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OVERVIEW OF RISK ASSESSMENTS IN THE WESTERN PART OF MUUGA HARBOUR

Viimsi Municipality

Compiled by: Purre Anna-Helena

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SUMMARY

In the territory of Viimsi Municipality is partly located Port of Muuga, which is the biggest cargo port in Estonia, where about 70% of Estonian transit is handled. They have capacity to deposit over 1 550 000 m3 of liquids (mainly oil products) in addition to other dangerous goods (e.g. fertilizers). There are currently ongoing plans to increase the capacities for storage of oil products. In the vicinity of this harbour is Viimsi rural municipality with over 21 000 citizens and also Maardu, small city with almost 16 000 people, and Jõelähtme rural municipality with about 6 000 people. Also Estonian capital Tallinn with over 400 000 inhabitants is near (or partly in) the harbour’s danger zones.

The main aim of this analysis is to provide an overview of risk analysis in Estonia and risk analysis in ports. In this paper we give an overview of places of origin of risks, the sources of the risk and the evaluation of frequencies and consequences of risks based on risk analysis of port operators dealing with dangerous goods, municipalities and other risk analysis. Risk in this study is defined as the probability and severity of consequences of negative event. Places of origin are storage facilities, infrastructure and so on where negative events could take place. Sources of risk are factor which could trigger the negative events such as extreme weather, crimes, and human faults. Negative events that could occur in their places of origin and on broader scale, and which severity and frequencies are assessed are fires, explosions, chemical spills and others.

In Estonia, need for conducting risk analysis for companies handling dangerous goods is stated in Chemicals Act, and for larger municipalities in Emergency Act. Main classes of risks could be brought out in connection with port-related risks: security, safety, environmental pollution, technical and legal risks and human faults. Risks could be divided by their cause, extent, permanency and other similar variables. More frequent accidents are leakages and environmental pollution, fires and explosions. Often with realization of one risk, some other risks can occur. Maritime accidents often occur in harbours, especially during loading and unloading activities.

In current study, 11 risk analysis were examined, seven of those were risk analyses of port operators, two were risk analyses of local municipalities and two other risk analysis documents were analysed. Three broader activities of port operators were derived: flammable liquids, ammonium nitrate and hydrogen handling. Frequent sources of risks were accidents in neighbouring companies and extreme weather situations, while in few risk analysis crime/terrorism was analysed and cyber-security was not analysed in any of the risk analysis.

In all risk analysis, impact of risks in human life and health, properties of company itself and its surrounding subjects, environment and durability of vital services. In all risk analyses, risks related to deposit units have been assessed, while risks related to loading infrastructure and transport by pipelines have also been analysed. In all risk analysis documents risk matrixes with five levels were used, where 1 indicates low and 5 very high probability of risk occurrence and “A” shows low importance of consequence and “E” catastrophic consequences. The use of similar risk matrix allows us to compare risk estimations from various risk analysis.

Risks related to handling of ammonium nitrate has estimated to have most severe, catastrophic consequences, while the probability of such event is very low. In case of accidents with handling of flammable liquids, probabilities are low or average, but consequences are severe. In relation with transport, most probable are leakages and environmental pollution, which have been included in many risk analyses. In case of flammable liquids risks related to fire were also analysed, while explosion risks were analysed in relation with handling ammonium nitrate and hydrogen.

This analysis is supported by European Union through European Development Fund. The legal analysis has been created as a part of INTERREG Baltic Sea Region programme project HAZARD (Mitigating the Effects of Emergencies in Baltic Sea Region Ports (2016-2019)). We thank AS Tallinn Harbour and Estonian Rescue Board for their help in data collection for this analysis.

TABLE OF CONTENTS

1 INTRODUCTION

There are many high-risk companies concentrated in the area of Muuga Harbour, which are mainly engaged in the transportation and storage of liquid fuels and fertilizers. About 70% of Estonian foreign trade in goods passes through Muuga Harbour, and the port has the capability to simultaneously store more than 1 550 000 m3 of liquid fuels. Several of these enterprises and a large part of the infrastructure are either located in the territory of Viimsi Parish or affect Viimsi Parish by their potential danger areas which inter alia reach densely populated areas. In addition to Viimsi Parish, with more than 21 000 inhabitants, the city of Maardu (with 16 000 inhabitants) and Jõelähtme Parish (with 6 000 inhabitants) are in immediate proximity to the industrial area. In addition, Tallinn is also partly located in the danger area of the enterprises of Muuga Harbour. Due to the concentration of a large number of high-risk enterprises in the vicinity of densely populated residential areas, this topic is subject to increased interest and need for analysis.

The purpose of this work is to provide an overview of the preparation of risk assessments in Estonia and of the risks associated with ports on the basis of scientific literature. In addition, the given work analyzes the reflection of various risk sites and risk sources related to Muuga Harbour in the risk assessments of local governments, hazardous enterprises, and in other risk assessments, and compares the estimation of the likelihood of occurrence and consequences of the risks in various risk assessments. Based on the given work, risk is understood as the ratio of the probability of the occurrence of a negative situation and its resulting consequences. Risk sites are potential places of occurrence of an accident - storage units, transportation routes, etc. Risk sources, however, are the factors that can trigger accidents, such as extreme weather conditions, crime, and human error. Negative situations that may arise from risk sources include fires, chemical leaks and pollution, and explosions, the probability/frequency of which are evaluated in risk assessments.

This work has been supported by the European Union through the European Development Fund. The work is part of the HAZARD Project of the INTERREG Baltic Sea Region Program (Mitigating the Effects of Emergencies in Baltic Sea Region Ports (2016-2019)). We thank Port of Tallinn and the Estonian Rescue Board for their assistance in collecting data.

2 ABOUT ANALYZING RISK

Risk assessment is the most important aspect of risk management and, therefore, also in civil protection. Risk management involves analyzing, evaluating, and, if necessary, preventing risks, and in case of the realization of risks, the mitigation of their consequences. In Estonia, more attention was paid to analyzing risks beginning in 1992 when the parliament of Estonian adopted the Civil Protection Act, although it did not define the concept of risk (Tammepuu, 2014). Risk is mostly understood as the ratio of the probability of the occurrence of a negative situation and its consequences, and risk assessment allows for scientifically based and systematic assessment of the potential consequences and frequency of risks. In the years 1993-1999, only a few risk assessments were prepared, mainly for the companies dealing with hazardous chemicals (Tammepuu, 2014). The need for risk assessments was laid down in the first Chemicals Act, which was adopted in 1998. According to the Chemicals Act (KemS, RT I, 10.11.2015, 2, Section 21 (8)), risk is the probability of occurrence of a consequence within a certain time or in case of certain circumstances.

