A framework for risk assessment of ammonia storage and bunkering at ports

Qu, W.; Duinkerken, M.B.; Schott, D.L.

Publication date
2024

Document Version
Final published version

Published in
Proceedings of the International Physical Internet Conference, IPIC 2024

Citation (APA)
Qu, W., Duinkerken, M. B., & Schott, D. L. (2024). A framework for risk assessment of ammonia storage and bunkering at ports. In *Proceedings of the International Physical Internet Conference, IPIC 2024*

A framework for risk assessment of ammonia storage and bunkering at ports

Wenhua Qu *, Mark Duinkerken and Dingena Schott

Faculty of Mechanical Engineering, Delft University of Technology, Delft, The Netherlands
Corresponding author: w.qu@tudelft.nl

Abstract: Ammonia stands out as a promising option for maritime fuel, offering the potential to reduce greenhouse gas emissions. However, its adoption comes with inherent risks, including: toxicity, flammability, corrosiveness, and odor. As the maritime industry is in the initial stages of the exploration of using ammonia as fuel, it is imperative to acknowledge and address these risks. This work focuses on the acknowledging port authority and terminal operators, whose responsibilities are a safe and efficient facilities construction and inter terminal fuel transportations. This profound risk assessment should be conducted in advance to identify risks alongside with potential consequences. In this article, we provide a risk assessment framework consisting of qualitative and quantitative assessment tools. This framework can facilitate the responsible integration of ammonia as a maritime fuel at the port level. In particular, it can provide the port authorities with meaningful guidance for the prevention and risk mitigation strategies for ammonia storage and bunkering to the vessels. This work aligns with the concept of physical internet nodes, as it illustrates how an emerging application such as alternative fuel is embedded and integrated into a connected multi-machine system like inter-terminal logistics

Keywords: *Physical Internet Port, Ammonia, Risk assessment Framework, Bow tie diagram, Bayesian network*

Physical Internet (PI) Roadmap Fitness*: Select the most relevant area(s) for your paper according to the PI roadmaps adopted in Europe and Japan:* ☒ *PI Nodes (Customer Interfaces, Logistic Hubs, Deployment Centers, Factories),* ☐ *Transportation Equipment,* ☐ *PI Networks,* ☐ *System of Logistics Networks,* ☐ *Vertical Supply Consolidation,* ☐ *Horizontal Supply Chain Alignment,* ☐ *Logistics/Commercial Data Platform,* ☐ *Access and Adoption,* ☐ *Governance.*

Targeted Delivery Mode-s*:* ☒ *Paper,* ☐ *Poster,* ☐ *Flash Video,* ☒ *In-Person presentation*

1 Introduction

New energy is currently seen as one of the most important measures to reduce the negative impact of transportation to the environment. Ammonia has caught significant attention due to its carbon-free composition and relatively higher energy density compared to liquefied hydrogen. At the same time, ammonia has its own hazardous characters of corrosive, toxic and odor. Compared to conventional fossil fuel, ammonia storage and bunkering is associated with possible risks related to cryogenic liquid/high-pressure liquid transfer and vapor return. This risks are hurdles and challenges in the adoption of ammonia as a maritime fuel.

To be technically ready to use ammonia as a maritime fuel, the port authorities should preliminary be aware of the operation procedures. Ammonia operation procedures at the port area mainly relates to three processes: storage, bunkering process, and the inter-terminal logistics among different locations. Bunkering is the process of transferring fuel from a supplier or storage to the fuel receiving ship. These three processes can be similar to conventional fuel, but variations arise in the extra effort to liquification and its hazardous characteristics. By recognizing these similarities and differences, port authorities can accordingly plan the infrastructures constructions and equipment purchase. Taking into account the lead time of infrastructure construction, these activities should be conducted in the early stages. Meanwhile the bunkering and inter terminal logistics operations should be regulated in advance before the real application.

This integration of safety handling into a hyperconnected network mirrors the principles of the physical internet, emphasizing the efficient flow of goods and information across interconnected nodes (Ballot and Fontane, 2008, Montreui 2011).

These hazardous characteristics and corresponding risks can be understood, prevented or mitigated accordingly. The ammonia-related risks have been studied in existing literature from different angles, e.g. from the perspective of historical accidents analysis (Duong et al. 2023, Machaj et al. 2022), from experimentation at lab, or from simulation via specific software(Ng et al. 2023). However, the acknowledgement of the risky characteristics remains insufficient since the data of ammonia pertains as agriculture fertilizer or small-scale simulations are adopted. The transshipment of ammonia as freight (fertilizer) and its usage as a maritime fuel requires vastly different location distributions inside the port and time requirements. This leads to consider the question: How can these risk studies inform the planning of infrastructure construction and inter terminal fuel logistics to ensure safety storage and bunkering? The interpretation is the indispensable link in between. However, The risk assessment from the view point of inter terminal logistics side is still an open field. Both industry and academic are at the beginning stages of using ammonia as fuel.

