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FIRESPILL

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Methodology / Guidelines for Risk assessment for Oil Spills in the Adriatic Sea

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PREAMBLE

The preparation of the Methodology / Guidelines for Risk Assessment tor Oil Spills in the Adriatic Sea was carried out as one of the activities within the project “Fostering Improved Reaction of crossborder Emergency Services and Prevention Increasing Safety Level“ (FIRESPILL). FIRESPILL project is part of “Interreg V-A Italy - Croatia Programme“ co-financed by the European Commission. The Methodology was prepared by ATRAC, FIRESPILL Project`s partner, and the Faculty of maritime studies, University of Rijeka as external contracted party.

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Content:

1 Introduction

These Guidelines are developed as a part of the project "Fostering improved Reaction of cross-border Emergency Services and Prevention increasing Safety Level - FIRESPILL". FIRESPILL overall objective is to enhance the capacity of Emergency Service Organisations to increase cross-border effectiveness in tackling natural and man-made disasters, decreasing the exposure of the populations to the impact of hazards and increasing the safety of the Croatian and Italian Adriatic basin by improving emergency prevention and management measures and instruments. Project joint activities will be implemented per each risk taken into consideration, aiming at (a) the improvements of the existing Emergency Services Regulatory System; (b) the improvement of Emergency Management Systems (EMS) in terms of new and innovative solutions; (c) the activation of citizens' participatory process. Specific actions will be dedicated to each main risk in chosen pilot areas (fire, oil spill and other marine hazards, earthquake, pandemic).

The project is co-financed from the program InterReg V-A Italy - Croatia.

The project development has been awarded to the University of Rijeka, Faculty of Maritime Studies (as a Contractor) by the Adriatic Training and Research Centre for Accidental Marine Pollution Preparedness and Response – ATRAC (as a Client) via a public procurement process concluded on 06 September 2021.

The main objective of this Guideline is to provide a uniform, consistent methodology for the oil spill risk assessment process within the area under project consideration. To maintain as wide usability as reasonable possible, the methodology must be implementable by different authorities or interested parties, providing comparable results, thus fostering the harmonised implementation and improving emergency service capacities.

These Guidelines follows the provisions and recommendations of international treaties binding the Republic of Croatia and the Italian Republic on the protection of the sea from pollution, in particular:

- International Convention on the Prevention of Pollution from Ships, 1973 (London, 02 November 1973), (MARPOL Convention), (Official Register of the SFRY: International Treaties 2/85),
- 1978 Protocol relating to the International Convention on the Prevention of Pollution from Ships, 1973 (London, 17 February 1978), (Official Newspaper SFRY: International Treaties 2/85),
- International Convention on Oil Pollution Preparedness, Response and Cooperation, 1990 (OPRC Convention), (Official Gazette 2/97),
- Protocol of 1992 to amend the International Convention on Civil Liability for Oil Pollution Damage 1969 (CLC Convention), (NN-MU 2/97),
- Protocol of 2003 to the International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage, 1992 (NN-MU 2/97),

- Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972 (London, 29 December 1972), (Official Newspaper SFRY: International Treaties 13/77),
- International Convention on the Control of Harmful Anti-fouling Systems on Ships, 2001 (London, 05 October 2001), (AFS Convention), (NN-MU 10/06),
- International Convention on Civil Liability for Bunker Oil Pollution Damage (BUNKER) 2001 (Official Gazette 9/06),
- Agreement on the Sub-regional Plan of Interventions for the Prevention of, Readiness for and Response to Sudden Pollution of the Adriatic Sea on a Larger Scale (Sub-regional Intervention Plan), (Portorož, 09 November 2005), (NN-MU 7/08),
- Protection of the Mediterranean Sea from Pollution (Barcelona, 16 February 1976), (Official Newspaper of the SFRY, International Treaties and Other Agreements 12/77),
- Protocol on the Prevention of Pollution of the Mediterranean Sea due to the sinking of waste and other substances from ships and aircraft (Barcelona, 16 February 1976), (Official Newspaper SFRY, International Treaties and Other Agreements 12/77),
- The Protocol for the Prevention of Pollution in the Mediterranean Sea by Dumping from Ships and Aircraft or Incineration at Sea. (NN-MU 17/98)
- Protocol Concerning Cooperation in Combating Pollution of the Mediterranean Sea by Oil and Other Harmful Substances in Cases of Emergency (Barcelona, 16 February 1976) (Emergency Protocol), (Official List of the SFRY, International Treaties and Other Agreements 12/77),
- Protocol for the protection of the Mediterranean Sea against pollution from land-based sources (Athens, 17 May 1980), (LBS Protocol), (Official Newspaper SFRJ). International Treaties 1/90).

This Guideline bear in mind as much as reasonably possible the guidelines or recommendations of international and national official and unofficial organisations with expertise in the field of marine environmental protection, in particular:

- International Maritime Organisation - IMO,
- European Maritime Safety Agency - EMSA,
- US National Oceanic and Atmospheric Administration - NOAA,
- International Tanker Owners Pollution Federation – ITOPF,
- International Petroleum Industry Environmental Conservation Association– IPIECA.

These Guidelines do not apply to events that may not cause marine oil spills. In addition, these Guidelines do not apply in case of events causing oil spills in such quantities or locations that even in most favourable conditions, the remedial actions would not produce any tangible effects.

The findings presented here should enable the comprehensive oil spill risk assessment in a standardised and harmonised manner. These guidelines do not present the manual for risk assessment. It is assumed that, if required knowledge does not exist, external experts will provide specialised knowledge on the risk assessment to those who will perform the assessment if needed. The references at the end of this document should be consulted for further information on proposed specialised methods. Appropriate literature or education on standard risk assessment procedures, widely available, should be consulted.

2 Glossary

The terms used in this document follows as much as appropriate the terms and their definitions as it is defined in ISO 31010 and UNISDR Terminology on Disaster Risk Reduction (2009).
Terms related to maritime traffic and maritime accidents likely to cause oil spills are compiled from different sources provided by IMO (FSA) and IALA.
The most important terms and their definitions are listed below.

Accident
An unintended event involving a fatality, injury, ship loss or damage, other property loss, damage or environmental damage.
Accident category
A designation of accidents according to their nature, such as:

- **Collision**: striking or being struck by another ship, regardless of whether underway, anchored or moored (does not include striking underwater wrecks);
- **Grounding**: running aground or hitting/touching shore or sea bottom or underwater objects (wrecks, etc.);
- **Contact**: striking any fixed or floating object other than those included under collision or grounding;
- **Foundering**: sinking due to heavy weather, the springing of leaks, breaking into two, etc.).

Incident
An unforeseen or unexpected event that may have the potential to become an accident but in which injury to personnel and/or damage to a ship or the environment does not materialise or remains minor.
Initiating event
The first of a sequence of events leading to a hazardous situation or accident.
Disaster
A serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources.
Early warning system
The set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organisations threatened by a hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss.
Exposure
People, property, systems, or other elements present in hazard zones that are thereby subject to potential losses.

Hazard
A dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.
Hazard identification
The process of recognising that a hazard exists and defining its characteristics
Frequency
The number of occurrences per unit time (e.g. per year).
Loss
An injury or damage to health, property, the environment, or something else of value.
Risk assessment
A methodology to determine the nature and extent of risk by analysing potential hazards and evaluating existing conditions of vulnerability that together could potentially harm exposed people, property, services, livelihoods and the environment on which they depend. The overall process of risk estimation and risk evaluation.
Risk
A measure of the likelihood that an undesirable event will occur together with a measure of the resulting consequence within a specified time, i.e. the combination of the frequency and the severity of the consequence. This can be either a quantitative or qualitative measure.
Risk control option or mitigation measure
An action intended to reduce the frequency and/or severity of injury or loss, including a decision not to pursue the action.
Risk identification
The process of recognising that a risk exists and defining its characteristics.
Risk estimation
The activity of estimating the frequency or probability and consequence of risk scenarios, including considerations of the estimates' uncertainty.
Risk evaluation
The process by which risks are examined in terms of magnitude and distribution and evaluated in terms of acceptability considering stakeholders' needs, issues, and concerns.
Risk management
The systematic application of management policies, procedures, and practices to analyse, evaluate, control, and communicate risk issues.
Residual risk
The risk remaining after all risk control options have been applied.
Stakeholder
Any individual, group, or organisation able to affect, be affected by or believe it might be affected by a decision or activity.
Vulnerability
The characteristics and circumstances of a community, system, or asset due to which it is susceptible to a hazard's damaging effects.

