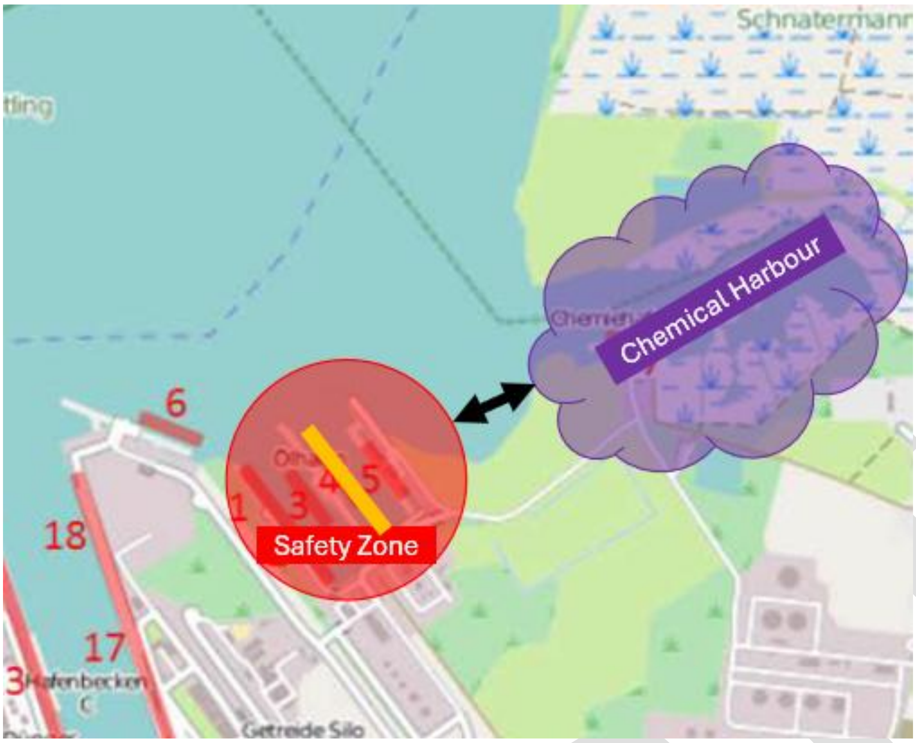

Figure 3-9 An example of estimating the safety distance from critical infrastructure in GIS tool

3.6 Regulatory Coverage

The applicable law in Baltic region is international, European and national law from the Baltic states. Local regulations may exist for individual federal states and ports.

3.6.1 Binding International law

The binding international law covers in particular the construction and the operation of vessels, navigation rules, environmental and sustainable aspects, safety of life and training people, among others. Issued by international organisations (UN) and agencies (IMO), the regulations were developed, negotiated and issued in a process of democratic centralism.

SOLAS – International Agreement about Safety of Life at Sea

The SOLAS agreement is an international treaty on maritime safety, has been ratified by almost all states and is therefore also national law. It is generally regarded as the most important of all international agreements on the safety of commercial ships. SOLAS requires flag states to ensure that their ships meet a minimum level of safety standards in design, equipment and operation. The following sections are of greatest importance for LF-fuels:

- Chapter VII – Carriage of dangerous goods

  Part A of this chapter requires that the transport of dangerous goods is carried out in accordance with the relevant provisions of the IMDG Code (International Maritime Code for Dangerous Goods).

  Part B requires that the design of ships carrying chemicals in bulk or tankers comply with the guidelines of the IBC Code (International Bulk Carrier Code).

  Part C defines the construction and equipment of ships carrying liquefied gases in bulk: It refers to the International Gas Carrier Code (IGC-Code).

- Chapter II-2 – Fire protection, fire detection and fire extinction

  Part B – Prevention of fire and explosion; Regulation 4.2.1.1: no oil fuel with a flashpoint of less than 60 °C shall be used.

The use of other LF fuels, like Ammonia or Methanol, is not included in the SOLAS agreement. This gap is closed by the IGF Code (International Code for the Construction of Gas Fuelled Ships) for the use of LNG as fuel and the interim guideline MSC.1/Circ.1621 for Methanol as fuel or MSC.1/Circ.1687 for Ammonia as fuel.

Applicable: all aspects in global shipping and especially all vessels bunkering low-flashpoint fuels including bunker vessels.

MSC.1/Circ.1621 – Interim Guidelines for the Safety of Ships Using Methyl/Ethyl Alcohol as Fuel

The interim guideline MSC.1/Circ.1621 aims to define international standards for the transport and use of methanol and ethanol on ships. The main parts of this document are to provide guidelines for design and installation, control and monitoring devices and facilities for the use of methanol as a fuel. The aim here is to minimize the risk for the crew, ship and the environment.

The guideline claims to create guidelines based on sound shipbuilding and engineering principles, taking into account current operational experience and the latest findings from research and development.

Applicable: vessels operated with and operations related to Alcohols.

MSC.1/Circ.1687 – Interim Guidelines for the Safety of Ships using Ammonia as Fuel

The goal of these Interim Guidelines is to provide for safe and environmentally friendly design, construction and operation of ships, and particularly their installations of systems for propulsion machinery, auxiliary power generation machinery and/or other purpose machinery using Ammonia as fuel.

Applicable: vessels operated with and operations related to Ammonia.

IBC Code (International Bulk Carrier Code)

The IBC Code (International Code for the Construction and Equipment of Ships carrying Dangerous Chemicals in Bulk) contains requirements for the transport of dangerous chemicals and harmful liquids in bulk by sea. The IBC Code contains regulations on the construction and ship equipment, particularly of chemical tankers.

Applicable: all vessel types of bulk carriers, e.g. a Methanol tanker.

IGC Code (International Gas Carrier Code)

For seagoing vessels used to transport LNG, the international code for the construction and equipment of ships carrying liquefied gases in bulk (International Code for Construction and Equipment of Ships carrying Liquefied Gases in Bulk) applies. The IGC Code applies to all seagoing vessels that transport LNG in international traffic. This includes both gas tankers and LNG bunkering ships.

Applicable: all vessel types of gas carriers.

IGF Code (International Code for Ships Using Gases or Other Low-Flashpoint Fuels)

The aim of the IGF Code is to create international standards for ships that operate with gas or other low flash point fuels (<60°C), provided these ships do not already fall under the IGC Code.

The basic philosophy is to establish mandatory criteria for the design and installation of machinery, equipment and systems for ships operating on low flash point fuels in order to minimize risks to the ship, crew and the environment arising from the characteristics of these fuels.

The IGF Code covers all areas of the ship that have specific features due to the use of low flash point fuels. The basic philosophy is a goal-based approach (MSC.1/Circ.1394). Therefore, goals and functional requirements for each area of the ship form the basis for design, construction and operation.

Applicable: all vessels operated by LF fuels.

3.6.2 Rules by Classification Societies

The International Association of Classification Societies (IACS) is a technically based non-governmental organization that currently consists of twelve member marine classification societies, ABS / BV / DNV / LR / KR among others. The IACS sets minimum technical requirements for the Classification Societies

Classification Societies are non-governmental organization that establishes and applies technical standards for the design, construction, and operation of ships and offshore structures.

Flag states authorize Classification Societies to act on their behalf to carry out surveys and certification required by international conventions, such as SOLAS and MARPOL.

Ships bunkering low-flashpoint fuels must be built according to the technical rules of a Classification Society.

Applicable: all vessels, shipyards, owners, operators and charterers.

3.6.3 European / regional law

Regional law covers regulation specific for the European and Baltic region which are not concern of international agreement. Here the EMSA (European Maritime Safety Agency) acts as a decentralized agency to provide technical, operational and scientific assistance and guideline.

ADN - European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways

The European Agreement concerning the International Carriage of Dangerous Goods on Inland Waterways ADN applies to inland vessels used to transport LNG (e.g. as bunker barges). Furthermore, like seagoing vessels, these ships must also have a class certificate from a classification society and approval from the Central Ship Inspection Commission (ZSUK – Zentrale Schiffsuntersuchungskommission).

Applicable: Inland water ways and – vessels transporting LF fuels as cargo.

ADR - European Agreement concerning the International Carriage of Dangerous Goods by Road

The transport of dangerous goods by road is covered by the European Agreement concerning the international carriage of dangerous goods by road, commonly known as ADR ("Accord européen relatif au transport international des marchandises dangereuses") of the Economic Commission for Europe (UNECE or ECE). The ADR is translated and included in the national legislation of the countries. The agreement itself is short and simple. The second article is crucial. This explains that, with the exception of some excessively dangerous goods, other dangerous goods may be transferred internationally in road vehicles as long as they are subject to the compliances set out in Annexes A (packaging and labelling) and B (design, equipment and operation of the vehicle carrying the goods in question).

Applicable: all road transport of dangerous goods.

3.6.4 National / local law

The local law covers the regulations by flag states, municipalities and port authorities. Specific regulations issued by terminal operators and shipping companies are listed here as well. The specific port locations in Germany require German law and the implementation of European law respectively. For Hamburg Port e.g, the

GGBVOHH 2021 – Gefahrgut- und Brandschutzverordnung Hafen Hamburg

is mandatory. The GGBVOHH came into force on 1st of April 2013 and regulates the safety of dangerous goods and the fire protection. It regulates the obligation to register dangerous goods in §3, defines basic berth regulations in §10, special safety regulations for tankers in §12 and the bunkering of ship fuels in §14. During bunkering of ships, $14 is only permitting for fuels with a flash point above 55°C. GGBVOHH requires a Risk Assessment to issue administrative approval for bunker operations.