This work provides a risk assessment framework of ammonia as a fuel, aiming to offer decision support to port authorities in the strategical planning and terminal operators in the operational regulations. The framework consists of two perspectives: qualitative and quantitative. The qualitative risk assessment aims to draw efficient and direct conclusions based on qualitative characteristics such as descriptions, categories, and expert judgments. On the other hand, the quantitative assessment further involves the objective measurements and risk analysis using numerical data and mathematical models to estimate probabilities, consequences, potential impacts of prevention and mitigation events.

The contributions of this work are as follows. First, in section 2, we summarize the facilities and inter terminal logistics to be conducted at the port for using ammonia as a maritime fuel. The corresponding risks are intensively studied via literature, historical documentations and some industry regulations, which are interpreted from the logistics viewpoint. We also highlight the necessity of a comprehensive risk assessment to interpret the chemistry characteristics to port infrastructure planning and logistics management. Second, we develop a risk assessment framework based on the previous analysis in Section 3. The assessment methodology resorts to both qualitative and quantitative assessments utilizing Bow tie diagrams and Bayesian networks. This article concludes with a summary and outlook in section 4.

2 Ammonia operations and associated risks

In this section, we first describe the ammonia operations at the terminals, which includes the storage, bunkering and transshipment in between. Next, we review the ammonia hazardous characteristics, and discuss possible risks in the described operations. We compare and highlight distinctions from the inter terminal logistics of conventional combustion fuel. Lastly, we identify research gaps and lay the foundation of what to expect from the risk assessment framework.

2.1. Ammonia storage, bunkering and the transshipment

This subsection reviews the operations of ammonia at the port area. The processing encompasses various stages, including the receiving, storage, fuelling, and internal transportation within the terminal, as described in Figure 1. We concentrate on the utilization of ammonia as a fuel, thus omitting the cracking related operations.

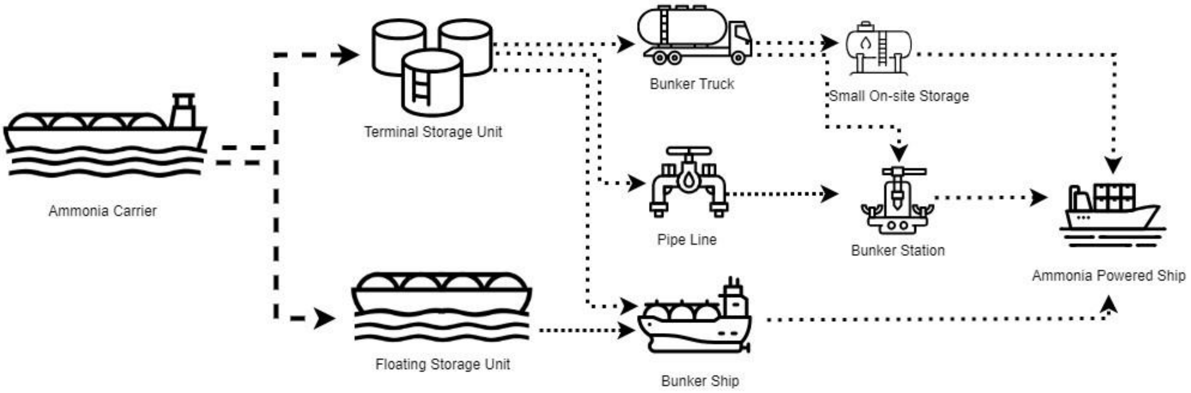

Figure 1: The ammonia flow inside the port, resource the authors

To make efficient usage of ammonia, it is generally compressed into liquid phase, relying on refrigeration (-33 ◦C) or pressurisation (around 10 bar pressure). In most literature (Duong et al. (2023), Machaj et al. (2022), Yang and Lam (2023)) and some industry reports (MAGPIE (2023), Global Centre for Maritime Decarbonisation (2023)) the refrigeration is more economic efficient and currently chosen in Port of Singapore and Port of Rotterdam.