A risk assessment evaluates risks to human life and health, the environment, and property, as well as to the functioning of different areas. In case of such important areas, risk assessments must be reasonable and based on scientific grounds. For this purpose it is essential to thoroughly document all phases of a risk assessment (Federal Office of Civil Protection and Disaster Assistance (FOCPDA), 2011). Most of risk assessments are ordered from respective service providers and fewer risk assessments are prepared by the organizations themselves (Karsanov, 2012). In risk assessments, danger usually includes situations and characteristics that may lead to the occurrence of harm to a person's life, health, or the environment. The potential effects of risks are related to the likelihood of the occurrence of an unwanted event, the amount of exposure, the frequency of exposure, and the possibility of eliminating or minimizing negative consequences (Tchórzewska-Cieślak et al., 2017).

The preparation of risk assessments of the Republic of Estonia, and if needed, of its regions and local governments, is regulated by the Emergency Act (HOS, RT I 2009, 39, 262). The risk assessment of a local government must reflect emergencies, dangers that cause emergencies, the probabilities and consequences of emergencies, and other relevant information regarding emergencies and references to the sources used for preparing the risk assessment (§ 21 (1) of the HOS). The requirements for the risk assessment of emergencies are specified in the Regulation of the Minister of the Interior "Guide to the Preparation of a Risk Assessment of an Emergency" RT I 2008, 8, 145. The annexes to this regulation provide information about the likelihood of occurrence of emergencies, their consequences, and about the institutions involved in the determination of risks.

In a risk assessment, potential risk sources (accidents, malfunctions, crime, etc.) are identified, the probability and possible consequences of their occurrence (usually within a certain time period) are assessed, and preventive measures are planned. Based on the Chemicals Act (§ 22 (2)), a risk assessment is required for the companies involved with the hazard categories (C (hazardous enterprise), B and A (major accident hazard). Risk assessments are coordinated by the Technical Surveillance Authority and the Rescue Board (§ 23 (2)). Requirements for risk assessments are available in the regulation of the Minister of Economic Affairs and Infrastructure No. 18 "Requirements for Compulsory Documents and Their Compilation for Hazardous Enterprises and the Companies Carrying Major Accident Risk, and for Public Information About Accidents" (RT I, 02.03.2016, 3). Legal acts that regulate risk assessments and port security, and their interpretation, vary from country to country within the European Union. However, Estonian experts were the only respondents who found that port security, subject to central regulations, does not vary within the country (Ahokas and Laakso, 2017), which implies that risk management in different ports in Estonia is similarly organized and in accordance with requirements.

It is permitted to use reasonably different methods of risk assessments in the regulation "Requirements for Compulsory Documents and Their Compilation for Hazardous Enterprises and the Companies Carrying Major Accident Risk, and for Public Information About Accidents" which sets out the risk assessments of hazardous enterprises. In the risk assessments of local governments, it is only permitted to use the risk assessment method – risk matrices – set out in the guidelines for compilation of risk assessment of an emergency. Tammepuu (2014) finds that the risk assessments based on the Chemicals Act and the Emergency Act, are practical to be combined with similarly established requirements and criteria.

In addition, the requirement to assess risk results from several international standards, such as ISO 31000: 2009, where the principles and guidelines of risk management are also applicable to risk assessments regarding ports. In Estonia, the Estonian-language risk assessment standard EVS-EN 31010:2010 is used. In addition, the International Maritime Organization (IMO) has drafted the International Ship and Port Facility Code (ISPS), which inter alia sets out the minimum amount of information about cargo to be provided by the vessels in a port, as well as requirements for security assessment and training. However, these documents are quite general and only provide minimum requirements.

A variety of methods are used to identify risk, and risks are usually identified by experts in a specific topic. For this purpose, specific technical systems and their parts are examined, and different situations are discussed (questions like "What if?", "How is this possible?", etc). Accident scenarios must be clear and described with sufficient thoroughness. It is recommended to take scientific or statistical data as the basis for developing scenarios (Federal Office for Civil Protection and Disaster Assistance, 2011). In order to determine the risks resulting from man-made mistakes, various diagrams are used which take into account the probability of different cases as a result of certain actions or omissions. The most commonly used risk identification methods are error analysis, event analysis, checklists, HAZOP (Hazard and Operability Analysis), SWIFT (Structured What-If Technique Checklist), impact diagrams, spatial risk analysis, and FMEA (Failure Modes and Effect Analysis) (Tchórzewska-Cieślak et al. 2017).

A risk matrix is one of the most important methods of risk assessment, as it assesses the outcome of the realization of a danger as well as the likelihood of occurrence in the form of a table and allows a uniform comparison of different risks. The larger the effect and likelihood of occurrence of a negative event, the greater the risk. A risk matrix also enables the categorization of risks by importance, which increases diagonally and evenly. At first, steps are taken to mitigate the risks associated with higher probability of occurrence and greater impact. Mitigating the risks associated with smaller impact and lower probability of occurrence is secondary. Error analysis makes it possible to clarify the possible causes of a particular risk, and event analysis allows identification of the potential consequences of the realization of a risk. Different risk analysis methods are often used together for risk analysis and assessment (Figure 1).

The importance of risk assessment is also laid down in the Seveso III Directive (Directive 2012/18/EU), which aims to protect the environment and human lives from major disasters. The Seveso III Directive regulates, inter alia, the following issues: classification of chemicals, labeling, packaging, civil protection mechanisms, protection of critical infrastructure, and liability for damage to the environment (European Commission, 2016). Whereby the threshold quantities of hazardous chemicals for the Estonian enterprises with the A and B level risk of major accidents result from the same Seveso directive, however, the quantities of chemicals for the enterprises with the C level risk are substantially lower than set out in the Seveso Directive (Tammepuu, 2014). In addition, the need for risk assessment is also reflected in the environmental management system standard ISO 14001: 2015. Different methods and elements of risk assessment have also been used in planning hazardous enterprises for Environmental Impact Assessments (EIA) and Strategic Environmental Impact Assessments (SEIA), although there is no such requirement in the legislation and there are no methodological guidelines (Tammepuu & Sepp, 2012). However, § 32 (3) of the Chemicals Act (RT I, 10.11.2015, 2) states that if an EIA or an SEIA is carried out when planning an enterprise, risks associated with the enterprise are assessed and publicly disclosed. At the end of 2017, the Ministry of the Internal Affairs also drafted a "Guide for Compilation of a Risk Assessment and Plan for Occupational Exposure to a Critical Service Provider" and "Local Government Guide for Crisis Management" (2014) has been prepared under the management of the Rescue Board. It is important to keep in mind the combined effects of different risks and integrated mapping of emergency risk areas (Tammepuu, 2014), which is increasingly addressed nowadays.