Applicable: all kind of locations (sites, terminals etc.) of Hamburg Port.

GGVSEB – Gefahrgutverordnung Straße, Eisenbahn und Binnenschifffahrt

GGVSEB is the ordinance on the domestic and cross-border transport of dangerous goods by road, rail, and inland waterways, in force since 18th Aug. 2023. It acts as an important piece of implementation of ADN into national law. This includes the transport of dangerous goods by seagoing vessels on inland waterways and adjacent seaports as well.

Applicable: all BSV, even sea going vessels in the Port of Hamburg.

GGVSee – Gefahrgutverordnung See

This regulation governs the transport of dangerous goods by sea-going vessels. For the transport of dangerous goods by sea-going vessels on navigable inland waterways in Germany – indeed Hamburg Port is – see GGVSEB above.

Applicable: BSV navigation on German waters.

BImSchG – Bundesimmissionsschutzgesetz (Federal Immission Control Act)

The BImSchG is the German law to protect people, species and environment from harmful effects.

– § 50 BImSchG Trennungsgrundsatz in der Bauleitplanung

  Municipalities are required in spatial planning (such as land use plans) to separate areas in need of protection residential areas or schools from emission-producing facilities e.g. commercial or industry. The aim is to avoid harmful environmental impacts as much as possible.

Applicable: If the bunker site is a site coming under the Seveso Directive (EU, 2012). E.g. at a chemical plant or fuel storage, it is definitely a BImSchG site. Normal bunker sites as those in harbour are not affected.

Leitfaden KAS-18 – Kommission für Anlagensicherheit (Commission on Plant Safety)

Is the direct implementation of §50 BimSchG. It contains recommendations for appropriate distances between industrial facilities and protected areas such as residential neighbourhoods.

Applicable: Shore-to-Ship bunkering on BImSchG sites.

3.6.5 Guidelines

Guidelines denote recommended procedures which are inherently not mandatory but can be made required by authorities. In that context, the IMO MSC.1/Circ.1621 or MSC.1/Circ.1687 are addressed, see 3.6.1.

Since some of the technology is still new and use cases are currently rare, most regulations are under development, making occasional updates necessary. If there is no applicable guideline available to date, the LNG-related ones are supposed to be a good reference.

EMSA – European Maritime Safety Agency

The European Maritime Safety Agency is a European Union agency charged with reducing the risk of maritime accidents, marine pollution from ships and the loss of human lives at sea

- Guidance on LNG Bunkering to Port Authorities and Administrations

  The guidance aims to support port authorities and administrations backing the use of LNG as a ship fuel, as part of a joint effort to increase safety and sustainability The guidance is not a standard in the strict sense. Rather, EMSA has provided port authorities with comprehensive guidelines to carry out and examine risk assessments and safety concepts for LNG bunkering in their ports. In many aspects, EMSA refers to the aforementioned standards as well as other industry standards that were developed, for example, by SGMF (Society for Gas as Marine Fuel) and SIGTTO (Society of International Gas Tanker and Terminal Operators).
  Applicable: all bunker operations.

- Potential of Ammonia as Fuel in Shipping

  Ammonia is viewed as a promising long-term marine fuel because it can offer zero or near-zero carbon emissions and could enter the market relatively quickly. Although maritime experience with ammonia as fuel is limited, decades of land-based industrial use and established requirements from the IGC Code provide a solid basis for its safe handling and integration on ships. Its significant toxicity and associated risks, however, increase design complexity and make it most suitable for deep-sea cargo vessels rather than short-sea or passenger ships. The study identifies key challenges, advantages, regulatory and technology gaps, and incentives that will shape ammonia's adoption as a marine fuel.

Applicable: all parties involved in Ammonia bunkering and bunker planning.

SIGTTO Society of International Gas Tanker and Terminal Operators

SIGTTO is an international body established for the exchange of technical information and experience, between members of the industry, to enhance the safety and operational reliability of gas tankers and terminals. The purpose of the Society is to promote shipping and terminal operations for liquefied gases which are safe, environmentally responsible and reliable. To fulfil this mission it will:

- Proactively develop best operating practices and guidelines
- Sustain a learning environment by sharing lessons learned
- Promote training and development of all within the industry
- Foster mutually beneficial relationships with regulatory authorities and other stakeholders
- Conduct its business with professionalism and integrity.

Applicable: all tanker and terminal operators, procedures, technology.

SGMF – Society for Gas as a Marine Fuel – FP23-01_Ammonia – Safety and Operational Guidelines – Bunkering

This document draws on the current experience of LNG bunkering, the wider Ammonia marine transport industry and shoreside Ammonia production and transportation industry experience which shows when good practice is followed by building upon existing risk-based approach, bunkering risks can be effectively controlled and mitigated. The overall aim of this guideline is therefore to ensure that Ammonia-fuelled ships are bunkered safely, reliably, efficiently and in an environmentally responsible way, without any operational or fugitive emissions of Ammonia.

Applicable: all parties involved in Ammonia bunkering.

SGMF – Society for Gas as a Marine Fuel – FP22-01_Methanol As Marine Fuel – Safety and Operational Guidelines – Bunkering

This publication sets out how to the safety and operation framework for methanol bunkering operation. The guidance will discuss items as key safety risks associated with the use of methanol as marine fuels, bunkering procedures, safety zones, equipment requirements and vessel interfaces such as bunkering safety link and manifolds arrangements.

Applicable: all parties involved in Methanol bunkering.

OCIMF – ISGOTT – International Safety Guide for Oil Tankers and Terminals

The ISGOTT is the authoritative safety reference for the safe operation of oil tankers and oil terminals. The 6th edition 2020 emphasizes the human factor, safety management systems, gas detection, and alternative fuels to prevent accidents during the handling of liquid cargo.

Applicable: all tanker and terminal operators, procedures, technology.

IAPH – The International Association of Ports and Harbors

IAPH acts as the global alliance for port authorities and operators, aiming to foster collaboration, share best practices, and drive industry standards in sustainability, digitalization, and risk management.

- IAPH – Port Readiness Leve for Marine Fuels (PRL-MF)

  IAPH issued a non-mandatory maturity assessment framework that ports can use to self-assess their readiness and identify areas requiring further development in order to facilitate bunkering with LF fuels (LNG, methanol, ammonia, hydrogen derivatives). The tool uses a series of checklists to help ports prepare for and execute bunkering with LF fuels. It entails milestone levels for the research, development and deployment phase. PRL-MF covers

  - strategic / market decisions (forecasting CAPEX/OPEX),
  - the need of and benefit of GHG reduction (analyses and recommendation),
  - site selection / availability of infrastructure,
  - safety considerations and hazard identification and
  - harmonizing the regulatory interpretation and safety concepts.

  DNV and HPA directly operationalize the PRL-MF concept in the universal Port Bunker Mapping Instrument to assess bunkering site suitability, establish criteria, support approval processes, and generate bunker manuals. The Instrument is linked to PRL-MFs 4-6, development.

- IAPH Bunker Checklists

  IAPH in cooperation with maritime industry partners that have expertise in bunkering of vessels have developed standardized bunker checklists covering all common bunkering modes, which are widely accepted and used in Baltic Sea area. The checklists cover

  - Ship-to-Ship (STS),
  - Truck-to-Ship (TTS) and
  - Shore-to-Ship (ShTS).

  These checklists mitigate the risk related to bunker media. For bunker modes STS and TTS checklists exist for alcohol-based fluids (e.g. Methanol), LNG and refrigerated toxic fluids (e.g. Ammonia). The terminal checklist (ShTS) covers all fuels.

Applicable: All bunkering and planned bunkering in Baltic Sea area.

ISO/TS 16909:2022 – Guidance on performing risk assessment in the design of onshore LNG installations including the ship/shore interface

This document provides a common approach and guidance to those undertaking assessment of the major safety hazards as part of the planning, design, and operation of LNG facilities onshore and at shoreline using risk-based methods and standards, to enable safe design operation of LNG facilities.

Applicable: This document is applicable to all facilities inside the perimeter of the terminal and all hazardous materials including LNG and associated products.

ISO/DIS 6583:2024 – Methanol as a fuel for marine applications — General requirements and specifications

This document defines the general requirements and specifications for methanol from all forms of production at the point of custody transfer, prior to any onboard required treatment, for use as fuel in marine diesel engines, fuel cells and other marine applications. The specifications in this document can also be applied to methanol used as fuel in land-based applications of the same or similar type as those used for marine purposes.

Applicable: all tanker and terminal operators, bunker technology.

ISO/TS 18683:2021 - Guidelines for Systems and Installations for Supply of LNG as Fuel to Ships

This guideline designed to ensure the safety and effective risk assessment of LNG fuel bunkering operations. ISO 18683 provides a robust framework to help organizations navigate the complexities of LNG bunkering, ensuring both safety and efficiency. The risk assessment described in ISO/TS 18683 has become the international standard for risk assessments of such kind. The purpose of this technical specification is to provide guidelines for the design and sizing of

- bunker facilities,
- the connection interface ship to bunker facility,
- connection and disconnection procedures,
- coupling ESD and
- process control during LNG bunkering.

It must be ensured that a ship refuelled with LNG can be reliably and safely bunkered again, regardless of the type of bunkering facility, with a high degree of safety, integrity, and reliability. This technical specification applies to both sea-going and inland vessels. It covers LNG bunkering from both land-based and ship-based LNG supply facilities. The specification addresses all relevant process steps, such as inerting, refuelling, cooling, loading, and more. Additionally, it sets forth requirements and recommendations regarding the competence and training of operators and ship crews. It also includes functional requirements for the necessary equipment to ensure the safe bunkering of LNG-powered ships.