Before diving into the detailed description, it is important to establish some definitions that will be frequently used. There are three primary types of ships involved in the ammonia operations at port: ammonia carrier vessels, ammonia powered ships, and ammonia bunker ships. Figure 1 depicts these three ships. Ammonia is usually not produced at the port but carried to the port by **carrier vessels**. These already exist since ammonia has been widely used as fertilizer for a long time (Machaj et al. (2022)). The ammonia powered ship are those that use ammonia as fuel resource. Bunker ships transfer the ammonia from the storage place to the ammonia powered ship. Presently, there are only a few bunker ships and ammonia powered ships operating in Singapore (Duong et al. (2023), Global Centre for Maritime Decarbonisation (2023)) .

Upon the carrier vessel's arrival at the port, the ammonia will be off loaded and stored, for the next step utility. There are two types of large scale storage: **terminal storage unit** at land side and **floating storage unit** offshore. Besides, there will also be a **small on-site storage unit**, which typically is in the form of bullet tanks.

Ammonia bunkering for commercial purposes contains various methods, including ship-to-ship, truck-to-ship (Duong et al. (2023), Yang and Lam (2023)) and pipe to shipe. **Ship-to-ship** bunkering was the most commonly employed method of delivering marine fuels to ships (Yang and Lam (2023)). Calderon et al. (2016) evaluated the ship-to-ship bunkering as an attractive LNG bunkering solution. The reason was four folded: (1) no expensive infrastructure; (2) bunker ships offer high flexibility; (3) high utilisation rates from the flexibility; (4) ships to be fuelled were often hard to manoeuvre, the bunker ships could improve efficiency by supplying the bunker fuel. This provides referential value to the ammonia bunkering.

Truck-to-ship bunkering is conducted by trucks carrying the ammonia storage tank. As pointed out by Global Centre for Maritime Decarbonisation (2023), this required road access to the berth, and vehicle access near the storage tank area. Leveraging existing ammonia tanks and supporting infrastructure could reduce the impact on the current operations and development costs.

The ammonia **pipeline transportation** is via carbon steel pipelines about 0.15-0.25 m diameter and with a pressures of around 17 bar (Papavinasam (2014)). According to Fertilizers EU (2013), the ammonia pipeline has been operating for decades for the agricultural fertilizer in America. In Europe only short pipeline systems were in operational at that time, the largest being 74km in Italy. According to a simulation result of Schotman (2023), pipe to ship indicates a higher bunkering efficiency and a lower operating cost in medium and large sized port.

Summarizing, facilities for storage and bunkering can take different combined forms. The most suitable solution depends on port storage and bunkering demand and site-specific factors. The size and amount of large storage units should be calibrated to ensure sufficient inventory for the bunkering and cracking demand. The flexible storage are strategically located nearby the bunker site to ensure a short bunker time. bunkering facilities should meet the volume of fuel demand, being accessible at the chosen bunkering methods, and fitting into existing infrastructures. The site of storage and bunkering are the originals and destinations of inter terminal fuel transportations, the distance among which directly affects the operating time and cost. Meanwhile their sites selection can be restricted to land availability and hazardous exclusion zones.

2.2. Ammonia Risks

Ammonia is characterized by flammability (Park et al. (2023)), toxicity (Duong et al. (2023), Ng et al. (2023), Park et al. (2023)), corrosiveness (Duong et al. (2023)), and odor (Machaj et al. (2022), Park et al. (2023)), making safety a challenge. To address these risk, we provide an review of the corresponding literature, industry reports and regularities.

Ammonia does not burn readily thanks to its narrow **flammability** range, high ignition temperature and low laminar burning velocity. The risk of an ammonia fire is lower compared to other fuels. The **corrosive** effect of ammonia is due to possible reaction with water and form ammonium hydroxide. It can cause damage to various materials, such as metals, plastics, and rubber. Corrosivity can be avoided by cautious handling and appropriate precautions to prevent materials' exposure. This includes proper storage and handling procedures, as well as the use of protective coatings and materials that are resistant to alkaline substances.

Toxicity was regarded as the greatest risk for liquid ammonia storage (Yang et al (2023), Zhang et al. (2023)) and bunkering (Ng et al. (2023), Yang and Lam (2023), Fan et al. (2022)). In this regard, special safety precautions are necessary to prevent **leakage** and subsequent **dispersion**. Ng et al. (2023) simulated how key operational parameters affect ammonia dispersion. Yang and Lam (2023) also studied the environmental impacts of ammonia bunkering. The effects of large spills of ammonia on people and ecosystems are still relatively unknown and based on limited case studies.