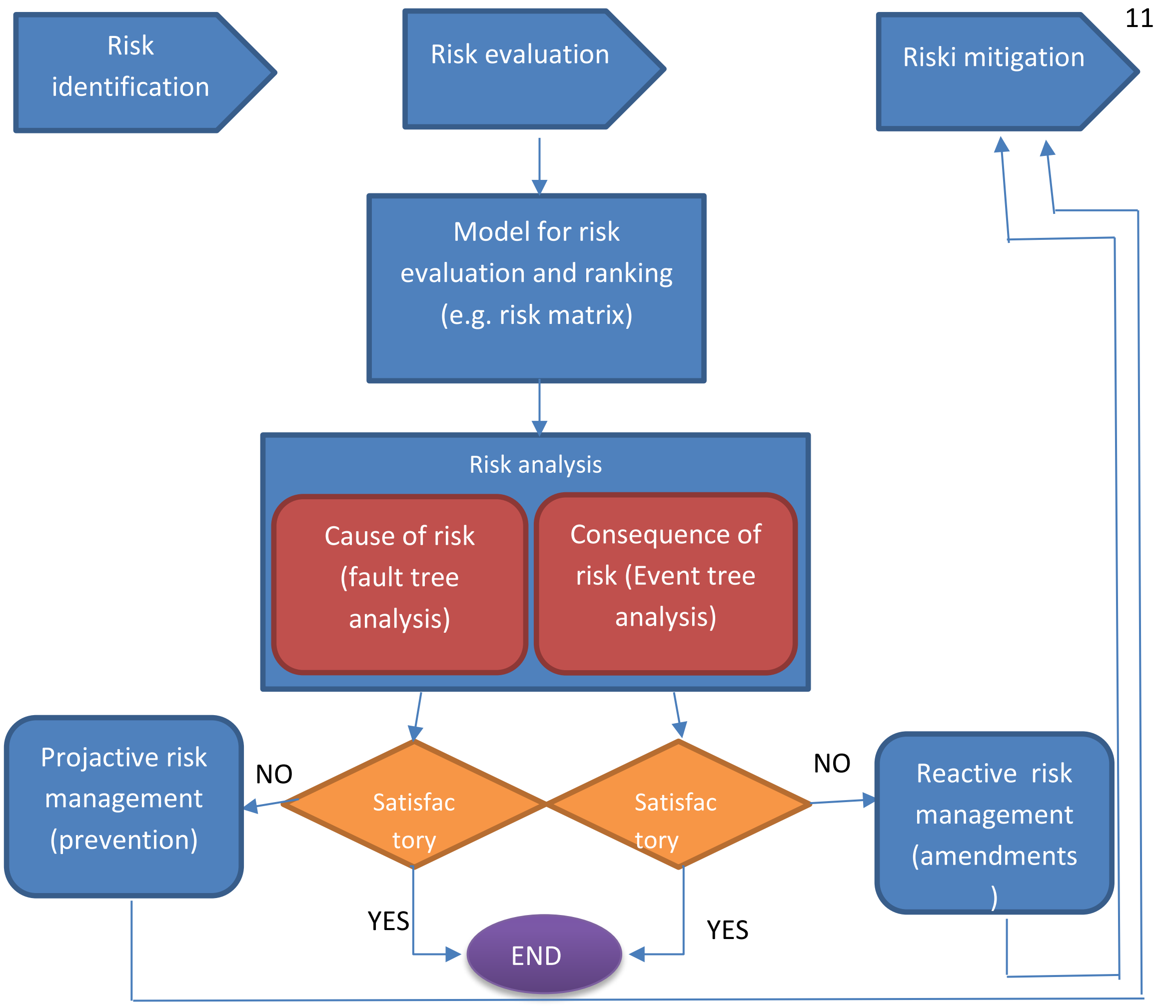

Figure 1. The process of risk management (amended, Mokhtari and others, 2011)

3 RISK IN PORTS

All human activities are related to risk. Nagi and others (2017) emphasize the difficulties of balancing the need for ports to be part of the world trade, including transporting hazardous substances, while often finding themselves close to living areas, ensuring the organization's internal (eg, employees) and external (eg, nearby businesses and residents) safety. The need for risk assessment of the port area is also provided in the Harbour Act (RT I, 03.03.2017, 24). The given risk assessment is carried out by the Maritime Administration.

Darbra and Casal (2004) found that 59% of the major accidents in ports in the 20th century occurred in the last decade of the 20th century. The increase in the density of accidents has been affected by the fact that the recent accidents have been better documented and analyzed, but also by the increased activity and volumes of the industry and ports. According to the European Maritime Safety Agency (EMSA) (2017), 45% of the maritime transport accidents by merchant ships over the past decade have occurred in the port area. In most accidents, people are not killed or injured, and there are few accidents involving large numbers of victims, whereby there are smaller probabilities for accidents with large casualties in European Union countries than elsewhere in the world (Darbra and Casal, 2004). However, accidents in ports can be regarded as potential sources of danger for the surrounding population, since a large part of the ports are located near residential areas and industrial areas and are connected to public infrastructure. Since the 1980s, when scientific literature related to ports has begun to be assesed, the amount of scientific research related to port risks has also increased (Nagi et al., 2017).

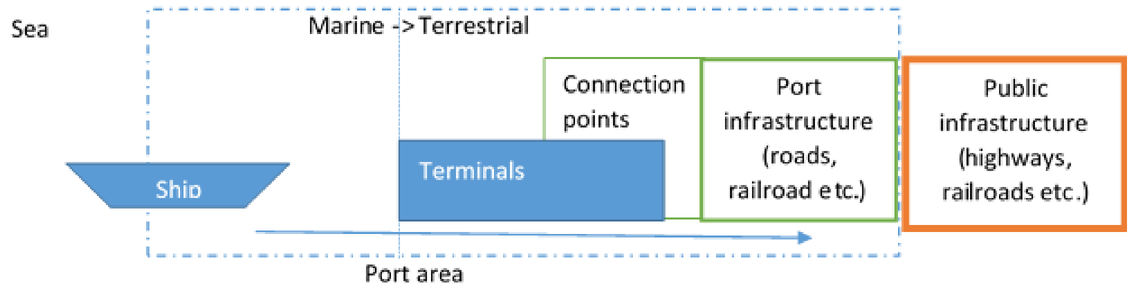

Figure 2. Water and land relations in the port system (amended, John and others, 2014)

Tchórzewska-Cieślak and her colleaguess (2017) systematize dangers by their causes (internal and external hazards of the company), durability (rare, long-term, cyclic), extent (local, wide (regional, global)), and stability of distribution (accelerating or decelerating).