However ISO 18683 is meant to regard LNG, its sections about Safety Analyses and Risk Assessments are also applicable to other LF fuels.

Applicable: bunker procedures, bunker equipment.

ISO 20519:2021 – Ships and Marine Technology – Specification for Bunkering LNG-fuelled Ships

This document specifies requirements for LNG bunkering transfer systems and equipment used to bunker LNG fuelled vessels, which are not covered by the IGC Code. This document is applicable to vessels involved in international and domestic service regardless of size, and addresses the following five elements:

- hardware: liquid and vapour transfer systems,
- operational procedures,
- requirement for the LNG provider to provide an LNG bunker delivery note,
- training and qualifications of personnel involved,
- requirements for LNG facilities to meet applicable ISO standards and local codes.

However ISO 20519 is meant to regard LNG, its generic sections are also applicable to other LF fuel transfer equipment and bunkering procedures.

Applicable: bunker transfer equipment.

ISO/AWI 26201 – Specification for bunkering of ammonia-fueled vessel

This document specifies principles, requirements and procedures for bunkering of Ammonia-fuelled vessels. The document covers the main elements as follows:

- Operational procedures, equipment requirements and bunker checklists to ensure safe, reliable and efficient bunkering operations
- Risk assessment criteria, bunkering zones requirements (such as hazardous areas, safety zones, toxic areas/spaces, monitoring zones, security zones)
- Emergency procedures - Simultaneous operations (SIMOPS) requirements
- Training and competency.

Applicable: all parties involved in bunkering Ammonia, bunker procedures, bunker equipment.

ISO/DIS 22120 – Ships and marine technology – Specification for bunkering of methanol fuelled vessels

This document sets requirements for methanol bunkering transfer systems and equipment used to bunker methanol fuelled vessels. This document includes the following five elements:

- transfer systems,
- operational procedures,
- risk assessment,
- safety protection and

- personnel training.

Applicable: all parties involved in bunkering Methanol, bunker procedures, bunker equipment.

SN-CWA 17540:2020 (under development) – Ships and marine technology - Specification for bunkering of methanol fuelled vessels

This CEN Workshop Agreement document (CWA) was initiated to address the emerging and anticipated demand for methanol as a fuel in industry and shipping. Its purpose is to develop standards for methanol bunkering to meet maritime requirements for safety and quality.

This CEN Workshop Agreement includes the following four elements:

- Guidelines for usage of hardware and transfer system,
- Operational procedures,
- Requirement for the methanol provider to provide a bunker delivery note and
- Training and qualification of personnel involved.

Applicable: all parties involved in bunkering Methanol, bunker procedures, bunker equipment.

4 PHASE 2: INSTRUMENT APPLICATION

The Port Bunker Mapping Instrument developed in Phase 1, is intended to be universally applicable across ports. The focus is on the various future ship fuels, which include LNG, methanol, ammonia, and hydrogen. The instrument should be usable for different types of bunkering (Ship-to-Ship, Truck-to-Ship, and Shore-to-Ship) and should take into account different bunker locations within ports (berths at various terminals, waiting berths at sea).

4.1 Workflow

At this point we draft a potential pathway from the early stages of consideration until the final approval to establish a permanent bunkering at an elected harbour site. Not all of this shown steps are concern for the report on hand; but are essential to implement the whole process. The main outcome of the overall process should be a permission and all required documents like the Bunker Manual or the Joint Plan of Operation among others.

To get there, Qualitative Risk Assessments as well as Safety Zone Assessment (QRA) have to be done and are described in detail in the respective Chapters.

Remark that the steps from “General Qualitative Safet Analysis” until “Site Evaluation” are called Instrument. The boundaries are not completely defined, and Instrument responsibilities might be overlapping. Starting at the “General Qualitative Safet Analysis” the Instrument is to gather all required data for evaluating the site feasibility. As it might be an iterative process, both steps belong to the Instrument.

The Application of the Instrument ends after the “Individual Qualitative Risk Assessment” has been closed. The “Compile Documentation part is not directly linked to the Instrument, but its outcome is the required for approval.

Four milestones were defined, helping to split off the tasks and assigning the responsibilities. That are:

- Definition Phase completed, pointing out that the pre-work has been done.
- Data gathering completed, showing that the data basis for a bunker case persists and so far, no contraindications emerged.
- Application Phase completed, ready for Approval.
- Approval passed, head over to the practical part implementing the joint bunker operation.

In the following, the complete process is drafted, the herein covered Instrument particulars as well as all the other required steps.

Table 10 Application Workflow as proposed

Define the Scope on a high level • What to bunker? (medium: Ammonia, Methanol, Hydrogen, etc.) • How to bunker? (tronsfer technology: Ship-to-Ship, Truck-to-Ship, etc.) • How much to bunker? (transfer equipment, safety equipment, etc.)	Definition Phase
Site Screening • Pre-select bunker sites on a high level. What is suitable? What rules?	Definition Phase
General Qualitative Risk Assessment • Perform a generic Qualitative RA on core bunker procedure and parameters. • Consider processes and SIMOPS as possible • Do a Safety Zone Assessment. (QRA for selected the bunker setups)	Data Gathering (filll the Instrument)
Site Evaluation • Perform a systematic self-assessment using the criterai catalogue. • What are the requirements? • Response „instrument“ (green) **feasible** / (red) **not feasible**	Data Gathering (filll the Instrument)
Individual Qualitative Risk Assessment • Application of the „instrument“ to selected bunker site • Perform dedicated Qualitative RA on selected bunker operations and SIMOPS • Evaluate safety distances using database and geo information system	Application (of the Instrument)
Compile Documentation • Bunker Manual, Joint Plan of Operation	
Approval (depending an local regulations) 1. case-by case approval (document upload to approving authority) 2. formal approval using schema (saves workload perhaps) 3. supplier approval using a temporarily granted license Approval may require a site validation (by 3rd party or authority)	
Assessment during Approach • perform pre-bunkering assessment including specific → time, → traffic, → weather and → temporary restrictions at bunker site • compatibility check, approach for bunkering	Bunkering

4.1.1 Define the scope on a high level

The port needs to assess the to-date options to bunkering on a high level. It has to be defined, which bunker scenarios have to be facilitated in port area in the near future. The IAPH Port Readiness Level (IAPH, 2024) gives a good guidance here or also the Green Shipping Initiative (Mærsk Mc-Kinney Møller Center, 2025), to name a few.

Defining the Bunker Setup represents the very first step in this pathway. It requires considerations made in advance in the pre-feasibility phase, e.g. the decision for the LF fuels to be supported. Although it is not the concern of this report it is mentioned here for completeness. The main considerations following Itemized:

1. energy transition outlook and carbon reduction potential
2. availability / demand
    a. bunker demand, Shipping Companies participating in the program
    b. bunker medium and available production facilities,
    c. availability of technology and transportation infrastructure
3. business case evaluation (based on energy transition outlook and the availability / demand before),
    a. pretty safe CAPEX and
    b. estimated OPEX for some chosen scenario.
4. define bunker media based on the availability (Ammonia, Methanol, Hydrogen, etc. depending on the considerations above as well)
5. define bunker scheme based on expected demand (Ship-to-Ship, Truck-to-Ship, etc. depending on the considerations above as well)
6. define bunker parameter and requirements based on expected demand and the technological progress (transfer equipment, safety equipment, etc.)

Responsible: Port Authority or appointed authority / institute.

4.1.2 Site Selection

The next step is the site selection, similarly, done on a higher level of view as described in 3.3 Selection of potential bunker sites. As the port has a fairly good understanding of its facilities, a good preliminary filtering can be done here. To name a few questions:

1. What rules in which port area? or
2. What is counter-indicated and why?

Narrowing down the scope of considered bunker locations helps to proceed faster to the final goal. Any of those steps can be re-done at any time.

Responsible: Port Authority or appointed authority.

4.1.3 Milestone 1: Definition Phase completed

This Milestone is pointing out that the pre-work has been done. Responsibilities may change here.

4.1.4 General Qualitative Risk Assessment

On the basis of the aforementioned decisions and fixated bunker parameters, a Qualitative Risk Assessment must be performed for each individual bunker medium and the respective aspired bunker technology. This opens up a matrix of only a few cases. The respective dimensioning bunker parameters here should take as the maximum possible for each case. I.e. if a Truck-to-Ship bunkering is considered, this potentially delimits the bunker rate to approximately 50 m^3/h at a 4 inch hose. The aspired total bunker volume is an important measure as well. Higher bunker volumes require a shift in bunker technology as well. Other generic considerations should be taken into account as well: are there any foreseeable SIMOPS for bunker operations?

Determination of Safety Distances

Still in the generic Risk Assessment phase and no location information is present, it is time to perform the assessment of the Safety Zones as they only depending on the chosen bunker setup(s): bunker media and technology used for bunkering.

For this purpose, a determination of the safety distances has to be done for the selected scenarios by means of state-of-the-art dispersion analysis tools like Phast or BASiL. Theres is no prescribed approach on how to perform this Quantitative Risk Assessment (QRA). It can be done using a consequence-based approach (deterministic) or a risk-based approach (probabilistic).

A common way is to perform it in a mixed mode, as it entails some advantages before the stricter modes above. It is to calculate the direct release consequences for the maximum credible accidents and build up the envelope under consideration of local climate and environment. The remaining risk than is to be calculated by assumptions, how often accidents can happen. Those assumptions basing mainly on statistical data, as far as they exist.