There are several risk prevention and mitigation methods against the leakage during the storage and bunkering process. Those methods involve **double-walled storage** tanks, implementing a **safe zone,** and completing **safety regulations** for the storage and bunkering. Ammonia in large quantities is refrigerated in cylindrical double-walled storage tanks (Ikaheimo et al. (2018)). Ng et al. (2023) stated that it was the safest to store ammonia fuel in fully-refrigerated tanks as an atmospheric pressure saturated liquid. Figure 2 shows a typical storage tank. Recommendations of Duong et al. (2023) based on a review of a number of research papers, emphasized the importance of regulations and guidelines, setting a **safety zone,** and completing **safety regulations**. The safety zone during the ammonia bunkering process refers to the designated area surrounding the bunkering operation, with restricted access and the implementation of the necessary safety measures. These observations indicate that the safety zone is not a static concept, rather, it may need to be adjusted based on changing circumstances or the ongoing risk assessments. Similarly, Ng et al. (2023) suggested no simultaneous operations such as inspection or maintenance while bunkering. This separation from time dimension blocks human access and other activities. The authors also suggested the bunkering heights would be lower than 5 meters, and should consider the wind direction to prevent a serious dispersion.

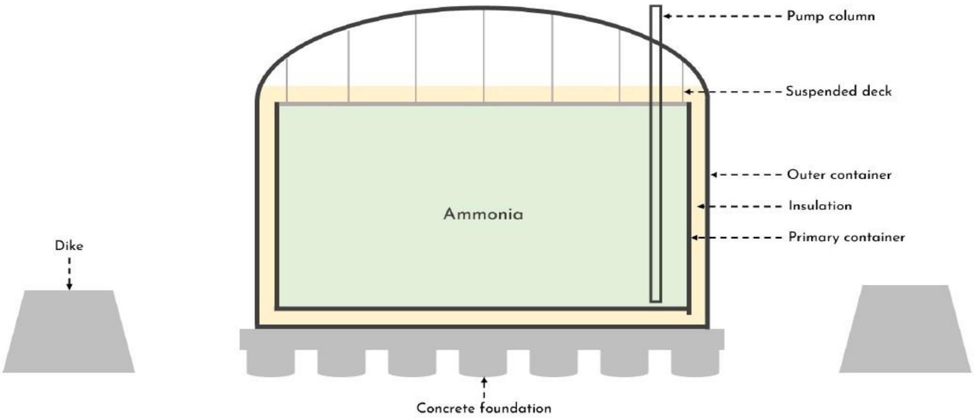

Figure 2: Double walled ammonia storage and safety zone surrounded by dike

As for the bunkering time, there is currently no revealed data yet regarding the real bunkering time duration, but it can be estimated based on similarities. Machaj et al. (2022) reviewed characteristic of ammonia and similarities, which led to a solution that LNG storage tanks and bunkering had great potential for ammonia storage. The simulation of Schotman (2023) also cited the LNG bunkering time duration from Park and Park (2019) and EMSA(2017).

The risks study should be used in the layout design of bunkering facilities, berth allocation and bunkering schedule planning. Certain safety measures can lead to higher construction cost (e.g., double wall storage tank and safety zone around), or higher operating cost (e.g., personnel training) or longer operating cost (e.g., no simultaneous operations, specific bunkering location). An inadequate guidance may compromise safety in construction and logistics operations, but an over-conservative safety measures could result in unnecessary higher costs and longer operating time. A balance between safety handling and efficient inter terminal logistics is vital for the ammonia transition.

2.3. Research gaps

The adoption of ammonia as a maritime fuel is challenging due to it hazard risks and safety concerns. The current applications are in the initial stages, and are predominantly led by the industry, primarily through pilot or demonstration scales at limited ports. There are several European commission projects are pushing the border of ammonia application, such as MAGPIE(Smart Green Port). The natural next steps are the upscaling of the usage volume or replication from one port to other ports. These technology solutions provide valuable insights, which necessitates case analysis, and requires summarizing the lessons learned.

Regarding the risks and safety operations, most data on risk analysis originate directly or secondarily from various sources. These include simulation results, international databases such as websites, regional standards by industry companies, and reports from ammonia or LNG-related organizations (DNV GL Group, the Port of Rotterdam, the Port of Singapore). This data leans towards the chemistry side instead of guidance to port authorities or terminal operators. Therefore, comprehensive interpretation is essential to ensure its understanding and application by port planners and operators. Beyond safety considerations, the port stakeholders also concern investment costs, operating cost, operating capacity and efficiency.