Risk management in ports is divided into four phases: prevention, detection, response/mitigation and recovery (Pinto and Talley, 2006). Mokhtari and others (2011) divide risks into the following groups (beginning from the most significant ones):

- security risks (e.g. human security, port assets, and profits),

- human error (errors made by operators, ship personnel, and other employees),
- safety risk (vessels' capability, traffic conditions, weather, goods, vessel traffic management),
- environmental pollution risk (pollution from ships or shipped goods, pollution from ports or operators, pollution from the surrounding area),
- technical risks (insufficiency in technical maintenance, IT technology, and navigation, including the dredging of channels),
- legal risks (changes in legislation, fraudulent contracts).

John and his colleagues (2014), however, classify port-related risks as follows:

- activity related risks (failures in port technology, ship and cargo related accidents, and human error),
- security related risks (sabotage, terrorism, monitoring system malfunction, fire),
- technical risks (inadequate maintenance of technological tools, IT systems, and shipways, deficiencies of navigation support systems),
- organizational risks (labor dissatisfaction, disagreements with authorities, congestion of quays, gates, or warehouses),
- natural risks (geological and seismic events, hydrology, and weather conditions).

Often, risk management, including risk assessment, is highly port-specific, depending on the operating area of the port and the goods being transported. Similarly, there are no universally accepted standards nor criteria for ports' risk assessments (Nagi et al., 2017). A survey carried out on hazardous enterprises in Estonia revealed that all companies saw fires as the most common risk, and most companies (80%) assessed the risks of hazardous chemicals as a serious danger (Tammepuu, 2014). In a second study, Tammepuu and et al. (2009) found that the Port of Tallinn's risk assessment regarded risks caused by hazardous chemicals and fire as irrelevantits. However, according to historical data, the most frequent accidents in ports are related to leaks (51%), fires (29%), explosions (17%), and dangerous gases (3%) (Darbra and Casal, 2004). In many cases, however, several different dangers can occur together. Leaks can be accompanied, for example, by fires, explosions, etc. As the potential hazards of main fuel terminals, Karsanov (2012) highlights spill fires, the ignition of containers, explosions of dispersed evaporative emissions, spark ignition, and boiling liquid expanding vapor explosions (BLEVE).

Almost 57% of accidents occur in the transportation of goods, while loading and storage of goods is less dangerous, with about 15% of accidents occurring in a port (Darbra and Casal, 2004). It has been found that approximately 40% of accidents occur at sea (shunting), 21% on land (storage, transportation and processing), and 39% at nautical and land borders (loading and maintenance) (Ronza et al., 2003). According to EMSA (2017), most of the accidents for cargo ships occur at anchor or in ports, as well as on arrival at a port. Nearly 60% of accidents involve oil products (Darbra and Casal, 2004).

John and his colleagues (2014) emphasize terrorism and human errors as the risks associated with ports. Most accidents have occurred as a result of collisions (44%), followed by mechanical errors (18%), external factors (17%), and human error (16%) (Darbra and Casal, 2004). Man-made mistakes, as the main causes of accidents, followed by frequent mechanical errors, are also highlighted by EMSA (2017). However, most of the scientific articles on port risk assessments focus on applying decision analysis methods to adopting economic, safety and port related decisions in different situations. They also focus on the potential hazards of climate change and dangerous environmental impacts on ports (Nagi and others, 2017). Therefore, there are no studies on potentially more dangerous issues, such as misuse of hazardous substances, errors resulting from human activities, and dangerous chemical explosions (Nagi and others, 2017). According to Tchórzewska-Cieślak and her colleagues (2017), more attention should be paid to integrating technical and environmental risks into risk assessments.

4 MUUGA HARBOUR

The Muuga Harbour is located in Harjumaa, in the territory of Viimsi Parish, Jõelähtme Parish and the town of Maardu (Figure 3). The territory of the port is 524.2 ha and the water area is 752 ha (AS Tallinna Sadam, 2016). Muuga Harbour is the largest cargo port in Estonia. The port is ice-free for the whole year and accepts vessels a draft of up to 18 m in length, that is, all a vessels that can access the Baltic Sea via the Danish Straits. In total there are 29 quays with a total length of 6.4 km (AS Tallinna Sadam, 2016). Muuga Harbour is able to handle various goods - there are 6 liquid cargo terminals (capacity of 1 550 150 m3), 2 multi-purpose terminals (one of them a cold storage complex), a container terminal, a ro-ro cargo terminal, and bulk cargo, grain, steel, and coal terminals (AS Port of Tallinn, 2016).