This approach is widely accepted by approving bodies across the Baltic area. For further details see Ammonia Bunkering in Hamburg Port (DNV, 2026) and the chapter Safety Analysis.

Bunker Manual

Some of the requirements for a Bunker Manual are fulfilled at this stage. They cover the generic bunker setup depending on the bunker medium and the main transfer parameters. The Bunker Manual will finally be compiled after the Individual Qualitative Risk Assessment" has been done, involving the location.

Responsible: Port Authority or appointed authority defines the corner stones and instructs a company facilitating Risk Assessment and QRA.

4.1.5 Site Evaluation

The site evaluation based on a quality rating system. It is to qualitatively and quantitatively rank pre-selected sites and shortlist only the suitable ones for bunker development. The evaluation is supposed to be the data population phase of the instrument. The main considerations are:

– The selection of potential bunker sites has been done based on high-level considerations. The most suitable bunker sites were selected from a bird's perspective. If there are counter-indications appearing in between;

site is neglected. This requires basic knowledge about aspired bunker setup as well as bunker medium and transfer procedure, as they affect local criteria as well as shown in 4.1.2.

- The site evaluation is based on a deeper look. Proceed on operating the catalogue for marine-based and land-based criteria one-by-one until all questions have been answered. This can be done in a process of self-assessment or by 3rd party.
- Additionally: do further requirements exist? Do records of the real distances to infrastructure exist? Are there limitations about implementing the required Safety Zone present?

All those considerations will be needed as feed in the the next step, Individual Qualitative Risk Assessment.

The final response of the site evaluation is the score given by the instrument: green – bunkering permittable within the boundaries of the instrument or red – not possible in the simplified way the instrument provides. The scoring system is described in section 3.4 and the deduction of the site evaluation into the score in section 3.2.

A subsequent site validation, preferably done by a 3rd party is not mandatory for process assurance. But it is highly likely that the approving authority requires any kind of validation. To achieve a good collaboration, the validation can be done in a latter phase: 4.1.7. Also the bunker partners need to validate if they can implement all requirements. Optionally, the approval body may subsequently require validating the decision on the basis of given information on hand.

Responsible: Port Authority or appointed authority defines the corner stones, instructs and supports a company facilitating evaluation.

4.1.6 Milestone 2: Data gathering completed

This Milestone is shows that the data basis for a bunker case safely persists and no contraindications emerged so far. The Individual Qualitative Risk Assessment might be a placed order to 3rd party.

4.1.7 Individual Qualitative Risk Assessment

The Individual Qualitative Risk Assessment now takes the location into account as well. This is what we would call the application of the “Instrument”. The significant parts are:

- looking up in the GIS map tool to find the attributes of the site
- performing a dedicated Qualitative Risk Assessment on selected bunker operations at selected bunker sites
- involvement of SIMOPS (water side and shore-side) into consideration
- Evaluation of the safety distances, based on the Safety Zone Assessment (QRA) beforehand and a database of geo information in a GIS tool. The implementation should be done acc. 3.5.4.3 Evaluation of Safety Distances.
- verify again the feasibility of the site. Are the conditions at location of the planned bunkering affirmed and parameters not off the limits? if e.g. the outcome Red score emerged in between, evaluate the option of performing a case-by-case negotiating process outside the Instrument, involving approving body and participants.
- draft a JBO

Responsible: Port Authority or appointed authority supervises contracted company.

4.1.8 Compile documentation

As now the complete safety Analysis has been done, consisting of General and Individual Qualitative Risk Assessment as well as determination of the Safety Zones, the documentation can be compiled. This requires the following:

- Bunker Manual – the general document to perform bunker operations in port area. This work package is a matter of the “General Qualitative Risk Assessment” as well, as the Bunker Manual is a more general document. It is mentioned here because some information might have been changed during performance of the “Individual Qualitative Risk Assessment”.
- Joint Plan of (Bunker) Operations – the dedicated document, containing the obligatory procedures and bunker checklists
- Training and drill documents – documents for educating scheduling and logging / documentation of trainings and drills.

Responsible: Port Authority or appointed authority instructs and supervises the implementation by all parties involved in bunkering.

4.1.9 Milestone 3: Application Phase completed

This Milestone is shows that all risk assessments have been successfully performed. Now the bunker site is ready for approval. The responsibility here is at the Port Authority.

The regard of the Port Bunker Mapping Instrument ends here. The following steps are mentioned here for completeness and to provide a whole picture.

4.1.10 Approval

For the approval there is no dedicated task but the delivery of the former compiled assessments and documents to the approving body. How the process looks in detail is a matter of the region and is not discussed here. The documentation involves

- the Safety Analysis and QRA for aspired bunker case,
- the bunker Manual and the JBO for the specific location and
- the other documentation, e.g. for training.

The approving authority may require a bunker case verification, including a site-verification in order to issue the permission.

For the permission issuance, three different kinds of procedures may be pointed out:

- the case-by-case approval – all bunker cases are treated separately. This might be required by local law.
- the formal approval, using a scheme agreed upon between approving body and port authority – it does re-use work priority done to fasten up the approval process.

- supplier approval scheme – the approving body issues a temporary license to the bunker parties. This granted permission is valid for the whole port area but can be revoked at any time by given reason.

Responsible: Approval body / authority.

4.1.11 Milestone 4: Approval passed

This Milestone shows that the permission for bunkering has been granted by approving body. The responsibility here is at the Port Authority to head over to the practical part, implementing the joint bunker operation.

4.1.12 Assessment during Approach

If the Approval for bunkering is granted, the final step is the pre-assessment during (before) approach. The assessment is performed in collaboration by bunker parties, requiring qualified expertise and covering non-conforming topics at the time of bunkering.

It is not a direct task of the project on hand. But as it involves a Risk Assessment and is linked the categories mentioned in the above steps, we're listing here the details:

- perform pre-bunkering assessment including
  - specific time
  - current and expected traffic
  - current weather forecast at bunker site,
  - restrictions at bunker site (if any, potentially unforeseen?)
  - planned SIMOPS, which do not collide with the Safety Zone
- communicate Bunker Manual and JPBO (should be in place)
- perform a compatibility check (transfer equipment, safety equipment, mooring lines, fenders)
- notify VTS (Nautische Zentrale) about bunker operation and approach

The affirmative outcome is the permit to bunker, responsibles are the terminal operator, the bunker supplier and the bunker receiver.

4.1.13 Bunker Management Plan

The Bunker Management Plans is the central repository of all bunkering-relevant information. It is a formalized regulatory, and mandatory document for bunkering. It includes the traditional Bunker Manual, the bunker compatibility checklists and the Joint Plan of Bunker Operation (JPBO).

It is tightly coupled to risk assessments, authority approvals, and safe-system-of-work requirements. BMP goes beyond a classical Bunker Manual, because it serves as a compliance document. It is a prerequisite for licensing and is the formal risk-management document.

The SGMF requires the BMP to entail:

- an emergency response plans,
- SIMOPS assessments,
- compatibility reports,
- Safety Zones and risk mitigation measures,
- communication & mooring plans,
- equipment certification and
- system descriptions.

This content is **mandated or expected** in order to satisfy port authorities and regulatory bodies.

4.1.13.1 Bunker Manual

The classical Bunker Manual instead is an operational guidance book, valuable for training and procedural consistency but not a regulatory compliance document and not sufficient on its own for alternative fuels.

The Bunker Manual contains all the relevant standards and requirements for bunker supply vessels, bunker trucks and bunker equipment. It defines the bunker modes, the individual process parameters, the conditions for which the simplified approval can be applied and the procedures. In this report, the Bunker Manual is split off into two parts, the first bunker setup-specific, which then can be inherited and applied to not-yet-approved locations later-on. The second part is the time and location-dependent part which contains location-specific requirements and weather or daytime data.

Listed here after the Bunker Manual Requirements for a generic bunker setup, depending on the bunker medium and the main transfer parameters:

- Requirements to BSV, dangerous goods truck and bunker equipment concerning build standards, training standards, common industry standards and inspection state of the assets
- Requirements to bunker modes and process parameters
- Requirements to the bunker procedures, as e.g. notification requirement, setup-individual risk assessment, safety zones and IAPH checklists
- Required ISPS Security level, normally only permitted at level 1

For the individual (specific) Bunker Case, a more detailed approach is needed on the case-by-case basis to examine the influence of the location and all other boundary conditions, as

- Requirements of the specific location, e.g. the berth and its applicable laws and guidelines (global/regional/local)
- Requirements of the specific location neighbourhood, e.g. critical infrastructure nearby
- Requirements to the required location- and case-specific simultaneous operations (SIMOPS)
- Requirements of the (long-term) climate and (occasional) weather situation, e.g. mooring study, wind, ice and sea state
- Requirements of the Terminal, e.g. minimal training level/skills/certificates, emergency response plan, escape routes and safety barriers

4.1.13.2 Joint Bunkering Plan (JBP / JPBO)

The JPBO is a short, practical summary derived from the Bunker Management Plan and adapted to a specific vessel–facility combination at a defined location. It is required by Port Authority and Approving Body.

It contains:

- essential operational information,
- Safety Zone and SIMOPS controls
- mooring and communication arrangements,
- critical steps and
- timing of the operation.

4.1.13.3 Training Requirements and Documentation

All personnel involved in bunkering must receive a role-specific training to ensure they understand the hazards, procedures, and safe handling requirements of the bunker medium. The training must cover the physical and chemical properties, including risks, flammability, toxicity, physical / vapour behaviour and environmental impact. Training must be planned, documented, assessed and refreshed.