The ammonia transition at ports entails an involved cycle of interpretation, trial and calibration. Risk assessment can guide the ammonia storage site selection, and storage and bunkering infrastructures construction, material choices and others. This must be planned well in advance due to the construction lead time. Furthermore, risks assessment affect the operational processes, such as the berth allocation to those ammonia-powered ships, scheduling of ammonia bunkering activities, and other related tasks. Additionally, port authority should be full aware on the kind of accidents that can occur, in which part of the operations these may take place, understand it consequences in terms of related losses in subsequent stages. Last but not least, what effective actions can be undertaken to prevent or mitigate these risks. This demands a dynamic closed-loop assessment instead of a static approach. Based on these four interpretation requirements, we propose a risk assessment framework regarding the ammonia usage as a marine fuel, i.e., the storage and bunkering at the port.

3 Risk Assessment Methodology

The risk assessment and its methodology are not new, whose forming as a scientific field can be tracked back to 1970s (Aven , 2016). But content-wise it is to our knowledge not yet explored regarding the ammonia as a maritime fuel. The assessment methods have a big impact to the assessment results, the level of details to the decision support (Abbasi Kharajou et al. (2024)). The focus of this work is on overall framework construction and the choice of proper assessment methods therein, instead of developing new assessment method. In the following we briefly describe the chosen risk assessment in this work together with the choice reasons.

3.1. The assessment framework

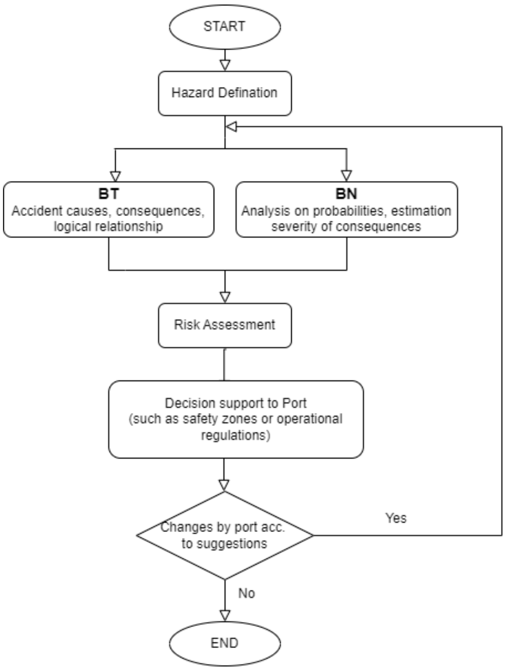

Figure 3 the proposed risk assessment framework, by authors

Based on the described gaps and the fundamental objectives in section 2, we build the risk assessment framework, as described in Figure 3. There are two approaches, qualitative and quantitative assessment. The qualitative approach usually concerns subjective evaluation to draw rough, but quick, conclusions. The quantitative assessment, on the other hand, resorts to numerical data and mathematical models to estimate probabilities and consequences. We choose the Bow Tie (BT) Diagram and Bayesian Network (BN) as the qualitative and quantitative assess tools, respectively.

To selection of the assessment tools lies in the assessment goal and methods themselves. The Bow Tie diagram offers a direct cause-effect visual expression that facilitates effective communication with the audience, whereas the Bayesian network provides a quantitative insight into the causality of the events. Moreover, Bayesian network allows for updating the event probabilities after the prevention or mitigation measures have been implemented. This is important for the cost benefit analysis of the prevention and mitigation. The BT and BN are described briefly in the following subsections.

3.2. Bow Tie diagram

BT is a graphical tool that illustrates an accident scenario, starting from accident causes and ending with its consequences (Khakzad et al. (2012)). Figure 4 presents the structure of the BT. It is centred around a critical event, which is connected by Fault tree on the left-hand side, and event tree on the right. The Fault Tree (FT) describes the top event influenced by risk factors. The Event Tree (ET) identifies its consequences. Safety Barriers in the FT act as the prevention mechanisms that reduce the probabilities of an accident. Furthermore, the Safety Barrier in the ET is the control process after the accident that aims to lower the impacts of the consequences of accidents (de Ruijter and Guldenmund (2016)).

3.3. Bayesian Network

Similar to BT, Bayesian Network (BN) method has been widely used in risk and safety analysis based on probabilistic and uncertain knowledge. BN is composed of two parts: graphical structure in the form of a Directed Acyclic Graph (DAG), and probabilistic structure in the form of conditional probability tables (CPT). Figure 5 shows a general DAG. The nodes represent the cause (node A and node H in Figure 5) and corresponding consequences (nodes D, F, G in Figure 5) of a chain event. Arcs between nodes signify direct causal relationships between the linked nodes, this is one important reason for choosing BN as the assessment tool.