3 Rationales and principles

Effective pollution preparedness and response, for the most part, depends on effective risk management. Ensuring a clean marine environment and other interests of different stakeholders is probably the most critical factor in the effective development of the coastal regions of any state. In the case of Adriatic states, a clean marine environment is even more critical due to the significant impact of the coastal activities on the overall economic activity. Risk management is defined as the process of analysing, selecting, implementing, and evaluating actions to reduce risk. Although there are many different risk management implementations, they often share similar foundations. Consequently, in this Chapter, the generic process applicable to the oil spill risk assessment in given circumstances will be outlined. The parts essential for the project outcomes will be underlined.
The generic risk assessment process consists of the following main steps:

- Setting the scene
- Risk assessment
  - Hazard identification
  - Risk analyses
  - Risk evaluation
- Risk treatment

The following paragraphs describe the foundations of the oil spill risk assessment conformant with the FIRESPILL goals.

3.1. Setting the scene

The initial phase of the oil spill risk assessment is to set the scene for the whole process. It includes the generic requirements, i.e. purpose, stakeholders, timeframe, scope, context, and criteria to be used.

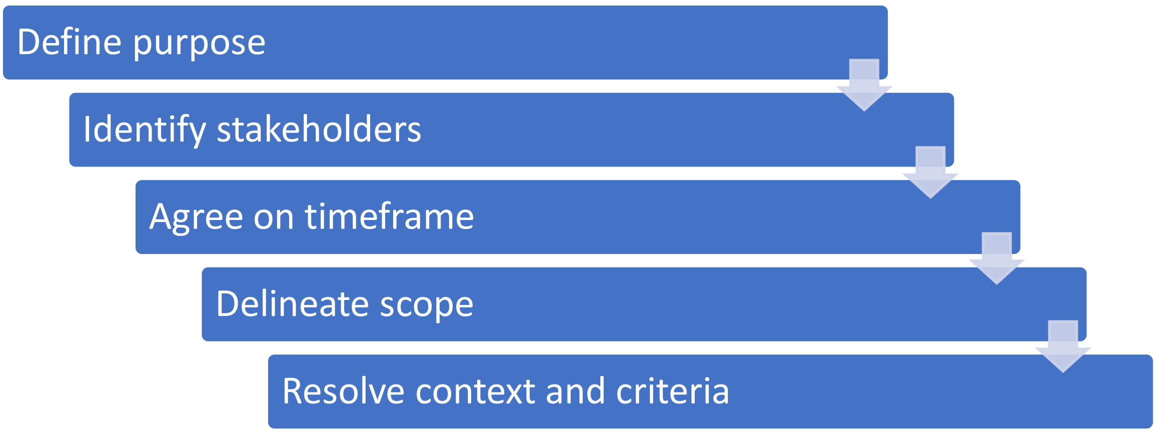


Figure 1 The oil spill risk assessment - the initial phase

Purpose

The purpose of the risk assessment is a transparent set of objectives that should be achieved at the end of the process. The objectives must be expressed simply and straightforwardly, minimising any possibility of misunderstanding. Objectives may be expressed as relative ("to decrease risk below present value, or as low as practicable") or in absolute terms ("to decrease the number of incidents below a certain number"). Objectives should be related to the subject of the assessment, measurable, achievable within the constraints and given timeframe, and relevant to the goals or context of the organisation.

Sometimes, the purpose may also include decisions or actions that will follow if certain conditions are met. In addition, the purpose may identify the nature of the output required (for example, whether qualitative, semi-quantitative or quantitative information is required). The purpose may be expressed as a set of questions that have to be answered during the process, such as:

- What hazards exist?
- Where may these hazards be expected?
- How often may hazards occur?
- What are the consequences of the particular hazard?
- Which control options should be considered as effective measures aiming to minimise risk?

The purpose of the process must be made available and clear to all participants.

Stakeholders

A stakeholder is any person or entity that has an interest in the activity to be carried out. In general terms, stakeholders influence the decision-making process.

The primary stakeholders are stakeholders who have direct responsibility for actions agreed or recommended. Secondary stakeholders are persons or entities that may influence the effectiveness of the follow-up process or those who will be affected by decisions reached and actions carried out.

Here, the term also includes persons or entities that may:

- provide information on the context of the process under consideration,
- possess the necessary knowledge and expertise about the risk under consideration;
- provide inputs to the risk value determination or risk acceptability.

Stakeholders should be identified and their perspectives considered, whether they are included as participants in the assessment process or not. Appropriate involvement of stakeholders helps ensure that the information on which risk assessment is based is valid and applicable and that stakeholders understand the reasons behind decisions. It is particularly valid for stakeholders having responsibilities defined by law.

Timeframe

Timeframe denotes a specified period in which planned activity is going to take place. Regarding risk assessment, timeframe denotes a time within which the circumstances affecting the risk are not expected to change significantly, and outcomes of the process are mostly valid.

Although it is not a precondition *per* se for the risk assessment process, it is a highly valuable input for all stakeholders when analysing data and considering future changes.

Scope

The scope refers to broader circumstances, in particular circumstances affecting decisions and actions based on the assessment and their reach.
A scope is predominantly defined as a geographic area under consideration. In addition, it may also be defined as a set of hazards to be considered or as a set of legal or other restrictions to be respected. In most cases, the scope is defined by the primary stakeholders. Generally, the broader the scope, the more stakeholders need to be involved, the number of possible hazards increases (if not expressly restricted), the forecasting become more complex, thus causing the overall reliability to decrease. Finally, involving too large an area or too many risks and stakeholders may increase the measures' complexity and jeopardise their effectiveness.

Context

The context refers to understanding the internal and external issues that contribute to the course of events under consideration as well as broader societal and environmental aspects. External context includes the legal, regulatory, financial, and social factors which can influence the risk. In most cases, the power to influence external factors is limited. However, it helps to understand key trends and drivers and facilitates shaping the future developments on the system under consideration.
An internal context depends mainly on the overall objectives and aims of the primary stakeholder(s). The most influential factors are the quality and capabilities of the internal management processes, governance strategies, roles and responsibilities, and interactions with other stakeholders. The internal context also includes the institutional and personal capabilities of those appointed to conduct the hazard identification and risk analysis.
The context, in general, is outlined through goals identified at the beginning of the process. Goals inevitably reflect stakeholders' interests and their ability (authority) to implement the mitigating (risk-reducing) measures. Consequently, these interests shape the whole process, techniques used and the outcomes.

Criteria

The criteria refer to the set of decision-making points relevant for the hazard identification and risk evaluation, such as risk acceptability, risk significance, the relationship between different hazards and risks, etc. It is essential to keep these criteria understandable and manageable, mainly when the risk management process entangles highly complex sub-processes (for example, forecasting oil spill trajectories). This is necessary because different stakeholders may have different risk perceptions and varying risk acceptance levels. Consequently, before the risk assessment starts, it is essential to define how the risk analysis outcomes will be described (qualitative or quantitative), how the risk level will be determined, and which decision criteria will be used. Unfortunately, the process itself will change the perception of risk, thus requiring amendments to the criteria and decision-making points in many cases.

3.2. Risk assessment

The main phases/processes of the risk assessment, as it is envisaged within the FIRESPILL project, are described in the following sub-chapters.

Hazard identification

Hazard identification is the first step of the risk assessment process. It aims to define hazards under consideration. The process should be carried out methodically and iteratively, ensuring that a list of identified hazards is thorough and substantiated. The most important outcome of hazard identification is a list of hazards with associated events, causes and main consequences specified. In addition, hazard identification should consider:

- significant uncertainty and their potential effects,
- circumstances or issues (either tangible or intangible) having the significant potential to cause noteworthy future consequences,
- causes that may initiate hazards or might initiate the development of certain risks,
- existing risk controls and their effectiveness,
- emerging risks (early warning signs of potential developments).