The SGMF defines structured competency levels requiring progressively deeper knowledge, practical skills, and decision-making ability for bunkering operations.

Main aspects of the training are:

- Use of equipment: inspection, limitations of safety equipment, gas detectors, PPE, firefighting systems, drip trays, and water curtains.
- Communication: training is mandatory to ensure clear information exchange, correct reporting, and coordinated actions between supplier, receiver, and port authorities.
- Procedures: emergency response training, activation of ESD systems, safe isolation procedures, evacuation routes, and the use of firefighting equipment.
-

Regular reassessment and refresher training are required to maintain competency, incorporate lessons learned, and ensure alignment with evolving equipment, procedures, and regulations.

Table 11 **A direct mapping of the SGMF training and JPBO requirements to the IGF Code and ISO 20519**

Topic	**SGMF**	**IGF Code**	**ISO 20519**
Personnel training & competence	FP04-02, FP07-01	**IGF Code + STCW Reg V/3**	**ISO 20519 §8**
Training planning & drills	FP07-01 §5.8 / LNGBMP	**IGF Code Ch. 18**	**ISO 20519 §7, §8**
Written bunkering procedures	FP07-01 (LNGBMP/ABMP)JBP)	**IGF Code 18.2 & 18.4**	**ISO 20519 §7**
Joint Plan of Operations (JPO/JBP)	FP07-01 §3.6.4	**IGF Code 18.4.1**	**ISO 20519 §7**
PIC agreement & checklist	FP07-01 §7.3	**IGF Code 18.4.1**	**ISO 20519 §7.3**

4.2 Implementation

Documentation to come after closing Phase 2, Instrument Application.

5 CONCLUSION

5.1 Recommendations

5.2 Outlook

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6.1 Terms and definitions

ADN	Ordnung über die internationale Beförderung gefährlicher Güter auf Binnenwasserstraßen
ADR / RID	Ordnung über die internationale Beförderung gefährlicher Güter auf der Straße
ALARP	As Low As Reasonably Practicable, reducing a risk to a level that represents the point, objectively assessed, at which the time, trouble, difficulty, and cost of further reduction measures become unreasonably disproportionate to the additional risk reduction obtained.
Ammonia	NH_3, toxic gas, H_2-derivative
ATEX	ATmosphères Explosives, Explosionsschutz-Richtline
Attribute Table	Stored properties of an object inside the Shape Layer to make it unique and derive decision making (Safety Analysis)
BDN	Bunker Delivery Note
Berth	A site at a (cf.) terminal, where vessels berth for cargo operations.
BImSchG	Bundesimmissionsschutzgesetz (Federal Immission Control Act)
BS	Bunker Station
BSV	Bunker Supply Vessel
Bunker Case	An aggregate bunker procedure including the Bunker Setup, and Location at a specific time.
Bunker Location	Or Bunker Site, the location elected for bunkering, usually a berth.
Bunker Manual	The document issued by the Port Authority, containing the
Bunker Management Plan (BMP)	The formally required compliance and licensing document for bunkering.
Bunker Receiver	cf. RV – Receiving Vessel
Bunker Setup	A constitution of bunker equipment, bunker fluid and bunker procedure (operation), free of time and location. This setup is the basis for the Safety Zone determination.
Bunker Supplier	Also Bunker Provider, a company licensed to supply bunker to vessels.
Control Zone	Zones defined in advance defining the access level. E.g. the hazardous area, the safety zone, toxic and monitoring zones.
Compatibility Check	A pre-bunkering operation to align and verify the technical details bunker equipment, required as stated in the Bunker Manual.
Control Zones	Hazardous Area / Safety Zone / Monitoring and Security Area
CPP	Closest Point of Proximity
CRS	Coordinate Reference System
CTS	Container-to-Ship bunker method
Deterministic (consequence-based) approach	A set of representative conservative scenarios yielding the maximum horizontal and vertical dispersion. Where the superposition of them determines the maximum credible accident
DWT	Deadweight
EMSA	European Maritime Safety Association
EN	European Norm (standards)
EPSG	European Petroleum Survey Group (key code for GIS data transformation) EPSG 10732 – official system used in Germany (former EPSG 25832)
ESD	Emergency shutdown
ESRI	Environmental Systems Research Institute, developer of ArcGIS and native *.gdb format.
FMEA	Failure mode effect analysis
GGBVOHH	Gefahrgut- und Brandschutzverordnung Hafen Hamburg
GGVSee	Gefahrgutverordnung See (decree of transportation dangerous goods at sea)
GIS	Geo Information System
GIS location / position	An attribute, covering the latitude, longitude and elevation of the center point in RCS frame.
GT	Gross Tons
Guidance	A not mandatory receipt to perform assessments or technical operations, e.g. (SGMF, 2024). A Guidance can be made mandatory by a regulatory authority.
Hazardous Area	An area, allocated around bunker equipment to avoid potential flammable or toxic gas ingress in non-hazardous spaces. It requires special precautions for construction, installation and use of equipment.
HAZID	HAZard IDentification, held in form of a workshop. A HAZID process checklists all the failure scenarios and during workshop, the severity or consequence of the failure and likelihood or occurrence will be elaborated and finally ranked into a risk register.
HFO	Heavy Fuel Oil
Hydrogen	Two-atomic flammable gas, normally in deeply cold-liquefied form
IACS	International Association of Classification Societies
IAPH	International Association of Port and Harbours

IGC-Code	The International Code of the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk
IGF-Code	International Code of Safety for Ship Using Gases or Other Low-Flashpoint Fuels
IMDG	International Maritime Dangerous Goods
IMO	International Maritime Organisation, an authority of the United Nations
Instrument	The Port Bunker Mapping Instrument to process site selection (data gathering phase), safety analysis and feasibility scoring (application phase) in order to implement LF fuel bunkering in seaports in a structured way.
IRPA	Individual Risk Per Annum, the risk of an individual being part of a certain personnel group taking into account the actual time spent on average per year in different areas, cf. LSIR
ISO	International Organization for Standardization
ISPS	International Ship and Port Facility Security, ISPS defines diverse levels of security established at or required for a port area.
JPB / JPBO	Joint Plan of Bunker Operation, the final document on the performance of a bunker operation at a given time and location. It contains the checklists for all bunker related work.
LF(F)	Low Flashpoint denotes fuels of a category with a flashpoint below 60°C which require special safety measures, cf. IGF Code.
LNG	Liquefied Natural Gas, cryogenic liquid consisting mainly of CH_4
LSFO	Low-sulphur Fuel Oil
LSIR	Location-Specific Individual Risk, the risk for a hypothetical individual who is positioned for 24 hours per day at a specific location, 365 days per year, cf. IRPA
Map layer	GIS layer, covering the local map as a 2D projection of the world data transformed RCS
Methanol	Liquid organic compound of alcohols, CH_3OH
MDO	Marine Diesel Oil
MGO	Marine Gas Oil
MOF	Marine Offloading Facility, e.g. a bunker boom or a hose crane.
Monitoring Zone	The zone where activities, including shoreside/marine traffic, should be monitored to ensure they do not encroach on the safety zone.
MSC	Maritime Safety Committee (IMO)
MTTS	Multi-truck-to-Ship bunker method
Nautische Zentrale	Hamburg VTS
OCIMF	Oil Companies International Marine Forum
Ontology	In data science, an ontology is a practical approach tor knowledge representation. In delimitation to → Taxonomy, it consists of classes (categories), components (definitions) and relationships, which follow axioms (rules), not hierarchy. The advance is the high inter-operability e.g. between different data sources following different hierarchies; a drawback is the high expense for maintenance under big data and a steep learning curve.
OPS	Onshore Power Supply
PBM	Port Bunker Mapping, this project on hand.
PERC	Powered Emergency Release Coupling
PPE	Personal Protective Equipment
PRL-MF-MF	IAPH Port Readiness Level for Marine Fuels.
Probabilistic (risk-based) approach	The probabilistic approach uses risk criteria for the in the HAZID defined conservative scenarios. This results in a smaller safety zone compared to the distance determined from maximum credible release.
PTS	Pier-to-Ship bunker method, cf. SHTS
PRV	Pressure Relief Valve
QCDC	Quick-connect / disconnect coupling
QRA	Quantitative Risk Assessment, a systematic and formal method to assess the risks associated with the hazards performing a particular activity in absolute terms.
Qualitative Risk Assessment	cf. HAZID
RCS	Reference Coordinate System
RID	Ordnung über die internationale Eisenbahnbeförderung gefährlicher Güter
Risk Contour	Is an iso-line of a specific risk, superposed to the site topography at which a hypothetical individual staying there unprotected 24h times 365d p.a. This is the risk of cf. LSIR.
Risk Evaluation	A procedure based on the Risk Analysis to determine whether the tolerable risk has been achieved.
Risk Analysis	Systematic use of information to identify sources and to estimate the risk.
Risk Assessment	Overall process of Risk Analysis and Risk Evaluation.
Risk Matrix	A specific matrix translating the probability of occurrence and consequence or severity (if it occurs) into a risk value.
Risk Register	Outcome of a HAZID enlisting the risks being identified, assessed and properly controlled during workshop.
RTS	Rail-to-Ship bunker method
RV	Receiving Vessel, or the bunker receiver.