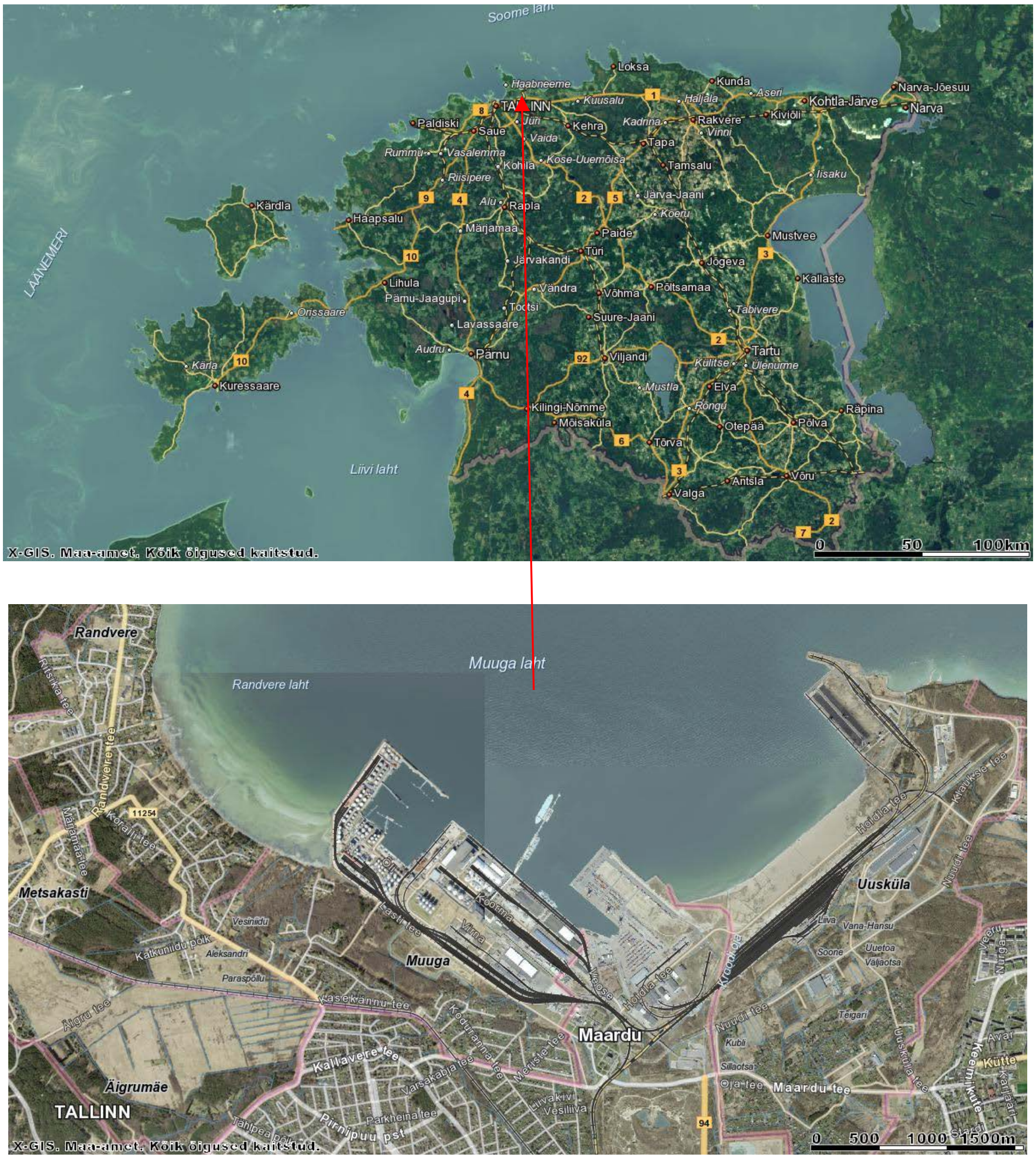

Figure 3. Location of Muuga Harbour (Estonian Land Board, 2016)

The cargo turnover of Muuga Harbour is about 75% of the cargo turnover of the Port of Tallinn and about 70% of the volume of Estonian transit (AS Tallinna Sadam, 2016). In 2016, 11,700,000 tons of goods transited the Muuga Harbour (Kuus, 2017). There are five companies in Muuga Harbour with a A-category major accident risk, one with the B-category major accident risk, and one hazardous enterprise. The companies with major accident hazards mainly deal with liquid fuels, although one also deals with fertilizers (ammonium nitrate).

5 RISK ASSESSMENTS OF THE WESTERN PART OF MUUGA HARBOUR

Tammepuu et al. (2009) found that the Port of Tallinn should (1) improve the methods for identifying potential risks and accidents, (2) specify more clearly the duties and responsibilities of operators in case of an accident, and (3) better cooperate with the port, its operators, and local authorities related to the port. It was also advised to give more instructions on how to behave in the event of a fire.

Hazardous enterprises operating in Muuga Harbour have risk assessments according to the Chemicals Act; risk assessments have also been prepared by the Viimsi Municipality and City of Tallinn in accordance with the Emergency Law. In addition, OÜ E-konsult, under the management of Lembit Linnupõllu, prepared the "Environmental Impact Assessment of the Western Part of Muuga Harbour" in 2007, in which one chapter gives a brief overview of earlier analyzes of the risks of Muuga Harbour (risk assessments of Viimsi and Maardu local authorities). Based on an order from AS Tallinna Sadam, OÜ E-konsult has also prepared a cumulative risk assessment of Muuga Harbour (2015).

One of the objectives of the development plan and budget strategy of Viimsi Parish for 2018-2022 (Viimsi municipality council and Viimsi municipality government, 2017) is to minimize environmental risks, which is to be achieved, inter alia, by upgrading the risk assessment of Viimsi Parish, continuous analysis of the state of the environment of Viimsi Parish, including monitoring of the environmental risks of Muuga Harbour and minimizing risks to the living environment, enhancing monitoring risk mitigation, and improving preparedness for rapid and appropriate responses to accidents. One of the tasks to also to implement measures to prevent the deterioration of the marine environment, reduce pollution risks, and to increase the capacity to respond to marine pollution. The 2014-2020 development plan of Maardu also presents the compilation of the risk assessment of the local authority, in cooperation with Viimsi and Jõelähtme parishes. So far, in Jõelähtme Parish, there is no risk assessment of emergencies, nor is it planned to be prepared in their development plan (Jõelähtme municipality council, 2016).

In the analysis, the compulsory risk assessments (RT I, 02.03.2016, 3) of the hazardous enterprises of the western part of Muuga Harbour (located in the territory of Viimsi Parish), as well as other risk assessments reflecting the given subject (cumulative, related to detailed plans, and those created by local authorities) were used. In Muuga Harbour, the handling of hazardous substances is divided into three categories: handling of flammable and combustible liquids, handling of ammonium nitrate, and handling of hydrogen.

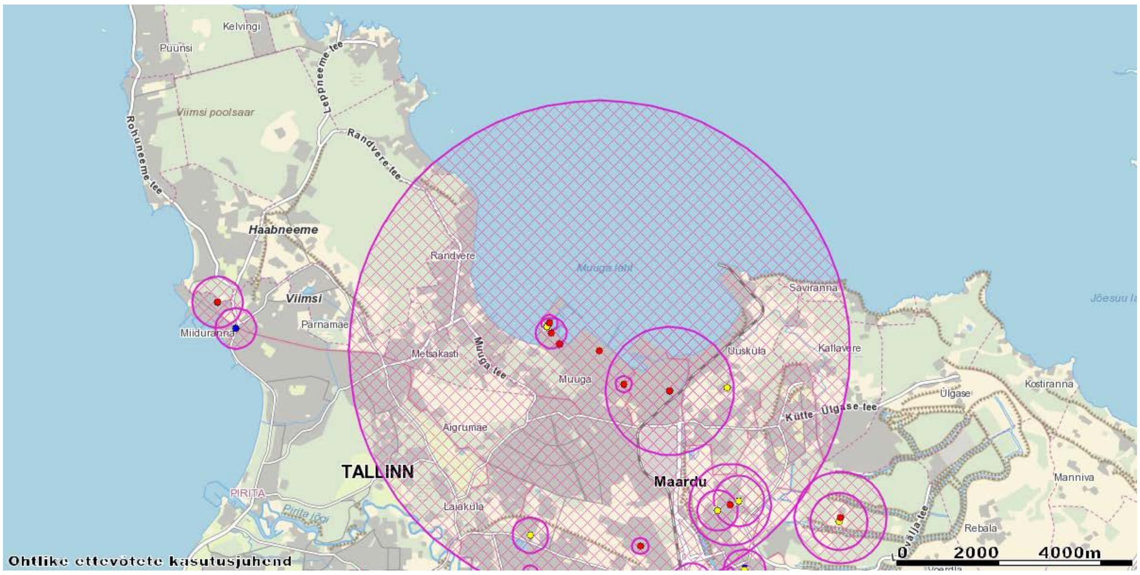

Figure 4. Hazardous enterprises in the area of Muuga Harbour and Viimsi Parish ● – Company with an A-category risk of major accidents, ● - Company with a B-category risk of major accidents, ● - hazardous enterprise, ⬭ - Danger zone of a hazardous enterprise (Estonian Land Board, 2017)