Evidence is vital to identify hazards successfully. This evidence usually comes from various sources, such as databases of past incidents or accidents, models, and simulations. Hazard identification often also involves expert judgement of knowledgeable stakeholders or subject matter experts.

Accident investigations can provide an essential source of in-depth information, particularly in high-risk industries such as maritime transportation. By carrying out accident investigations, databases can be created, which may help gain insights into failure processes and the mechanisms and factors governing the severity of the consequences. However, given the low occurrence frequency of accidents leading to extensive investigations, the in-depth understanding of known cases cannot necessarily be generalised to other instances in the maritime domain.

Data from past accidents or incidents can help to identify hazards and failures that were thought of previously and confirm expert judgments. Even if data is not available for precisely the same system or activity under consideration, relevant data from an equivalent system may be a good starting point for delineating possible hazards and failure mechanisms.

Hazards can also be identified through expert judgment, stakeholder consultation, or other means, such as simulator trials. Simulations are beneficial when the system or process being analysed is particularly novel or using actual equipment is not viable.

Risk analysis

The risk analysis aims to determine why and how risks arise, including their impacts on a system or process. As per the ISO 31000:2018 guideline, *Risk analysis involves consideration of the causes and sources of risk, their consequences and the probability that those consequences can occur. Factors that affect consequences and probability should be identified.*

Risk is often described in terms of risk sources, potential events, consequences, and likelihoods. The risk is generally described as a functional relation of Hazard (H), Exposure (E) and Vulnerability (V):

$$R = f(H, E, V)$$

In a simplified form, particularly in cases when the vulnerability of the community, system or asset could not be estimated, or it can assume highly variable values, the risk may be expressed as:

$$R = I \times F$$

Where I denote Hazard Impact and F the Frequency of its occurrence. Hazard impact is usually expressed in agreed units (for example, average cost), while the frequency is usually measured by the number of occurrences per unit time.
In other words, the risk analysis must result in the relative probabilities and consequences of the identified hazards. The basis for quantification includes data from various sources, expert judgment, models or simulation results, previous cases, etc. Validation of these sources is also considered as a part of the process.

Probability of the event occurrence

Estimating the probability of the event occurrence is the initial step of the risk analysis. The aim is to quantify the occurrence probability, the frequency or probability (P) of undesirable events. Ideally, it should rely on past system and accident data. However, such an approach is not feasible in many applications. The main reasons include missing or unreliable data, very low frequencies of undesirable events, occurrences spanning several decades and in different circumstances, etc. In such circumstances, the modelling techniques may be used. When modelling cannot provide the required reliability and accuracy, tools based on the expert understanding of the problem area may be used. In such circumstances using qualitative scales indicating the relative likelihood of considered events is the only way out. Such an approach is usually based on stakeholder consultation or subject matter expert judgment.

The severity of the consequences

Estimating the severity of the consequences in case of event occurrence is the next step in the process. The consequence severity (C) appraisal should be based on different evidence types, the most important being statistically significant data. If such data are not available, severity appraisal should be based on the accident data, stakeholder consultations and expert judgements, and model-based simulations. Attention must be paid to in cases considering hazards whose occurrence is already minimised with existing mitigating measures. Again, the output should be expressed as a quantitative numeral. If it is not possible (or unreliable), the severity should be expressed using a qualitative scale.

Strength of the evidence

Assessing the strength of the evidence for the probability and consequence estimation aims to prove that the whole process is based on the best available information and that uncertainties are estimated as accurately as possible.

Due to various imperfections hidden in the available data, the simplifications in the models, and possible disagreements between subject matter experts or stakeholders, a careful revalidation of the pieces of evidence gathered is highly recommended. If it is found that underlying assumptions are not correct or data are not reliable, the data collection should be repeated, data re-examined, and the strength of evidence confirmed.

The strength of evidence assessment is commonly a part of the risk analysis. However, depending on the method used, it may be carried out during the risk rating or implemented as a separate process.

Risk scale

Combining probability, consequence, and strength of evidence in a risk scale is the last step in the risk assessment process. There are different gradings of the overall risk value for hazardous events in use. Different approaches may be implemented:

- a risk rating value may be calculated following the agreed procedure,
- a combined risk rating value may be determined as a combination of the judgment(s) of one or more subject matter experts and the collection of evidence,
- the subject matter experts may estimate a risk rating value based on specific evidence obtained using various tools, e.g. one for building scenarios and their probabilities and another for estimating the severity of the consequences.

If qualitative methods are used, the decision whether linear or non-linear scale will be used should be made with particular scrutiny.

Risk evaluation

Risk evaluation is the final part of the risk assessment process. The aim is to evaluate risk values and risk values acceptability.

To evaluate the acceptability of risk, one should compare the risk rating value with criteria established as part of the context. One simple but often applied criterion is the number of exposures to a hazardous event. If data indicate that the risk limit value will not be reached, the risk may be deemed acceptable. Unfortunately, in many instances, such simple comparisons are not possible or not deemed appropriate.

In such cases, a method for risk evaluation and decision making is based on defined risk metrics. The most well-known approach follows the ALARP principle, which denotes that the system risks should be made "as low as reasonably practicable". Thus, if the risks are deemed significant, new risk control options should be implemented. However, if the costs or efforts involved are disproportionally high compared to the risk-reduction effects, another risk control option should be considered. If there is no such option available, the risk is considered inherent. The principle promotes the use of the risk control measures even if risks are low if the risk control option can be easily implemented at low costs.

Sometimes, one may focus less on the absolute values of the risk estimates and give more weight to the changes of the risk levels. When sudden significant changes are identified or incremental changes over an extended time are noted, the additional risk control option is considered and/or initiated.

It is important to note that risk evaluation also includes initial considerations of the risk control options. The purpose of these measures is to reduce either the probability or the consequences of undesirable events. They may be considered as risk barriers. At this stage, risk control options are not analysed in detail. The focus is on the initial estimation of risk reduction imposed by each "barrier". By doing so, the list of the most valuable control options is developed as input for in-depth analysis during the final stage.

Finally, risk evaluation should pay due attention to the socio-technological and legal context. These considerations should include the costs of the risk treatment options, social factors (such as creation or loss of employment), or other legal, political, or cultural factors.

3.3. Risk treatment

Risk treatment is the final stage of the risk management process. It aims to effectively remove or minimise identified hazards and associated risks by implementing a set of selected control options (mitigation measures). In that regard, it is also essential to ensure that new risk control and mitigation measures do not lead to the emergence of new hazards or be timely and appropriately managed.

Besides the full implementation of the selected measures, the risk treatment also includes "maintenance" activities. This stage includes monitoring the circumstances, hazard occurrences (incidents and accidents included), and timely initiation of the risk assessment renewal.

In many cases, the implementation phase requires long-term activities and extensive stakeholders involvement. Sometimes, the risk analysis will produce information and findings important for other actors, initially not recognized as stakeholders. It is especially the case in large-scale, distributed systems where legal and operational responsibilities may be shared among numerous entities. In such cases, effective communications and implementation coordination among relevant actors is a necessity. Therefore, communication and consultation activities are considered an essential and inherent part of the process.

Finally, information monitoring and reviewing the risk management process is another essential activity that cuts across the various risk management stages. The primary stakeholder should ensure that the information processed is adequately utilised to establish the context, assess risk, and implement appropriate risk control options. Such monitoring and review are critical to handle changes over time, to protect from the emerging risks or changes in probabilities and consequences. The continuous improvement of the overall risk management framework is assumed.

In the end, it must be emphasised that detailed risk treatment is not a part of the process considered in this Guideline.