Rule	A document made mandatory for specific purpose, issued by and / or required by an authority, e.g. DNV-RU-SHIP Pt.6 Ch.2 DNV Rules of Classification for Ships Part 6 Chapter 2
Safety Analysis	The entire process of developing scenarios and risk calculation, finally yielding a Safety Concept. The Safety Analysis covers a generic and qualitative risk analysis of the bunker procedure, a quantitative risk assessment (QRA) including the estimation of Safety Zones and a Safety Concept as outcome for decision making.
Safety Concept	The outcome of the Safety Analysis, covering procedural and location-based requirements among others, for decision making
Safety Zone	3D zone during bunkering around the transfer system determined from the results of deterministic or risk-based release computations. The Safety Zone extends the Hazardous Area. The safety Zone is defined by the Individual Risk Contour results from the QRA. SIMOPS and passing traffic may be prohibited or strictly controlled to maintain safety.
Schema	A database schema. In categories spoken, these are the header entries of the respective tables.
SeeSchStrO	Seeschifffahrtsstraßen-Ordnung
SGMF	The Society for Gas as a Marine Fuel
Shape layer	Hierarchical GIS information layer, covering the geodesic object like points, curves and shape as an overlay to the Map Layer
SIGTTO	Society of Gas Tanker and Terminal Operators
SIMOPS	SIMultaneous OPerationS. Those operations run concurrently with the bunkering process, either on land, water, or on vessel-side.
SHTS	Shore-to-Ship bunker method, cf. PTS.
SOLAS	Safety Of Life At Sea
STS	Ship-to-Ship bunker method, where a bunkering is performed between ships moored alongside each other. Such operations may take place when one ship is at anchor or alongside at berth.
Taxonomy	Classification method in which objects or concepts are assigned to categories (classes) according to specific criteria. Classification or categorization as such apparently follow a strict hierarchy and often are cumbersome to implement or modify.
Terminal	A harbour area controlled by a company (Terminal Operator), where cargo, bunkering and other operations occur, cf. Berth.
Toxic Zone	An area what can potentially have a toxic atmosphere, harmful to personnel in the proximity.
TTS	Truck-to-Ship bunker method
UPS / USV	Un-interrupted Power Supply
VSD	Vessel Separation Detection
VTS	Vessel Traffic Service
WKT	Well-known text geometrical objects, https://en.wikipedia.org/wiki/Well-known_text_representation_of_geometry
WSP	Wasserschutzpolizei, permission-making coastal police department Hamburg

6.2 List of Figures

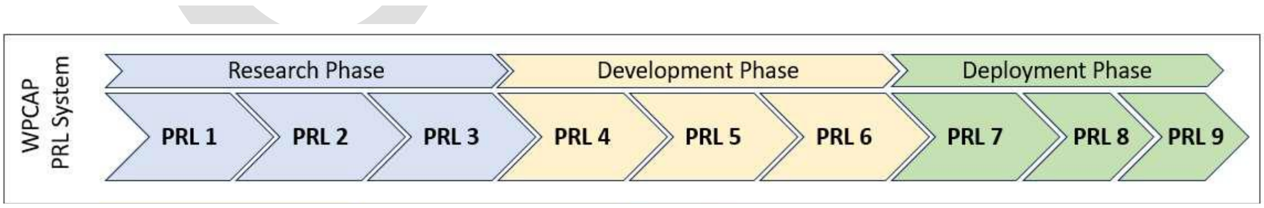
6.3 List of Tables

7 APPENDIX

7.1 Port Readiness Level for Marine Fuels

Table 12 PRL-MF outlined

		Bunkering of target fuel
PRL-MF 9	Deployment	Market penetration and growth for bunkering of target fuel
PRL-MF 8		Full capabilities for bunkering of target fuel
PRL-MF 7		Bunkering of target fuel established on a project basis
PRL-MF 6	Development	Pilot-scale demonstration of bunkering of target fuel
PRL-MF 5		Framework for bunkering of target fuel implemented and tested
PRL-MF 4		Framework for bunkering of target fuel drafted, timeline developed
PRL-MF 3	Research	Detailed research, analysis, and conclusions
PRL-MF 2		Stakeholder interest and feasibility assessment
PRL-MF 1		Foundational background information



7.2 Taxonomy

The human tendency to adhere to standards, combined with the Western paradigm focused on efficiency and scientific categorization, often results in special cases or aspects falling through the cracks in practice.

Taxonomies and their administrative offshoots, the organizational charts, are techniques of power based on a fundamental – the classification. They form the insuperable walls between intersection approach (outcome-oriented) on the one side and their application or acceptance in practice on the other, (Kathrin Schrader, 2022).

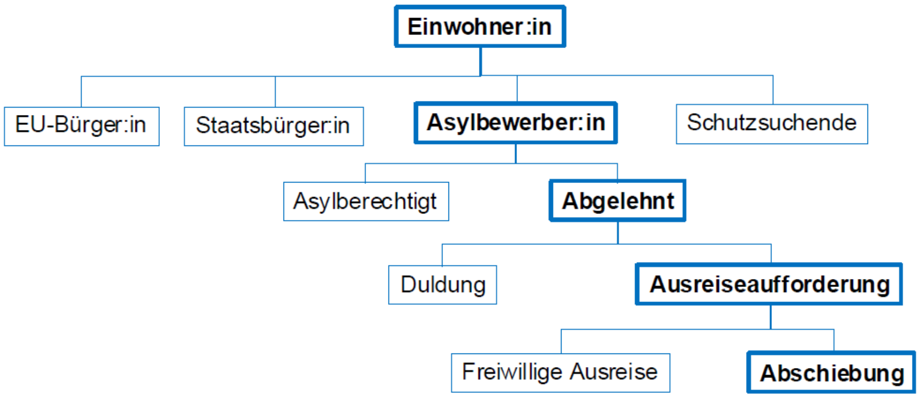


Figure 7-1 Example of a taxonomy (categorization from the viewpoint of civil services)

> In social science, intersectionality describes the overlap and simultaneity of multiple forms of discrimination, such as those based on gender, origin, disability, or sexuality. Taxonomy here refers to the systematic organization and categorization of social characteristics and inequalities. Intersectionality highlights that social categories cannot simply be added together but are intricately intertwined in specific configurations. This results in individual experiences of discrimination that cannot be captured by conventional “single categories.” An intersectional taxonomy therefore helps to represent social structures in a more nuanced and complex way. (Sources: Wikipedia, socialnet Lexicon, University of Freiburg)

Classification schemes and taxonomies are problematic in every scientific context because, while they often appear to be effective and efficient, they ultimately always hinder the acquisition of knowledge.

Classification systems and taxonomies are not only the established tools for communicating results but also structure knowledge within hierarchical systems. So they can only proof true what they stated before in the stage of research and knowledge production.

A more generic way of implementing knowledge is the use of ontologies. In the stricter sense of information technology, an ontology encompasses a representation, formal naming, and definitions of categories, properties and relations between concepts and data.

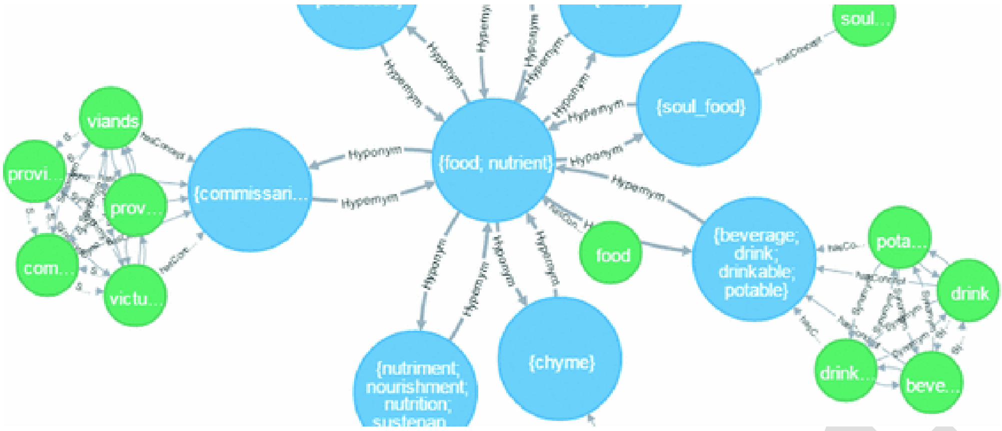


Figure 7-2 WordNet visualization of speech using Neo4j (excerpt)

It allows an approach to the matter of concern in a way that different levels of structure and representation can be explored at the same time. Ontology engineering (applied ontology) is a task of setting up methods and methodologies for building an ontology and the tools and languages that support it, (Wikipedia, 2026).

The hierarchy-free approach can be easily adapted into a database structure containing nodes, attributes and inter-linking relationships. Any of those entities may receive specific display properties to encompass for strength of relationship and to emphasize purpose or importance.

A state-of-the-art tool is the Neo4j graph database application based on Java. It encompasses cypher, visualization, drivers and tools for data science and export. For the Port Bunker Mapping on hand, Neo4j was applied to visualize the database schema. Attempts to fully implement the Port Bunker Mapping Instrument were rejected because of limited time and resources. The to date data basis and programming tools will be handed over at delivering the project. We consider the importance for further research and implementation into a GIS tool.

7.3 Database schema

A data base schema was developed covering the process of bunkering. The top categories from 3.2 do not entirely match, as this schema represents a more holistic view. I.e. it is greedily enlisting everything. Each node exists here only once as it is not a fully populated database.