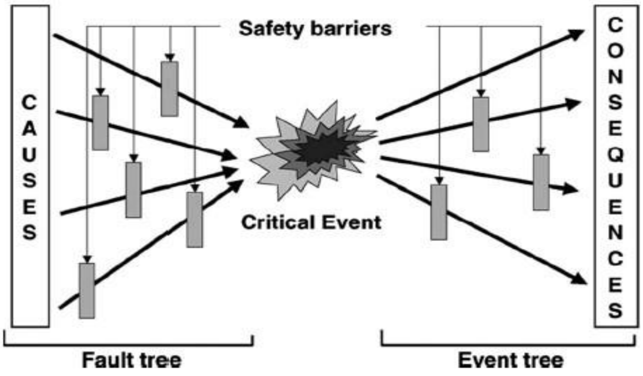

Figure 4: Generic example of a Bow Tie, taken from de Dianous and Fievez (2006).

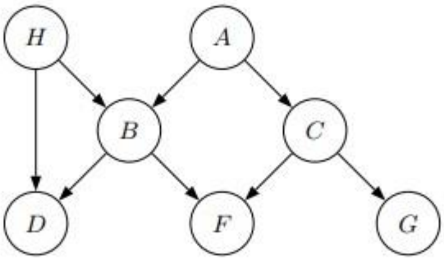

Figure 5: Generic example of a Directed Acyclic Graph by Bayesian Network, taken from Jensen and Nielsen (2007).

The quantitative contribution of BN originates from the probabilistic structure. It consists of two parts: (i) *prior probabilities* indicating the probability value of a certain basic node; and (ii) *conditional probabilities* predicting the probability value of one event based on the condition of another event. The prior probabilities can be obtained from historical accidents, failure records, or via an intensive literature collection. Furthermore, the conditional probabilistic can be calculated and expressed in *Conditional Probability Tables* (CPTs). This is the second reason for choosing BN is its advantages in checking the effectivity of preventing regularity or mitigating an event. This is referred to as the Roots to Bayes theorem. Given the information of prevention or mitigation information, BN re-evaluates from the original failure probabilistic (prior occurrence) to the reduced probabilistic or relieved accidents (posteriors).

3.3. BT and BN application to ammonia risk assessment

Using BT and BN, we describe the leakage or release of ammonia and the possible results during the bunkering process, see Figures 6 and 7. The consequence described in these Figures are based on the dispersion simulations of Ng et al. (2023).

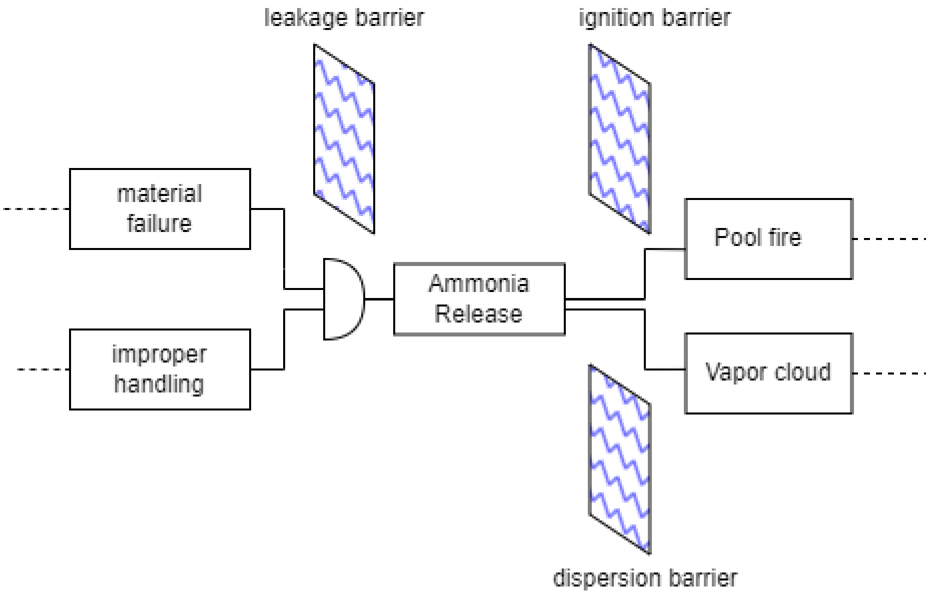

Figure 6: A bow tie description of ammonia leakage and possible results, resource: authors