4. Methodological approach

Although previous deliberations seem straightforward and unambiguous, the real-life implementation may face numerous issues preventing streamlined implementation. Consequently, although the risk management process is designed as a generic process, i.e. a process that can be implemented in any circumstances where identifiable hazards exist, the implementation significantly depends on the actual settings. It is worth noting that the oil spill risk assessment significantly depends on the local circumstances, complexity and novelty of the technologies used, and the level of availability of the relevant knowledge and understanding.

Consequently, the following discussions will be restricted to the oil spill risk management, specifically the oil spill risk assessment that may take place within the FIRESPILL project area.

4.1. Common considerations

There are three different approaches [3] to develop the oil spill risk assessment process: the intuitive, empirical, and simulation approaches.

The **intuitive approach** relies on gathering relevant information. This information is then used as the basis for the evaluation of oil spill risks. In most cases, the process is carried out by a group of subject matter experts or by decision-makers. The approach is characterised by large amounts of unstructured information in a narrative or graphic format. As a rule, there are no analytic tools used for the integration of the information. The methods are not explicit and only rarely or partially is based on quantified variables.

The quality of outcomes and conclusions heavily depends on the scope and quality of data and a level of expertise. Consequently, the approach does not provide reliable output. On the other side, it may be used in any circumstances or geographical areas and provide results in a relatively short time.

The **empirical approach** aims to develop a model based on a large sample of data, usually from national or international publicly available databases. The empirical models may be developed as direct projections, regression models, and probability models. In addition, if necessary data are available, the model may be geo-located; in that case, the quantified data are assigned to cells to predict areas or locations with the highest probability of accidents. Consequently, the approach is commonly implemented in port areas and their approaching waterways.

The quality of outcomes and conclusions depends on the availability of data, a level of similarity between the model and available data and means of verification of conformance with reality.

Simulation models attempt to simulate the most critical features of the system under consideration. Simulations require extensive data describing processes leading to or resulting from oil spills, sound theory, technical expertise, and general knowledge. Simulations may be used to describe maritime traffic within the given area or technical processes at transhipment facilities. Models used to simulate maritime traffic aim to reproduce the traffic flow, searching for the sequence of events that may occur while ships are sailing through an area, causing oil spills. Simulation models are helpful, particularly for maritime traffic modelling in approaching waterways and within the port limits. Depending on the level of sophistication, the simulation model may consider the effects of weather, currents, traffic, and other conditions.

Although such simulation models provide a high level of reality and reliability, the quality of outcomes and conclusion significantly depends on the appropriateness of the selected set of situations subject to simulations and quality of data

Finally, the last approach is the one combining some or all the previously mentioned approaches. For example, the frequency of collisions and groundings on the approaching waterway may be calculated using the functional (regression) model. In contrast, the simulation model may be used to determine the most probable locations of groundings and collisions. Finally, the consequences may be estimated by subject matter experts.

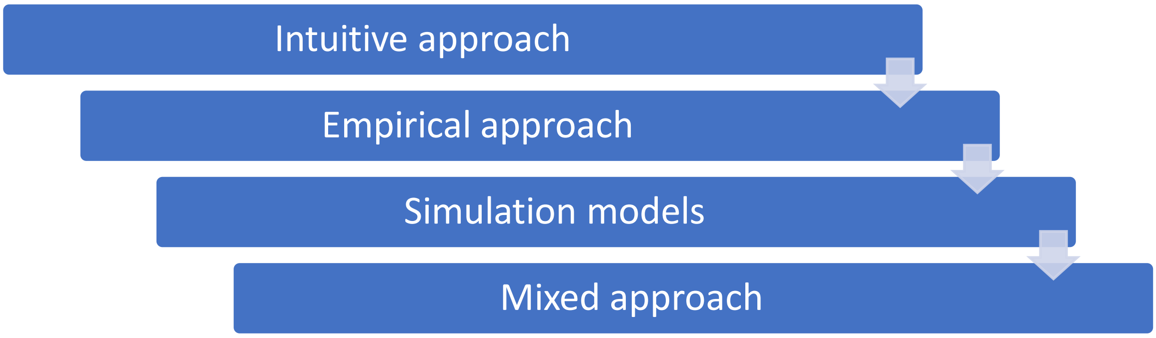


Figure 2 Different approaches to oil spill risk assessment

Although seemingly straightforward, each of the mentioned approaches has its downsides and benefits. Depending on the required outcome reliability, available data and resources, a particular approach may be the most preferable. However, if the scope includes large areas with significantly different navigational and environmental constraints, the most appropriate approach would be to combine several approaches or methods, ensuring comparable outcomes of the whole process.

In that respect, one should bear in mind that the validity of the risk assessment outcomes is acceptable if there are no significant changes in traffic patterns and environmental circumstances. If there is a significant change, a new or updated assessment is assumed, preferably using the best available method, delivering the most reliable outcomes.

The Adriatic Sea area contains several different environmental regions or areas of different traffic patterns. A mixed approach is preferable in such circumstances, using several different methodological approaches selected according to each region's needs and available data. Unfortunately, such risk assessment requires a considerable investment in funds and effort, expertise, and time.

4.2. Risk assessment techniques

This Chapter presents the results of the analysis of the most frequently used techniques. The aim was to identify techniques that provide the best results in the given circumstances and within the project scope.

Risk assessment techniques can provide qualitative, semi-quantitative and quantitative outputs. It is up to the primary stakeholder to set the minimum level of quantification. In any case, the main goal is risk reduction if the selected measures are reasonably practical. In general, qualitative approaches are easiest to apply (least resource demands and least additional skillsets required) but provide a minimal degree of insight. Conversely, quantitative approaches are more demanding on resources and skillsets, but as a rule, they deliver a more detailed understanding. Accordingly, the time and investment are significant. Semi-quantitative approaches lie in between these extremes.
Since project goals include very different sea areas (regions) with significantly diverse traffic and environmental load, the initial step was to identify all techniques that might be applied as a tool in the oil spill risk assessment. The list included all standard risk assessment techniques [55], [32], [41], but also several techniques developed by different developers as the dedicated marine applications [40], [53].
The following techniques have been selected as potentially exploitable and examined in detail:[1]

Delphi technique
Structured or semi-structured interviews and surveys
Failure modes and effects analysis (FMEA) and failure modes, effects and criticality analysis (FMECA)
Hazard and operability (HAZOP) studies
Scenario analysis
Structured *What If* (SWIFT)
Cindynic approach
Ishikawa analysis method
Bow-tie analysis
Hazard analysis and critical control points (HACCP)
Bayesian analysis
Bayesian networks and influence diagrams
Cause-consequence analysis (CCA)
Event tree analysis (ETA)
Fault tree analysis (FTA)
Human reliability analysis (HRA)
Markov analysis
Monte Carlo simulation
Causal mapping
Cross impact analysis
Risk indices
Cost/benefit analysis (CBA)
Decision tree analysis
Multi-criteria analysis (MCA)
Consequence/likelihood matrix (FN)
IALA Waterway Risk Assessment Programme
Simplified IALA Risk Assessment Method (SIRA)
Ports and Waterways Safety Assessment
Maritime Event Risk Classification Method
Accidental Damage and Spill Assessment
Model for Collision and Grounding
SeaTrack Web
Next Generation SmartResponse Web

[1] The International Maritime Organization (IMO) adopted several approaches based on the risk assessment methodology in the last decades. The Formal Safety Assessment (FSA) aims to support rule-making related to ships' construction and design, mainly to estimate the effects of the new regulations. IMO also published a manual on oil spill risk evaluation and assessment. It provides a generic basis for assessing oil spill risk, adopting the idea of a tiered response. However, it does focus on implementing risk management into organisational processes and provides little guidance on which tools can be used for more detailed risk assessment.

After a thorough examination, several techniques have been found appropriate for the oil spill risk assessment within the project scope. Although other techniques (those not mentioned in the following paragraphs) may also be useful in certain circumstances, it was deemed that too many techniques, many of them requiring extensive expert support, may present unnecessary difficulties for those responsible for their implementation.