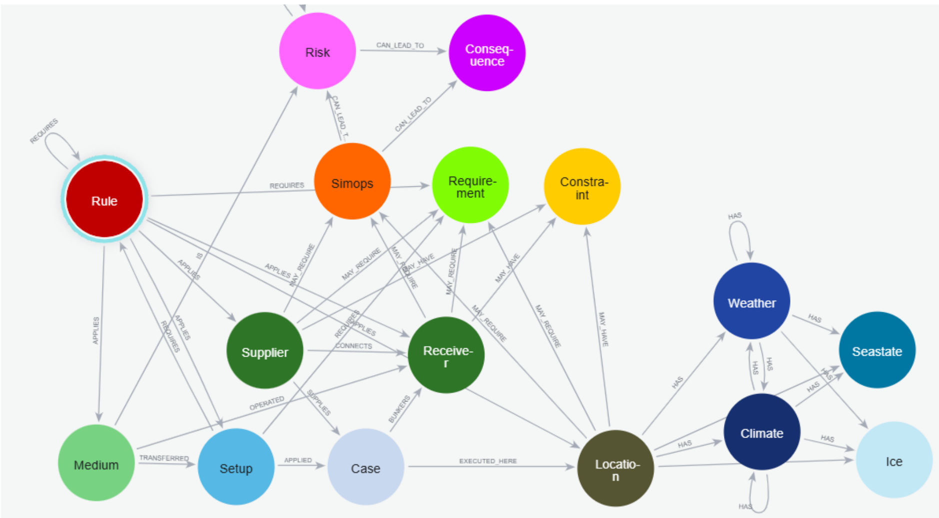


Figure 7-3 Neo4j database schema

It might appear too some readers that it looks like playing a computer game and work in itself. But it isn't. In the development phase of the Instrument and its generic structure, it was very helpful because the graph database approach projects the hidden structure clearer.

Database examples

An impression of a populated but still incomplete database can be taken from here: **Error! Reference source not found.**.

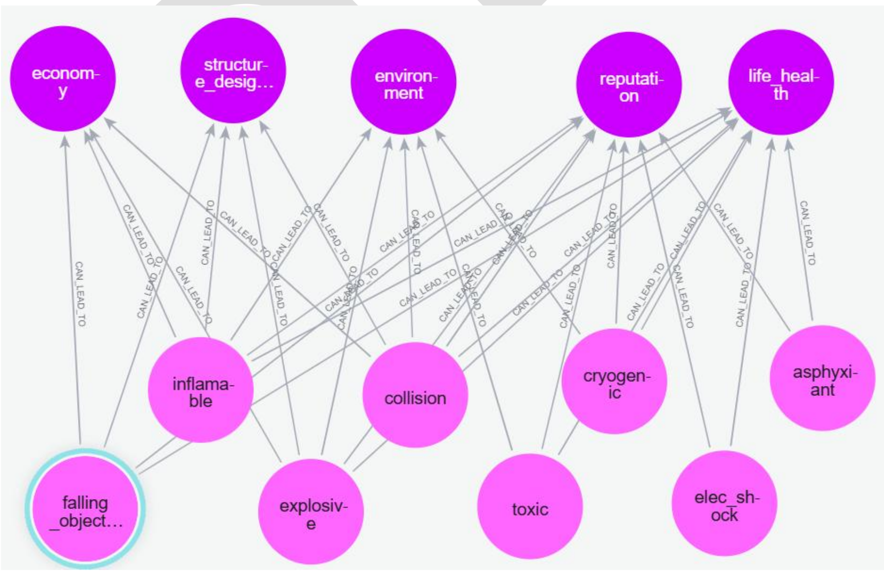


Figure 7-4 Bunker Case related risks and consequences

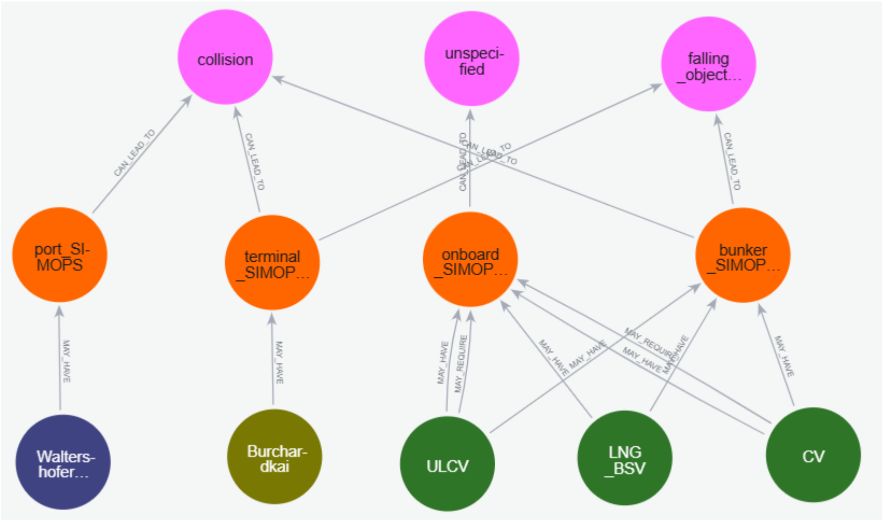


Figure 7-5 A variety of possible SIMOPS and entailed risks

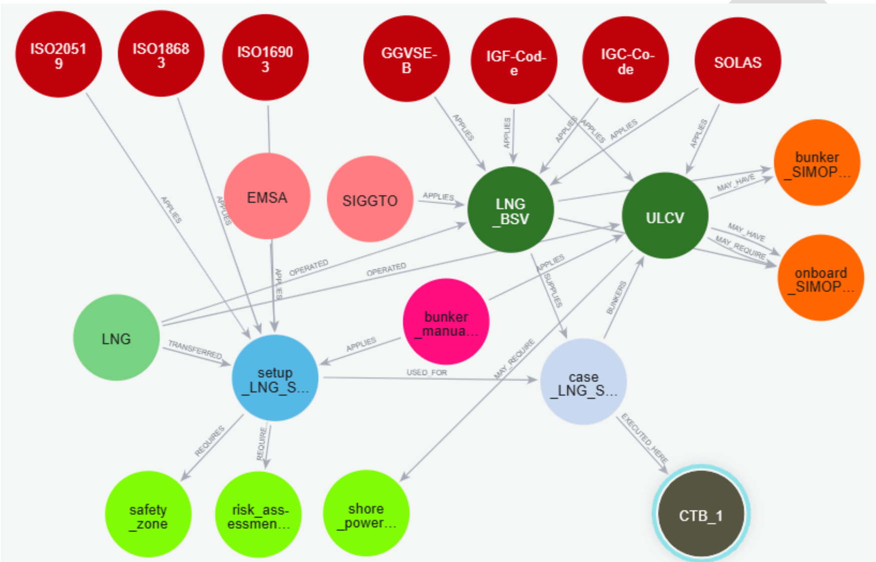


Figure 7-6 e.g. bunkering LNG at Burchardkai

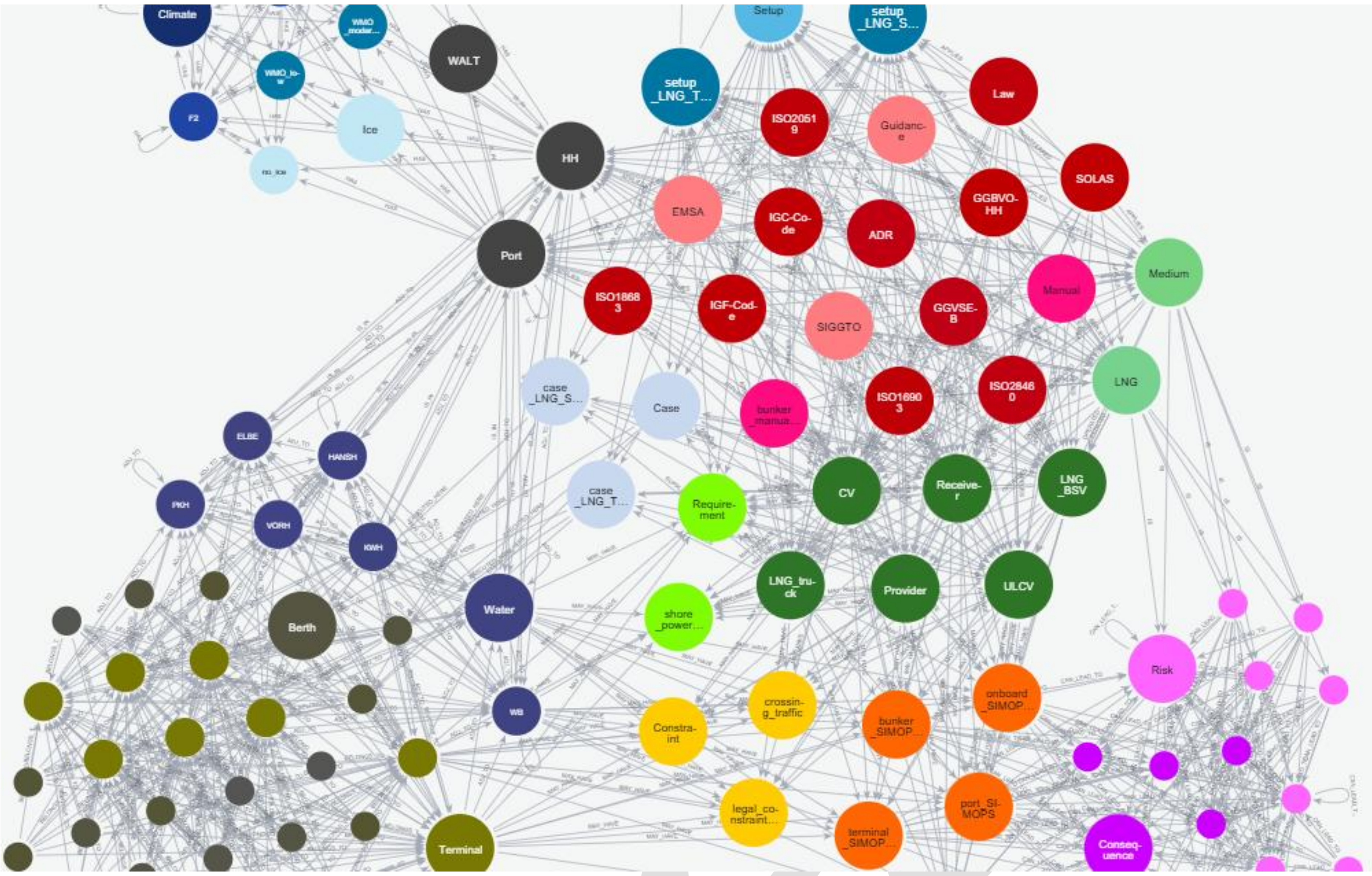


Figure 7-7 PBM database snapshot, lower left: some locations, lower right: risks and consequences, upper left climate and weather, red are rules and guidelines