Eleven risk assessments were included in the analysis, seven of which were compulsory risk assessments of hazardous enterprises, two of which were risk assessments of local authorities, and two of which were other risk assessments (the Port of Tallinn's cumulative risk assessment and an annex to the port operator's environmental impact assessment). According to the risk assessments of local governments, Muuga Harbour was addressed both in the risk assessments of Tallinn and Viimsi Parish. Jõelähtme Parish and Maardu have not been subject to public risk assessments. Most risk assessments (n = 7) have been ordered by operator companies dealing with liquid fuel, two risk assessments were commissioned by the local authorities (Tallinn and Viimsi), and one risk assessment apiece were ordered by bulk cargo operators and by the port itself.

Risk assessments have been prepared earlier. The average year in which risk assessments were approved is 2012. The oldest risk assessment dates back to 2005 and the latest from 2015. Risks change over time, as does the legislation on which risk assessments are based, thus ongoing monitoring and updating of risk assessments is required (Federal Office of Civil Protection and Disaster Assistance, 2011). Viimsi Parish's risk assessmentP needs to be updated as well. Preparation of a new risk assessment and its harmonization with the revised Emergency Law is planned to be carried out in 2018. All operators' risk assessments comply with the regulation No. 18 prepared pursuant to § 23 (8) and § 24 (6) of the Chemicals Act. Additionally, two other risk assessments are also in accordance with this regulation. This allows for a coherent assessment and comparison of the outcomes and probabilities of the risks presented in the risk assessments.

In case of risk assessments and management, the weather conditions in which risks appear, is an important factor, upon which the consequences and probabilities of a number of risks depend on. The emergence of risks resulting from natural disasters can be intensified together with the increase in extreme weather conditions associated with climate change. The average wind speed calculated in the risk assessment is 4.6 m/s, the lowest wind speed is 3.1 m/s and the highest speed is 5.5 m/s. The most frequent winds come from the southwest and south. Six of the risk assessments showed an average air temperature of 5.2 °C, varying from 5 to 5.5 °C. Two risk assessments showed the average temperatures of the warmest (18.4±1.0 °C with standard deviation) and coldest months (-7±1.4 °C).

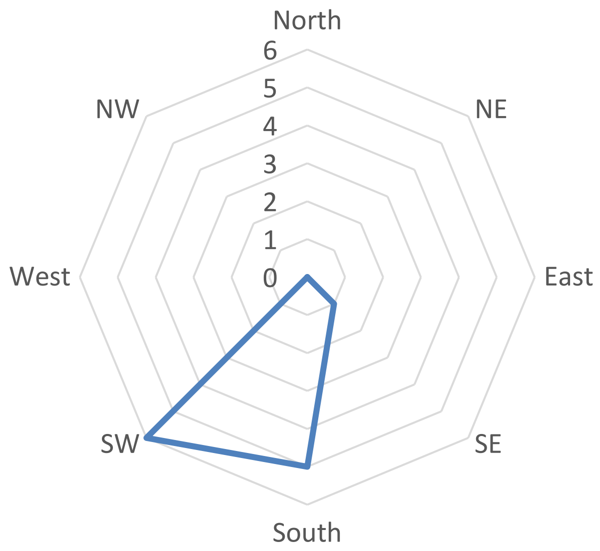

Figure 5. The most common winds in Muuga Harbour, based on risk assessments

Muuga Harbour's units are divided into storage units (container parks, dome-type warehouses), loading and unloading units (railway decks, car decks, and quays) and pipeline transportation. Risks related to storage units are addressed in risk assessments most often (Table 1). Nagi and others (2017) suggest that it is necessary to more thoroughly examine different potential sites and sources of risks through different risk assessment methods. Almost all risk assessments have analyzed the risks associated with railway decks and quays. Only one company has taken into account the risks caused by Muuga's conveyor transportation. However, the risks of the conveyor transportation have not been analyzed in any of the risk assessments of local governments. In addition to previous risk sites, the risks associated with car decks, pipeline transportation, and handling facilities have also been analyzed.

Table 1. Consideration of risk sites in risk assessments reflecting risks in Muuga Harbour

	Compulsory risk assessment of hazardous enterprise	Risk assessment of local government	Other
Storage unit			
Considered	7	2	2
No risk site	0	0	0
Not considered	0	0	0
Railway deck			
Considered	7	1	2
No risk site	0	1	0
Not considered	0	0	0
Car deck			
Considered	5	1	1
No risk site	2	1	1
Not considered	0	0	0
Quays			
Considered	7	1	2
No risk site	0	1	0
Not considered	0	0	0
Conveyor transportation			
Considered	1	0	1
No risk site	6	2	1
Not considered	0	0	0
Pipeline transportation			
Considered	6	1	2
No risk site	1	1	0
Not considered	0	0	0
Handling units			
Considered	6	0	1
No risk site	0	1	1
Not considered	1	1	0

Risk assessments analyze different sources of risk. Accidents in neighboring enterprises and natural occurrences have been taken into account the most in risk assessments, while the effects of an epidemic and aviation accidents have been analyzed the least (Figure 6). When accidents in neighboring enterprises and dangerous natural occurrences have been taken into account by almost all hazardous enterprises in their risk assessments, only a small number of companies have accounted for aviation accidents and bomb threats and other malicious activities (Table 2). Only one local government has examined the risks associated with an epidemic in their risk assessment.

Ahokas & Kiiski (2017) emphasize the port operation risks related to cyber-security, which can cause varying amount of damage, ranging from financial problems or loss of sensitive information to serious accidents. Taking into account cyber risks in the management of port-related risks is still in its infancy (Ahokas & Kiiski, 2017). Cyber risks, as well as the risks analyzed in the risk assessments so far, should be identified, their potential consequences and likelihood of occurrence should be evaluated, and preventive and mitigation measures should be applied. In a study conducted by Ahokas and Laakso (2017), port experts found that the risks associated with cyber-security were inadequately addressed in the risk management of ports. Cyber-security has not been examined in the risk assessments related to Muuga Harbour, while Estonia has previous experience in combating cyber threats and their consequences, and thus it would be necessary to also analyze these threats in the risk assessments of hazardous enterprises and organizations, such as not just port operators, but also local governments.