Scenario analysis

Scenario analysis is an intuitive method for developing responses to various future events to reduce uncertainty and maximise the probability of achieving the desired outcome. It includes a range of techniques used to develop events or sequences of events. In general terms, it aims to develop one or more realistic scenarios as a tool to describe various possible future developments. The method is most often applied by a group of stakeholders with different interests and expertise. Scenario analysis involves defining the scenario or scenarios to be considered and exploring the implications of each one, including associated risk. Due to the low level of detail, the method may be considered guided brainstorming on a given theme.

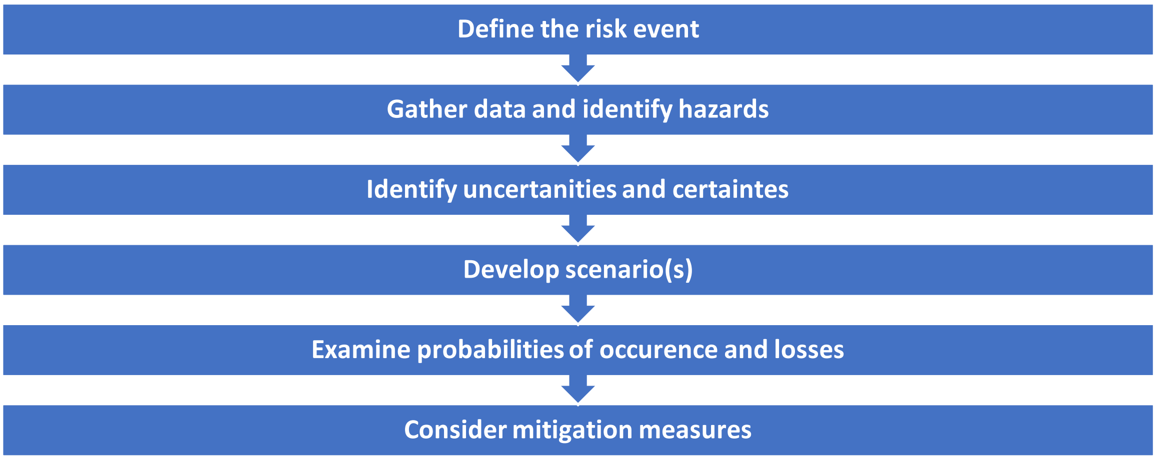


Figure 3 Scenario analysis process

The scenarios can be divided into two groups based on the type of event they describe. The first group uses historical events (accidents, near-misses or similar events) and examine the worst-case outcomes. The second group uses hypothetical scenarios. Those scenarios are based on some plausible sequence of events that have not happened yet, but a non-zero probability of their occurrence exists. If past data are not available, experts' opinions may be used to develop scenarios. It is essential to develop a realistic course of events, particularly in scenarios involving complex systems. Otherways, the results might be misleading.

A typical scenario consists of the description of a complex state that would impose an extreme load upon stakeholder(s), including:

- probabilities and frequencies of occurrence of the state,
- activities impacted by the event,
- maximum internal and external losses generated by occurrence of such event,
- possible mitigation measures.

Scenario analysis is most often used to identify hazards and explore consequences. It can be used at both strategic and operational levels. As a rule, scenario analysis does not try to predict the

probabilities of events or situation changes but considers consequences and help to adapt to foreseeable change. It is used to anticipate how threats and opportunities might develop and can be used for all types of risk.
The main output is a more thorough understanding of possible outcomes or effects, a list of risks that might emerge in the future, and an indicative list of mitigating measures. In other words, the stakeholders are expected to understand the chain of events and their root causes more thoroughly.

BowTie Method

The BowTie method [46] is an intuitive, linear diagrammatic way of describing, analysing, and communicating the pathways of the identified risks from causes to consequences. It is designed to better understand the risk by developing clear differentiation between proactive and reactive risk management. The power of a BowTie diagram is that it gives an overview of multiple plausible scenarios in a single picture that would be much more difficult to explain otherwise. The method provides risk assessment and decisions input, focusing on failure pathways and the most appropriate treatment strategies. The main strength of the BowTie method is its simplicity.
Using the diagram representation, the BowTie method focuses on the controls between the causes and the event and the event and consequences. The controls on the left side of the BowTie diagram aim to prevent the undesired event. The controls on the right side of the diagram aim to minimise the consequences of the undesired event.

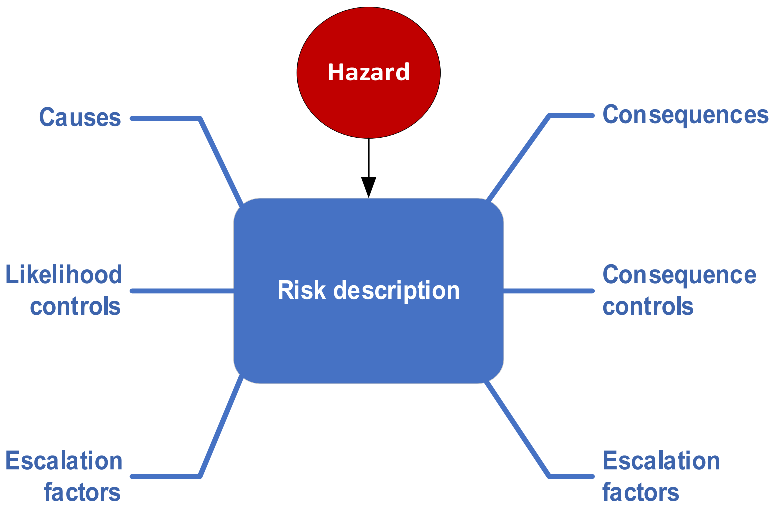


Figure 4 The basic BowTie diagram

The BowTie method also supports exploring the robustness of preventive and recovery controls, including escalation factors, which may negatively affect the implementation of control measures. For example, severe sea conditions can be an escalation factor, decreasing the effectiveness of the control measures (e.g. oil booms) and hence limit or even prevent their use. Furthermore, this method is designed to identify the owners of different controls, which is essential for communication and implementing the risk management solution in practice.
The BowTie method is applicable in cases having clear independent pathways leading to failure. It may be used to answer the following risk assessment questions:

— Which factors contribute to the event occurrence or its consequences?
— What is the effectiveness of the different controls to mitigate risk?

The BowTie method is primarily valuable for intermittent risk management, particularly for risk recognition and analysis stages. BowTie may also have a role in the strategic risk management process. The tool can provide qualitative and quantitative outputs.

Consequence & likelihood matrices

Consequence and likelihood matrices as a risk assessment tool apply an intuitive approach based on the qualitative description of the probabilities and consequences.

The method helps communicate risks to different stakeholder groups and decision-makers. When using risk matrices, one displays risks in ordinal categories on the likelihood and consequence dimensions, commonly using assigned a colour code to illustrate the risk level and indicate the acceptability of the risk, in line with the ALARP principle.

Although risk matrices are frequently used as a risk analysis tool, there are several recognised shortcomings. When using risk matrices, one can correctly and unambiguously compare only a tiny fraction, thus assign identical ratings to quantitatively very different risks ("range compression"). Due to inaccurate data, higher qualitative ratings may be wrongly compared to quantitatively more minor risks. Finally, inputs (e.g., frequency and severity categorisations) and resulting outputs (i.e., risk ratings) require subjective interpretation, sometimes causing very opposite ratings of the same quantitative risks.

Nevertheless, risk matrices are deemed particularly useful in the risk evaluation phase.

		PROBABILITY (LIKELIHOOD)				
		Very (1)	Rare (2)	Occasional (3)	Frequent (4)	Very frequent (5)
CONSEQUENCES	Catastrophic (5)	5	10	15	20	25
	Major (4)	4	8	12	16	20
	Severe (3)	3	6	9	12	15
	Minor (2)	2	4	6	8	10
	Insignificant (1)	1	2	3	4	5

Figure 5 Typical risk matrix

The scales do not need to be linear. Whether linear or non-linear (mostly logarithmic) scales will be used depends on understanding consequences and likelihoods statistics if known.

The same applies to the probability-consequence diagrams (PCDs),[2] a kind of continuous scale risk matrices. Such diagrams have some benefits over risk matrices (linear or logarithmic scale, better relation with ALARP principle) and are commonly considered a better decision-making basis.