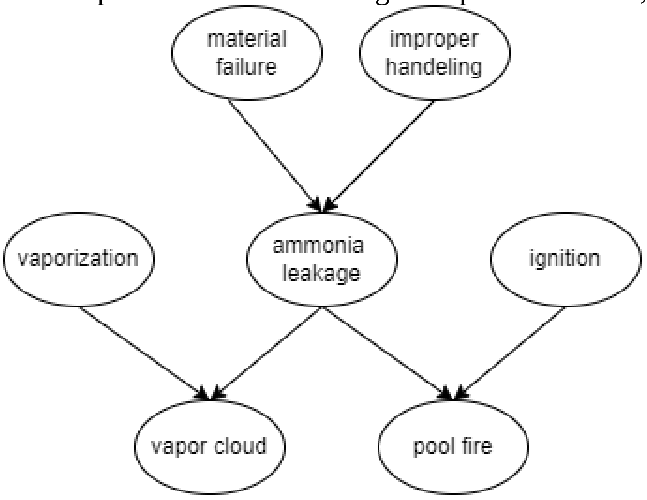

Figure 7: A Bayesian network description of ammonia leakage and possible results, the probabilistic information to be added from the next step, resource: authors

The next step is to design an interview or focus group in order to get input from chemical experts and Port of Rotterdam. Afterwards, the input (linguistic terms) will be converted to failure possibilities (numeric format). This can be achieving via methods such as linear opinion pool or max-min Delphi. On the other hand, the output, for example the suggested safety zones or regularities, will be validated with simulations, and calibrated by the port.

Hereby we answer the question regarding the safety consideration of site selection, which is mentioned at the end of section 2.1. The sites for storage tanks and bunkering berths can be firstly screened using the Bow Tie based on a set of safety requirements and expert opinions. Secondly, the sites will be evaluated by Bayesian Network to rank potential sites based on the probabilities together with the risk and mitigation costs. In the end, the port authorities and terminal operators will be aligned to verify the suitability of the sites.

4 Summary and outlook

The maritime industry is preparing itself to adopt new energy to realize its decarbonization goal. This work comprehensively reviews the ammonia storage and bunkering operations at the port, and provides a risk analysis of using ammonia as a fuel. Through this analysis, we identify research gaps that show the importance that the port should understand of ammonia risks, and should implement measures to prevent and mitigate possible risks in the infrastructure planning and daily operations.

Building on these findings, we propose a risk assessment framework aiming at interpreting the hazardous characteristics guided by safety protocols. The risk assessment consists of both a qualitative and quantitative assessment. Based on the assessment goal and available information, we select Bow Tie diagram and Bayesian network as assessment tools.

We note here, this is an ongoing work, the next step is to get input experts of both academic and industry. The experts opinion will be quantified and further used as input into the assess framework. The goal of this risk assessment framework aims to interoperate the risks into the regulations in port operations. The assessment output aims to provide the port authorities a clear overview of the different levels of risk, the corresponding probabilities the possible results and to what extend the regulations can avoid or mitigate the risk, together with the corresponding effects on the bunkering costs and time.

In the future, the proposed assessment will undergo calibration with the aid of industrial partners and chemical enterprises. The framework proposed in this study expands to other new sources of energy by examining the associated hazard characteristics.

Acknowledgements

This project has received funding from the European Union’s Horizon 2020 (MFF 2014-2020) research and innovation programme under Grant Agreement 101036594.

References

- Abbasi Kharajou, B., Ahmadi, H., Rafiei, M., Hanifi, S.M., 2024. Quantitative risk estimation of CNG station by using fuzzy bayesian networks and consequence modeling. Scientific Reports 14.
- Ballot E., F. Fontane, 2008: Rendement et efficience du transport: un nouvel indicateur de performance. Revue Française de Gestion Industrielle, v27, no2, 41-55
- Calderon, M., Illing, D., Veiga, J., 2016. Facilities for bunkering of liquefied natural gas in ports. Transportation Research Procedia 14, 2431–2440. Transport Research Arena TRA2016.
- de Dianous, V., Fievez, C., 2006. Aramis project: A more explicit demonstration of risk control through the use of bow–tie diagrams and the evaluation of safety barrier performance. Journal of Hazardous Materials 130, 220–233. doi:https://doi.org/10.1016/j.jhazmat.2005.07.010. outcome of the ARAMIS Project: Accidental Risk Assessment Methodology for Industries in the Framework of the SEVESO II Directive.