7.4 Control Zones

Table 13 Control Zones

Control Zone	Definition	Aim
Hazardous Zone(s)	3D zone where the presence of a toxic, combustible or explosive atmosphere is expected to occur frequently	Avoiding the ignition of potentially explosive atmospheres by selecting suitable (electrical) equipment
Safety Zone	3D zone during bunkering around the transfer system (or other relevant hazard source), determined from the result of a leak or emergency discharge or vapor return occurring. SIMOPS and passing traffic may be prohibited or strictly controlled to maintain safety.	Avoiding the ingress of ignition sources and avoiding risk exposure of people
Monitoring and Security Area / Security Zone	An area around the transfer system (or other relevant hazard source) that needs to be monitored as a precautionary measure to prevent interference with the hazardous operation or facility. Individuals entering or working within this envelope should undergo dedicated training in emergency response plans and may be required to wear or have access to PPE.	Preventing objects or people from entering the security zone by observing external activities
Marine Zone	A zone of sufficient size to prevent passing shipping from impacting on the hazardous facilities.	
External Zone / Assessment Zone	The outermost zone serves to identify, inform and prepare third parties and the public for the potential for ammonia releases and appropriate responses in case of exposure.	

7.5 Safety Analysis Process Overview

General Risk Assessment

- Rules & Guidelines (international / regional)
- climate / tide / currents
- nautical conditions and port facilities
- bunker fluid and properties
- bunker mode and process parameters (time limitations, pressure, bunkerrate, bunker equipment, etc.)
- BSV specific conditions (size, type, certificates, etc.)
- ship (RV) specific conditions (size, type, cargo, certificates)
- SIMOPS (general & BSV)
- Identification of possible accidents and evaluation of their consequences
- Safety measures

Individual Risk Assessment

location-specific

- local conditions (range, proximity, population, presence of persons)
- type of goods
- local traffic
- SIMOPS (RV & terminal)
- mooring concept
- Identification of possible accidents and evaluation of their consequences
- Safety measures

Qualitative Risk Assessment (HAZID)

Safety Zone Assessment

- general or individual for specific location
- consequence-based / risk-based estimation of safety zones
- as part of the HAZID

Assessment during Approval

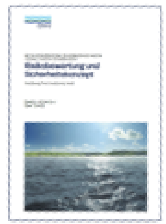
- expected traffic
- expected weather
- planned SIMOPS

requires qualified expertise

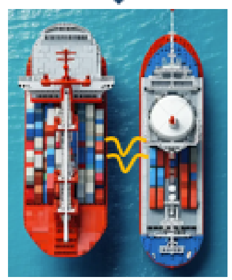
covering non-conforming topics **at time of bunkering**

GGVBOHH Einzel-ausnahme-genehmigung *

Bunker Manual



Joint Plan of Operation (JBO)



*) individual certificate of exemption, issued by WSP (Harbour Police) specific in Hamburg Port area

7.6 Risk Matrix

Table 14 Risk Matrix – exemplary, taken from (DNV, 2025)

Consequence			**Probability**				
Consequence	**Environment**		**Never heard in industry**	**Occurred in the industry**	**Occurred in the company**	**Occurred several times per year in the company**	**Occurred several times per year in the location**
			< 1 event / 1 million years	> 1 event / 1 million years	> 1 event / 10,000 years	> 1 event / 100 years	> 1 event / 1 year
			1	**2**	**3**	**4**	**5**
Zero injury	**Zero effect**	**0**					
Slight injury, superficial injuries, no loss of worktime	**Slight effect**, neglectable effect on environment	**1**					
Minor injuries, < 5 working days lost	**Minor effect**, in compliance with regulations	**2**					
Major injury, long term absence	**Local effect**, response required (inform authorities)	**3**					
Single fatality and / or permanent disabilities	**Major effect**, significant response required	**4**					
Multiple fatalities	**Massive effect**, damage over a large area and / or time	**5**					

Low	No action is required, unless change in circumstances
Moderate	No additional controls are required; monitoring is required to ensure no changes in circumstances
High	Risk is high and additional control is required to manage risk

7.7 Checklist Tables

7.7.1 Terminal Location

7.7.2 Marine Location

This table is drafted as an example and may be incomplete. If it does not fully satisfy the ports requirements, categories / criteria have to be added.

Category	Subcategory	Regard / Criterion	Value / Response	Evaluated
Marine	General	Id	0.1	
		Name	CTH_1	
		GIS object category	Berth	
		Description / adjacent to		
	Regulatory	internat. law		
		regional law		
		national law		
		ISPS level		
	Bathymetry	charted water depth		
	Location	center point		
		shape polygon		
		colour / texture / boundary		
	Navigation	space for manoeuvring		
		turning cycle		
		passage width		
	Proximity	crit. infrastructure		

		transportation infrastructure		
		residential area		
		recreational areas		
	SIMOPS	portside		
		vessel-side		
		bunkering		
	Time	time limitation		
	Misc			

7.8 Data Format

The Port Bunker Mapping tool is going to use the ESRI ArcGIS Pro geo data server in the version 3.4, current version is 3.6. ESRI ArcGIS file types are mostly compatible with open-source programmes, such as GRASS GIS, QGIS, etc.

Geo data for exchange shall be conform to version 3.4 or higher (v3.6). The processing of geo data is performed in Lagestatus 310 reference coordinate system ETRS89 / UTM, region Hamburg. The EPSG code is 25832 or 10732 respectively.

Table 15 Documents and data types

Data format	Type description
*.gdb	native ESRI ArcGIS geodatabase file
*.aprx	ArcGIS project data format
*.stylx	ArcGIS styles data format (pro / desktop / project / favourites / system / web / mobile styles)
*.mpkx	map packages format
*.ppkx	project / share packages format
*.lyrx	ArcGIS layer format

7.8.1 Open GIS data formats and toolboxes

https://de.wikipedia.org/wiki/GIS-Datenformat

Table 16 Free GIS applications

Application	Description
GeoServer	GeoServer is an open-source software server, allowing users to share and edit geospatial data. Designed for interoperability, it publishes data from any major spatial data source using open standards. https://geoserver.org latest version 2.28.1 requires Java 17 or. 21 JRE
GRASS GIS	**GRASS**, Geographic Resources Analysis Support System, is a powerful computational engine for raster, vector, and geospatial processing. It supports terrain and ecosystem modelling, hydrology, data management, and imagery processing. With a built-in temporal framework and Python API, it enables advanced time series analysis and rapid geospatial programming, optimized for large-scale analysis on various hardware configurations. https://grass.osgeo.org/ latest version 8.4.2

OSGeo4W	The OSGeo4W installer bundles relevant OSGeo software packages plus additional requirements into a convenient MS-Windows based installer. Re-running the installer will update existing packages and/or permit to modify the installation. https://trac.osgeo.org/osgeo4w/ GIS-dedicated PC recommended
SAGA GIS	SAGA (System for Automated Geoscientific Analyses) is an open-source geographic information system (GIS) used for editing and analysing spatial data. https://saga-gis.sourceforge.io/en/index.html latest version 9.11.1
QGIS	Create, edit, visualise, analyse and publish geospatial information. Recommended. https://qgis.org/ latest version Qt6 3.44.6 ArcGIS export ArcGIS-QGIS-Toolbox
mapbox	Mapbox, build and live-update customizable maps for web, mobile automotive and AR. Subscription model including limited free subscription. Make use of API, SDK and support (Mapbox Tiling Service). https://www.mapbox.com
MapLibre	Open-source fork of mapbox-gl-js. Tools and libraries for interactive maps and geospatial visualization — empowering developers, researchers, and organizations to create world-class mapping applications https://github.com/maplibre
Neo4j	Neo4j, a graph database system that stores data not in rigid tables (like SQL), but as a network of nodes and relationships and their properties. Graph databases are not restricted to a pre-defined model, they can provide more flexible approaches and strategies. https://neo4j.com/docs/getting-started/whats-neo4j/
Neo4j-spatial	Neo4j-spatial is an offshoot of Neo4j. It is an on top library of utilities for Neo4j that facilitate the enabling of spatial operations on data. In addition, Neo4j-spatial can expose the data to other GIS tools. https://neo4j.com/labs/neo4j-spatial/5/overview/introduction/ Note Jan. 2026: broken dependencies in up-to-date pnpm packages to quite outdated spatial packages.

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