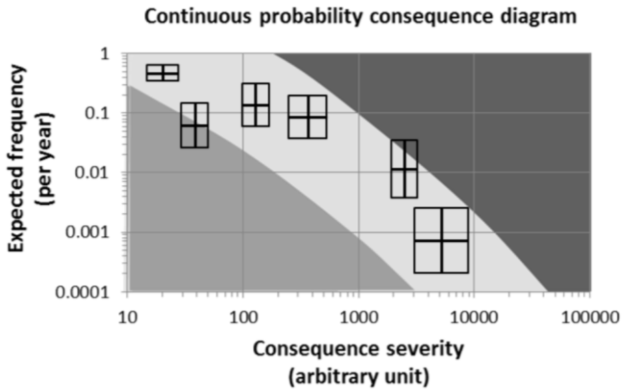


Figure 6 Example of the probability-consequence diagram [14]

The probability-consequence diagrams utilise a continuous, monotonically increasing or decreasing scale for the consequence and likelihood. Risk events can be displayed in different diagram areas, more clearly positioning different events against the others.

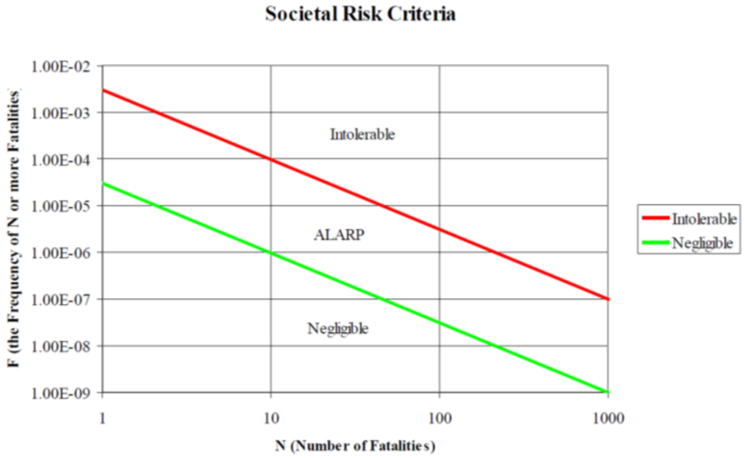


Figure 7 Example of the FN graph

The main strength of risk matrices and probability-consequence diagrams is a simple and readily understandable visual representation. The diagrams can be used alongside the strength of evidence assessment schemes and can be easily related to the ALARP principle. On the other hand, diagrams can be too crowded and fuzzy, mainly if different consequence dimensions (for example, life, ecological, and economical) are grouped. Using more matrices or diagrams provides a solution but makes the results more challenging to understand.

Delphi

The Delphi method is the subjective-intuitive method of foresight. The Delphi method is a procedure to obtain a reliable consensus opinion from a group of experts. It assumes that group

[2] The same has been known as Frequency/Number of fatalities graphs (FN – graphs).

judgments are more valid than individual judgments. The method incorporates three essential elements: the anonymity of participants, structured information flow and regular feedback, and statistical analysis.

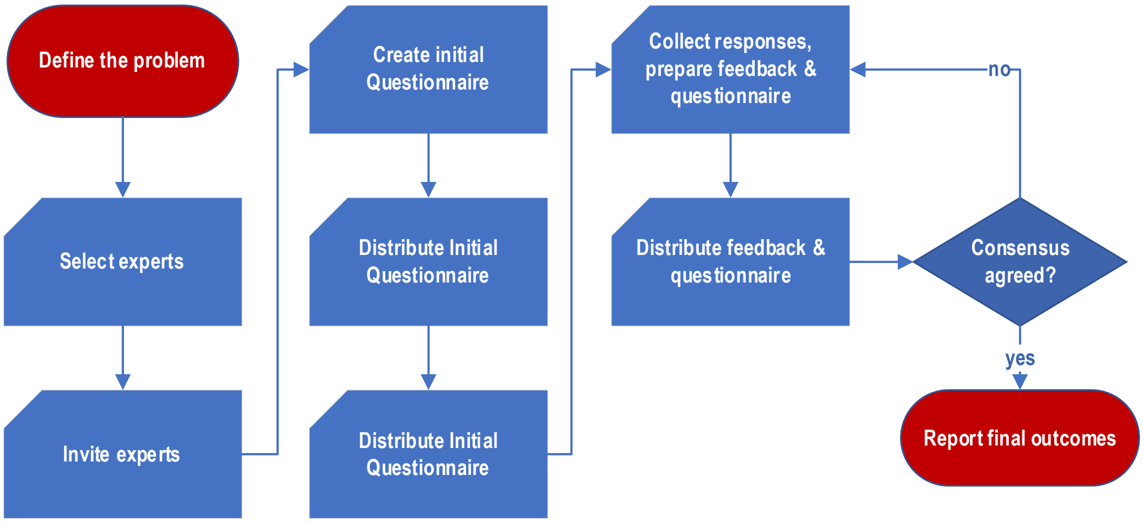


Figure 8 Delphi method

The anonymity of group members is used to encourage a genuine debate, independent of personalities. Furthermore, it encourages group members to express their opinions and openly and constructively discuss the matter. The second element is the controlled feedback process. Group members are asked to consider their responses to the responses of the rest of the group. Consequently, they are asked to respond to the next round of the survey. Extreme opinions are made open and transparent via controlled feedback, and estimates are achieved by analysing the problems through group dynamics. The third element is the ability to use a variety of statistical analysis techniques to interpret the data. It further reduces the potential of group pressure for conformity. In addition, the statistical analysis enables an objective and impartial analysis and summary of the collected data.

The method can provide valuable insights when there are no available measurements, so risk assessment must be based on expert opinions. It does not provide any quantification, so one must consider all possible prejudices and partialities. Also, the method is time-consuming and quite demanding in case of complex issues.

Simplified IALA Risk Assessment Method (SIRA)

SIRA is developed as an essential tool to consider hazards and associated risk control options within the scope of a Competent Authority as a part of its obligations under SOLAS Chapter V Regulations 12 and 13. It aims to promote the understanding of risks developed by maritime traffic and the maritime environment. The final goal is to qualitatively estimate the risk level and develop potential risk control options to reduce such risk to acceptable levels.

A "hazard" is defined as any action, occurrence, or circumstance that may cause an undesirable incident. The identification of hazards should be based on available information such as environmental data, adequacy of nautical charts, sea state and wind force, tidal flow, restricted visibility, ice, background lighting, natural hazards and dangers, nature of the seabed, changing bathymetry, the volume and mix of traffic and other factors.

Based on the identified hazards, possible incidents or scenarios are identified by stakeholders. Each scenario is then addressed. The process requires that stakeholders determine the probability or likelihood of the occurrence of each undesired scenario, as well as its impact (or consequences), considering both short- and long-term consequences.