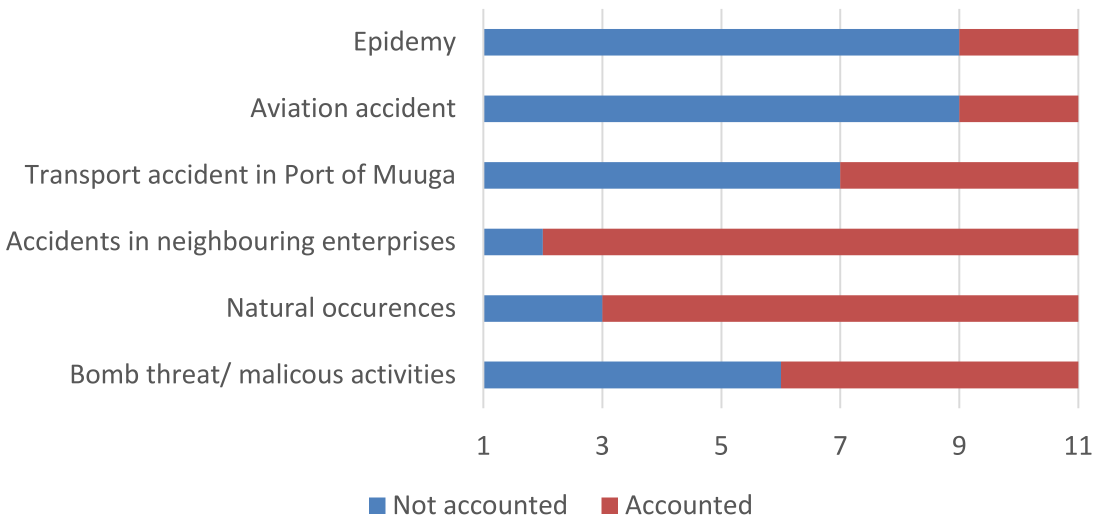

Figure 6. The number of risk assessments addressing the risks related to Muuga Harbour, taking into account risk sources

Table 2. Consideration of risk sources in risk assessments addressing risks in Muuga Harbour by types of risk assessments

	Compulsory risk assessment of hazardous enterprise	Risk assessment of local government	Other
Epidemic			
Considered	0	1	1
Not considered	7	1	1
Aviation accident			
Considered	1	1	0
Not considered	6	1	2
Transportation accident in Muuga Harbour			
Considered	3	1	0
Not considered	4	1	2
Accident in neighboring enterprise			
Considered	6	1	2
Not considered	1	1	0
Natural occurrences			
Considered	5	2	1
Not considered	2	0	1
Bomb threat / abusive activities			
Considered	2	2	1
Not considered	5	0	1

In the framework of this work, the risks were, according to their sites, divided into categories associated with storage units, railways, motor vehicle, marine, and pipeline transportation. The risk matrices in Table 3 outline the risks associated with their sites in the various risk assessments. A similar five-point risk matrix is also used in local governments' risk assessments in Germany (Federal Office of Civil Protection and Disaster Assistance, 2011). In the given risk matrices, the probabilities are expressed on a scale from 1 to 5, where 1 refers to a very small, 3 to an average and 5 to a very high probability. The consequences are also shown on the five-point scale (A to E), where A refers to a minor, B to a mild, C to a severe, D to a very severe, and E to a catastrophic consequence.

In circumstances involving the handling of flammable and combustible liquids, the consequences of all risks have been assessed as very severe (D) in the risk assessment of port operators. Frequencies are rated as either small or medium. Storage area and container fires, leaks, environmental pollution, and spill fires have been evaluated. The risks associated with leakage from storage units, environmental pollution, and container and storage area fires have not been analyzed in any other risk assessments. Karsanov (2012) addressed the risk assessments of Estonian fuel terminals in his work, which found that the probabilities of fires, spill fires and BLEVEs have been assessed as low, and the likelihood of container fires as very low, but the probability of leakage and environmental pollution as average. However, there were quite a few inconsistencies between the accidents reflected in the risk assessments of various fuel terminals and in the estimates of their likelihood (for example, most of the risk assessments have not addressed leakage and almost half of these have not addressed environmental pollution) (Karsanov, 2012).

Risks related with ammonium nitrate explosions have not been analyzed in any risk assessment of hazardous enterprises. In risk assessments, ammonium nitrate explosions have been considered to be one of the major accidents with the most severe consequences in Muuga Harbour (assessment 1E), which may be triggered by the dispersal and ignition of ammonium nitrate in the open air or a dome-type warehouse, or ignition of of ammonium nitrate stored in a warehouse or railway tank. The risks associated with a hydrogen explosion, which may be triggered by the leakage of a container, have only been analyzed in one "other" risk assessment with the assessment of 2C.

Table 3. Consequences and probabilities of risks in various risk assessments. The number of risk assessments of hazardous enterprises is presented **in bold**, where the given risk is estimated with the corresponding probability and consequence. The number of risk assessments of local governments is presented <u>underlined</u>, where the given risk is estimated with the corresponding probability and consequence. The number of other risk assessments is presented in *italics*, where the given risk is estimated with the corresponding probability and consequences.

Storage units

	1	**2**	**3**	**4**	**5**
A					
B					
C		Halyard fire (**1**) Container fire (**1**) Explosion of hydrogen (*1*)			
D	Explosion of ammonium nitrate (<u>1</u>)	Halyard fire (**6**; *1*) Container fire (**6**; *1*)	Leakage and environmental pollution (**7**; *1*)		
E	Explosion of ammonium nitrate (<u>1</u>; *1*)				

Railway transportation

	1	2	3	4	5
A					
B		Spill fire (*1*)	Leakage and environmental pollution (*1*)	Leakage and environmental pollution (**7**; *1*)	
C			Spill fire (1) Leakage and environmental pollution (1)		
D		Spill fire (**7**; *1*) Explosion of a tank carrying ammonium nitrate (*1*)			
E	Explosion of a tank carrying ammonium nitrate (1)				

Motor vehicle transportation

	1	2	3	4	5
A			Leakage and environmental pollution (**7**; *1*)		
B		Spill fire (*1*)			
C		Leakage and environmental pollution (1)	Spill fire (1)		
D		Spill fire (**7**; *1*)			
E					

Marine transportation

	1	2	3	4	5
A					
B		Leakage and environmental pollution in water area (*1*) Extensive leakage and environmental pollution (*1*) Spill fire (*1*)			
C				Leakage and environmental pollution in water area (1) Extensive leakage and environmental pollution (1)	
D		Leakage and environmental pollution in water area (1) Spill fire (**7**; *1*)	Leakage and environmental pollution in water area (**7**; *1*) Extensive leakage and environmental pollution (**7**; *1*)	Extensive leakage and environmental pollution (1)	
E					