- de Ruijter, A., Guldenmund, F., 2016. The bowtie method: A review. Safety Science 88, 211–218. doi:https://doi.org/10.1016/j.ssci.2016.03.001.
- Duong, P.A., Ryu, B.R., Song, M.K., Nguyen, H.V., Nam, D., Kang, H., 2023. Safety assessment of the ammonia bunkering process in the maritime sector: A review. Energies 16.
- European Maritime Safety Agency, 2017, Guidance on LNG Bunkering to Port Authorities and Administrations
- Fan, H., Enshaei, H., Jayasinghe, S.G., Tan, S.H., Zhang, C., 2022. Quantitative risk assessment for ammonia ship-to-ship bunkering based on bayesian network. Process Safety Progress 41, 395–410. doi:https://doi.org/10.1002/prs.12326.
- Fertilizers EU, 2013. Guidance for inspection of and leak detection in liquid ammonia pipelines. URL: https://www. fertilizerseurope.com/publications/guidance-for-inspection-of-and-leak-detection-in-liquid-amonia-pipelines-copy-1/.
- Galimova, T., Fasihi, M., Bogdanov, D., Breyer, C., 2023. Feasibility of green ammonia trading via pipelines and shipping: Cases of Europe, North Africa, and south america. Journal of Cleaner Production 427, 139212.
- Golbal Centre for Maritime Decarbonisation, 2023. Safety and operational guidelines for piloting ammonia bunkering in Singapore .
- Ikaheimo, J., Kiviluoma, J., Weiss, R., Holttinen, H., 2018. Power-to-ammonia in future north european 100 % renewable power and heat system. International Journal of Hydrogen Energy 43, 17295–17308.
- Jensen, F.V., Nielsen, T.D., 2007. Bayesian Networks and Decision Graphs. Information Science and Statistics, Springer New York, NY.
- Khakzad, N., Khan, F., Amyotte, P., 2012. Dynamic risk analysis using bow-tie approach. Reliability Engineering System Safety 104, 36–44. doi: https://doi.org/10.1016/j.ress.2012.04.003.
- Machaj, K., Kupecki, J., Malecha, Z., Morawski, A., Skrzypkiewicz, M., Stanclik, M., Chorowski, M., 2022. Ammonia as a potential marine fuel: A review. Energy Strategy Reviews 44, 100926.
- Montreuil B., 2011: Towards a Physical Internet: Meeting the Global Logistics Sustainability Grand Challenge, Logistics Research, v3, no2-3, 71-87
- Muniz, M.V.P., Lima, G.B.A., Caiado, R.G.G., Quelhas, O.L.G., 2018. Bow tie to improve risk management of natural gas pipelines. Process Safety Progress 37, 169–175. doi:https://doi.org/10.1002/prs.11901.
- Ng, C.K.L., Liu, M., Lam, J.S.L., Yang, M., 2023. Accidental release of ammonia during ammonia bunkering: Dispersion behaviour under the influence of operational and weather conditions in singapore. Journal of Hazardous Materials 452.
- Papavinasam, S., 2014. Chapter 2-oil and gas industry network, in: Papavinasam, S. (Ed.), Corrosion Control in the Oil and Gas Industry. Gulf Professional Publishing, Boston, pp. 41–131.
- Park, Nam Kyu, and Sang Kook Park. 2019. "A Study on the Estimation of Facilities in LNG Bunkering Terminal by Simulation-Busan Port Case" *Journal of Marine Science and Engineering* 7, no. 10: 354. https://doi.org/10.3390/jmse710035
- Park, Y., Park, S.Y., Lee, H., 2023. Consumers' acceptance of the explosion, toxicity, and odor potential of ammonia: A survey on consumers' choice of an ammonia-based hydrogen refueling station. Sustainable Energy Technologies and Assessments 58, 103374.
- Schotman, Hans-Pieter 2023, Ammonia bunkering and storage for the maritime industry during a global ammonia transition, Delft University of Technology doi : http://resolver.tudelft.nl/uuid:5355359d-3822-4792-9b87-9cd73e91eb2a
- Terje Aven, 2016, Risk assessment and risk management: Review of recent advances on their foundation, European Journal of Operational Research,Volume 253, Issue 1, 1-13
- Yang, M., Lam, J.S.L., 2023. Operational and economic evaluation of ammonia bunkering - bunkering supply chain perspective. Transportation Research Part D: Transport and Environment 117, 103666.
- Zhang, C., Wang, Z., Chen, X., Xiang, Y., 2023. Risk assessment of liquid ammonia tanks based on bayesian network and probit model. Process Safety Progress, 1-12