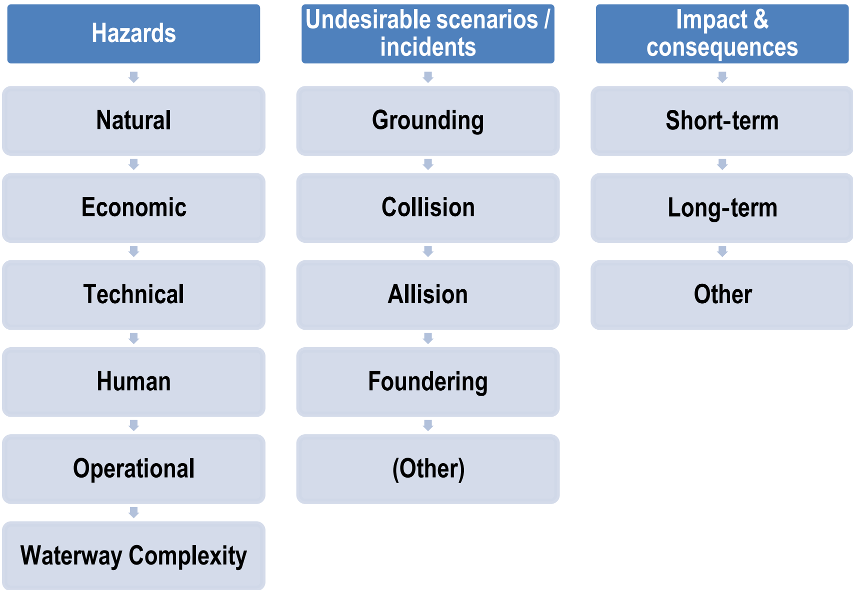
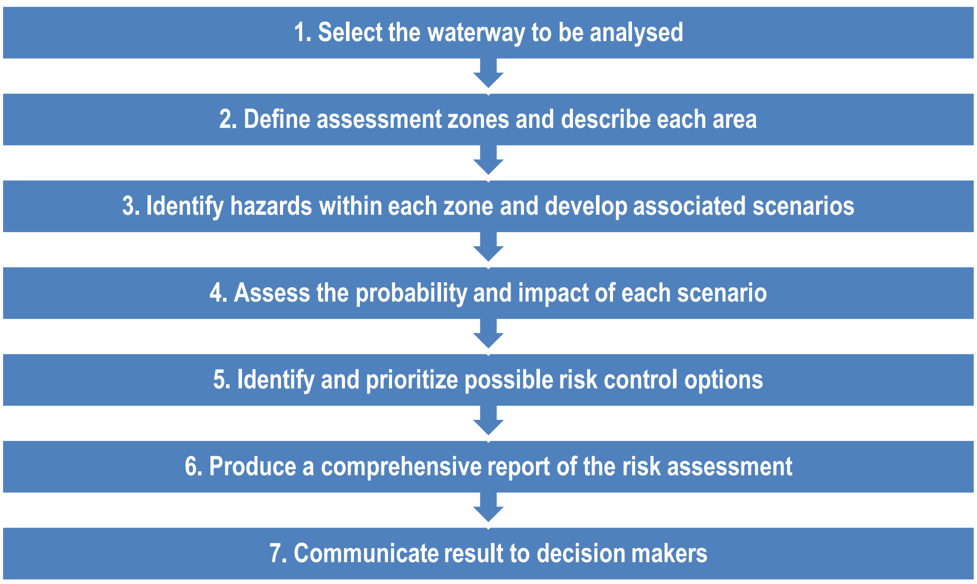


Figure 9 Causal relationship between hazards and consequences

Risk is defined as the product of two factors – the probability (or likelihood) of an undesirable incident occurring and, if it does occur, the severity of its potential long and short-term impact (or consequence).

Risk management aims to reduce risk to the "As Low as Reasonably Practicable (ALARP)" level.

The process includes the following steps:



The process is straightforward and is carried out during a one or two-day workshop. The list of participants must include the relevant stakeholders. Preparation for the workshop includes a preliminary zone selection, a detailed description of each zone, and identification of all relevant stakeholders. The most influential stakeholders are invited to participate in the workshop.
The workshop's outcomes should be adequately documented in a written report, supported by a risk matrix with the details of identified hazards, scenarios, and risk-mitigating measures for each zone.
Although straightforward and valuable, the process seems too simple to be implemented as proposed for the oil spill risk assessment.

IALA Waterway Risk Assessment Programme (IWRAP)

The IWRAP is a modelling tool [42] offered to the maritime authorities as a standardised quantitative method for estimating the probabilities of collision and grounding accidents in a given waterway or sea area. The tool can be used to analyse the accident probabilities in current traffic conditions and scenarios involving changes in traffic volume or composition, changes in route geometry, or changes in the applied aids to navigation in the area, or implementation of other mitigation options. It evolved from a probabilistic model for estimating the grounding and collision probabilities.

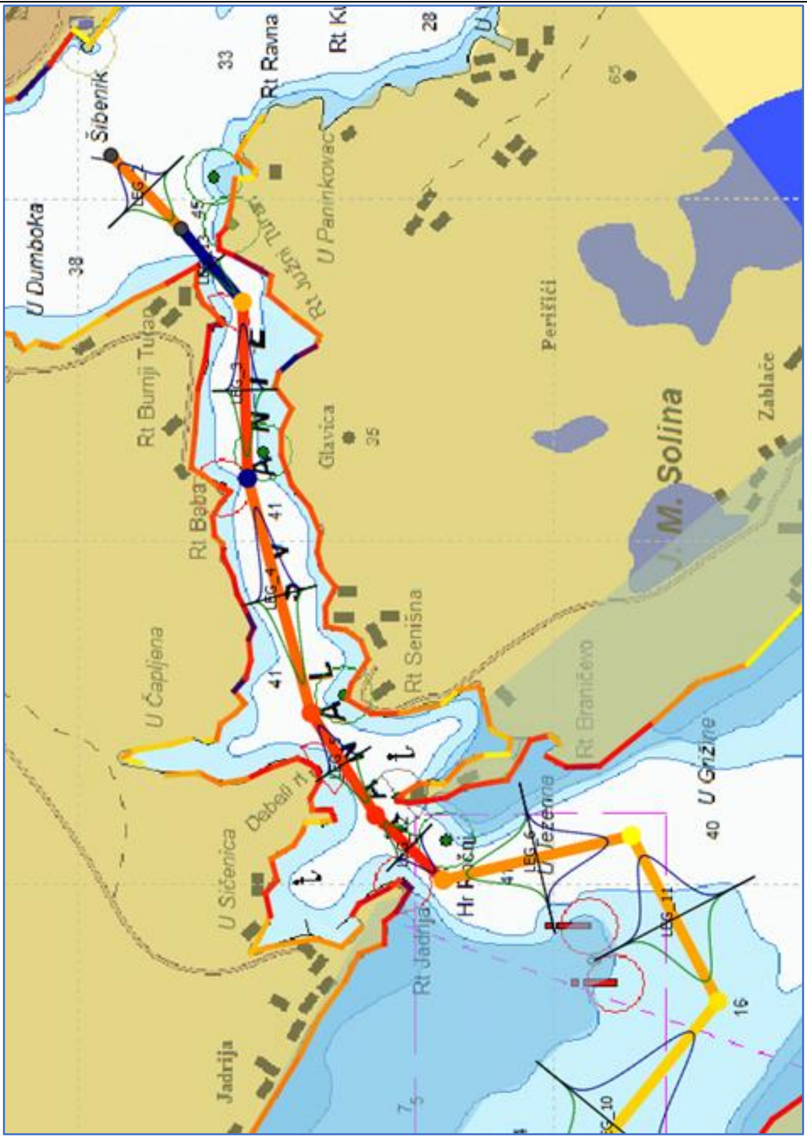


Figure 10 Areas of increased risk of collision (indicated by a darker colour of the route) and strandings (indicated by a darker coastal edge colour) according to the IWRAP model

The IWRAP tool can use various kinds of information to build a reliable model. The most valuable sources include:

- traffic information, particularly AIS data,
- hydrographic information,
- maritime accident and incident reports and analyses,
- wind direction data,
- data on the frequency of blackouts and repair times,
- expert knowledge.

The core part is a model for calculating the collision and grounding frequency on a specific route. It is based on the so-called causation probability multiplied with a theoretically obtained number of grounding and collision candidates. The causation probability models represent the probability that an officer on the watch will not react on time when the ship is on a collision course with another ship or a grounding course. Its numerical value is not uniform but varies for different geographical locations and navigation conditions. The values used are typically adjusted by calibrating them with available data, whereas default values are available from IALA. The theoretical number of grounding or collision candidates is deduced from the ship traffic in the given waterway or sea area.

Consequently, one needs to specify the routes and the associated traffic and group different ship classes according to ship type, size, etc. The number of ships per time unit per route segment also need to be included in the analysis. IWRAP can extract the traffic distribution and densities from AIS (Automatic Identification System) data.

As outputs, IWRAP produces graphical and numerical presentations of the annual average collision and grounding frequencies in the different route legs and waypoints. The output can be further split up for different ship types.