Pipeline transportation

	1	2	3	4	5
A					
B					
C		Leakage and environmental pollution (*1*) Spill fire (*1*)			
D		Leakage and environmental pollution (1) Spill fire (**7**; *1*)	Leakage and environmental pollution (**7**; *1*)		
E					

In the logistics of the port area, leakage of railway tanks carrying flammable and combustible liquids, and environmental pollution in the Muuga cargo station (5B) have been evaluated to be the most frequent accidents. Similar accidents in the railway sections of Muuga Harbour (4B) have also been evaluated to be the most frequent accidents. In railway transportation, accidents with the most serious consequences are deemed to be explosion of railway tanks carrying ammonium nitrate (1E), as well as boiling liquid expanding vapor explosions (BLEVEs) of railway tanks carrying liquefied petroleum gas (LPG). Spill fires related to railway and motor vehicle transportation have been rated between 2B to 3C. In maritime transportation, the risk of leakage and environmental pollution in case of an accident involving cargo ships in the Muuga Harbour water area has been rated at 3D, with somewhat lesser consequences for leakage and environmental pollution in the territory of Muuga Harbour for tanker trucks (3A). For tanker trucks carrying LPG, BLEVE has been rated at a low probability (2) but with very serious consequences (D).

All risk assessments have considered the effects on human life and health, the company itself and on the affected property, the environment, and the vital function of the critical service. At the same time, only one risk assessment of a local government has considered the need for intervention assets and evacuation. The potential effects of risks on different fields has been analyzed in risk assessments, which divide into five categories: people (deaths, injured, those who need humanitarian aid, etc.), environment (e.g damage to protected areas, water bodies, groundwater, agricultural land), economic losses (physical damage, indirect losses, unearned income and taxes), supplies (disruptions in supplying energy, gas, water, telecommunication services), and intangible damage (public order and safety, political and psychological consequences, damage to cultural property) (Federal Office of Civil Protection and Disaster Assistance, 2011).

Karsanov (2012) points out that in 2012, nearly three quarters of the studied fuel terminals' risk assessments were more or less insufficient. The risk assessments of fuel terminals also differed significantly in terms of the comprehensibility of their level of detail and accident scenarios. Kaurla (2016) found that the information exchange between different authorities should grow in the process of preparing and evaluating risk assessments, and more specific requirements and more precise methodologies for compiling risk assessment should be developed. The comparison of the results of the risk assessment is also impeded by the differences in their quality and lack of uniform criteria (Karsanov, 2012). Although it is necessary to bring the risk assessments of different operators to a similar level of detail, there are several ways to develop risk assessments. Nagi et al. (2017) emphasize the need for a cooperative risk assessment involving different stakeholders dealing with various port operations. The first step for this has been taken by AS Tallinna Sadam by preparing a cumulative risk assessment of Muuga Harbour.

6 SUMMARY

Muuga Harbour and its immediate surroundings are one of the most important industrial and commercial areas in Estonia, bringing together a wide range of companies at different risk levels. High-density areas close to the enterprises, such as Tallinn, Viimsi, and Maardu, make the risk management of these companies, including their risk assessments, more important. Therefore, it is important to conduct risk assessment and analysis that is transparent, evidence-based, and comprehensible for neighboring residents. The purpose of this work was to provide an overview about compiling risk assessments in Estonia, the risks associated with ports, and the reflection of various risk sites and sources associated with Muuga Harbour according local governments, companies using hazardous materials, and other risk assessments, and compares the assessment of the consequences of risks and the likelihood of occurrence in various risk assessments.

Economic activities are always associated with risk, while some economic activities also involve the risk of major accidents. The risk is mainly defined as the ratio of likelihood of a negative occurrence and its consequences. Risk assessment is one of the important parts of risk management that follows the identification of risks and allows the ranking of identified risks based on their relevance. Risk assessment allows the identification of the most important risks (with a higher likelihood of occurrence and more severe consequences) to develop prevention and mitigation measures. In Estonia, the need for compiling risk assessments in case of companies with a risk of major accidents derives from the Chemicals Act and, in case of local governments, from the Emergency Act.

The risks associated with ports can be divided into several main risk groups, namely security, safety, environmental pollution, technical and legal risks, and human error. Risks can be subdivided based on their cause, extent, duration, and other similar characteristics. In ports, the most frequent accidents are related to leaks (environmental pollution), fires, and explosions; however, the realization of some risks can often cause the occurrence of another risk. Maritime accidents often occur at ports, for example when loading and unloading.

The given work analyzed 11 risk assessments, most of which were conducted on behalf of port operators, two of them by local governments and two came from other sources. The risk assessments of port operators were divided into three categories: flammable and combustible liquids, ammonium nitrate, and hydrogen. Most of the sources of risk addressed were related to accidents from neighboring companies and extreme natural occurrences, a smaller number of risk assessments addressed crime/terrorism as source of risk, and cyber-safety was not analyzed at all.

All risk assessments analyzed the consequences of the occurrence of risks to human life and health, to a company with major accident risk and to its assets, to the environment, and to the vital function of critical services. Most of the risks in risk assessments were associated with storage units, as well as loading and unloading infrastructure and pipeline transportation. All risk assessments used the five-step risk matrix, where 1 refers to a small and 5 to a very high

probability of the occurrence of a risk. The letter ‘A’ indicates a minor consequence and ‘E’ a catastrophic consequence. Such risk matrices with similar structures make it possible to compare the risk evaluations presented in the risk assessments.

Risks with the worst catastrophic consequences, but with low probabilities of occurrence, are related to the storage and transport of ammonium nitrate. In case of accidents with flammable and combustible liquids, the consequences are extremely severe, but the likelihood of their occurrence is low or average. The most frequent accidents in transportation are related to leaks and environmental pollution, which are also often assessed in risk assessments. Regarding risks with flammable liquids, in addition to environmental pollution, there are also risks associated with fire, while the risks associated with explosions have been analyzed in relation to handling ammonium nitrate and hydrogen.

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HAZARD project has 15 full Partners and a total budget of 4.3 million euros. It is executed from spring 2016 till spring 2019, and is part-funded by EU's Baltic Sea Region Interreg programme.

HAZARD aims at mitigating the effects of major accidents and emergencies in major multimodal seaports in the Baltic Sea Region, all handling large volumes of cargo and/or passengers.

Port facilities are often located close to residential areas, thus potentially exposing a large number of people to the consequences of accidents. The HAZARD project deals with these concerns by bringing together Rescue Services, other authorities, logistics operators and established knowledge partners.

HAZARD enables better preparedness, coordination and communication, more efficient actions to reduce damages and loss of life in emergencies, and handling of post-emergency situations by making a number of improvements.

These include harmonization and implementation of safety and security standards and regulations, communication between key actors, the use of risk analysis methods and adoption of new technologies.

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