The main advantages include calculating probabilities for areas where actual accident data are missing (new routes) or scarce. It can be easily used for different areas. The software is stable, and IALA provides regular training sessions. On the other hand, the program calculates only the frequencies but not the consequences. However, since frequencies may be assigned to different ship types, determination of accidental consequences (e.g. oil spills) is more reliable. One must bear in mind that results are highly dependent on the expertise of the analyst.

Ports and Waterways Safety Assessment (PAWSA)

The aim of the process [46] is to get a comprehensive understanding of the importance of various aspects contributing to the risk levels in specific waterway areas and assess the effectiveness of mitigation measures. The method was developed to meet the requirements of the United States Coast Guard (USCG).

The method was developed through a national dialogue group in which maritime and waterway community stakeholders convened to identify the needs of waterway users and to identify significant waterway safety hazards, estimate risk levels, and evaluate potential mitigation measures through expert inputs. The overall goal is to find cost-effective solutions and meet the needs of waterway users and stakeholders.

The method relies on a formal multi-attribute decision analysis model carried out during dedicated PAWSA workshops. Discussions carried out during workshops should result with numerical ratings, providing a comprehensive but rather simple picture of the participants' expertise, the importance of different risk factors, the effectiveness of existing risk mitigation strategies, and additional mitigation actions. These ratings are organised into logical segments, referred to as "books". The responses are recorded in an aggregate form and discussed in the appropriate subsequent phases of the PAWSA process among the participants.

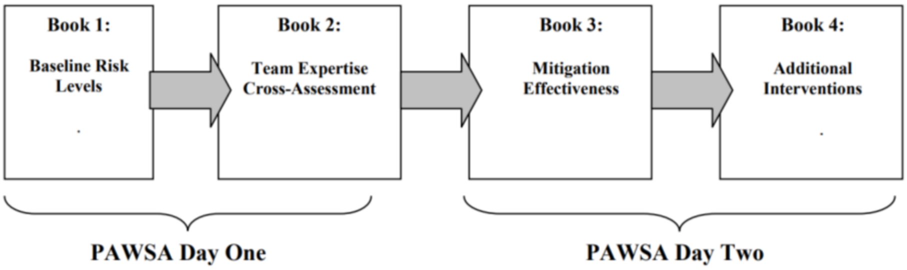


Figure 11 PAWSA method steps

Waterway Risk Model					
Vessel Conditions	**Traffic Conditions**	**Navigational Conditions**	**Waterway Conditions**	**Immediate Consequences**	**Subsequent Consequences**
Deep Draft Vessel Quality	Volume of Commercial Traffic	Winds	Visibility Impediments	Personnel Injuries	Health and Safety
Shallow Draft Vessel Quality	Volume of Small Craft Traffic	Water Movement	Dimensions	Petroleum Discharge	Environmental
Commercial Fishing Vessel Quality	Traffic Mix	Visibility Restrictions	Bottom Type	Hazardous Materials Release	Aquatic Resources
Small Craft Quality	Congestion	Obstructions	Configuration	Mobility	Economic

Figure 12 The PAWSA risk model

PAWSA is an expert- and stakeholder-centred process, in which a workshop where discussions and assessments are made is an essential element. The process is resource-intensive, both in terms of financial, personnel and time commitments. It is best suited for local waterways or port areas. It is not intended for large sea areas, where the number of experts and stakeholders likely would be impracticable to handle. The ratings are inherently qualitative and context-dependent.

Maritime Event Risk Classification Method

The Event Risk Classification (ERC) method **Error! Reference source not found.** was developed according to the ARMS methodology for operational risk assessment. It was initially developed for the aviation industry by the ARMS working group between 2007-2010. Currently, this method is widely used by airline companies and has a strong track record. The method aims to produce the event classification matrices for environmental damage, loss of life or injuries and economic losses, and in a process for risk identification and initial risk assessment.
According to the ARMS working group, "Risk is a state of uncertainty where some of the possibilities involve a loss, catastrophe, or another undesirable outcome" (ARMS WG 2010).

Consequently, the ARMS methodology has two main components: Event Risk and Safety Issues. By definition, the Event Risk is a risk present in an individual, experienced event in a specific context. The ERC-M considers different types of consequences of an event, as they can be multiple and qualitatively different. For this purpose, it is necessary to use separate matrices for the risk of loss of human life, environmental damage, and economic losses. The criteria of these matrices have been derived from the ARMS methodology and adapted to maritime needs. Furthermore, the ERC-M considers the adequacy and effectiveness of the remaining controls.

Although the ERC-M is useful for assessing the risk of individual events, the primary use is to identify Safety Issues; it is more important in the given context to identify phenomena based on aggregate statistics rather than assess the risk of single events. Once such phenomena have been identified, they can be explored with other risk analysis methods.

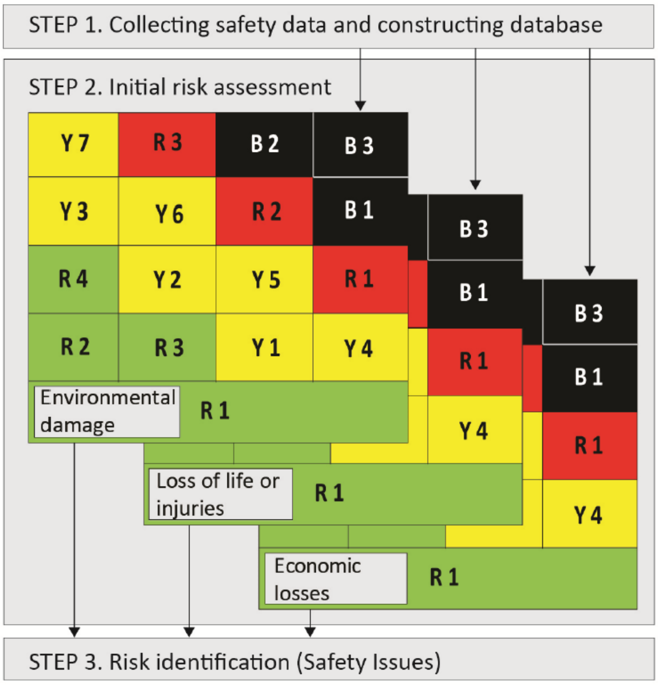


Figure 13 Simplified summary of the ERC-M process [22]

The primary output of the ERC-M method is a register of identified risks and hazards related to environmental damages, loss of life or injuries and economic losses. These identified risks are also classified, providing (relatively coarse) risk level results for the risk analysis stage. The outputs can be presented as geographical maps or charts describing different aspects of risk on ship types, time periods, and accidents. The output can also include information about the adequacy and effectiveness of the controls.

The method mainly focuses on events that occurred in the past, assisting in identifying risks and the safety issues involved in the event occurrence. Accordingly, a rapid ranking of risks into different levels can be achieved. The method is easy to use, does not require dedicated software, and provides the spatial distribution of hazardous event occurrences.

However, it provides relatively coarse information, is limited to historical events, and depends on the availability and quality of data and information about events.

5. Risk assessment process

In general, the oil spill risk assessment should address the likelihood of liquid hydrocarbon releases to the Adriatic Sea and the potential for ecological and socio-economic consequences of such oil spills.

The Adriatic Sea is an arm of the Mediterranean Sea, lying between the Italian and Balkan peninsulas. The Strait of Otranto is a south-easterly limit and connection to the Ionian Sea. It is about 400 miles long with an average width of 70-80 miles and a maximum depth of 1,324 metres. The total area is 131,050 km².

Two coastlines, east and west, are outstandingly different. The west coast is relatively straight and continuous, with almost no islands, whereas the east coast has more than 1.000 islands, most of them generally running parallel to the coastline, with numerous bays. The depths are usually a continuation of the adjacent coasts; if coasts are high and mountainous, the nearby depths are considerable, and vice versa.

The seabed consists of yellowish mud and sand, containing shells, fossil molluscs, and corals fragments. The most prominent winds prevailing in the area are the bora, a strong northeast wind that blows from the nearby mountains into the sea, and a south-easterly wind named the sirocco (jugo) that may create quite large waves, causing difficulties, especially to smaller crafts. The tides follow a complicated pattern, with a range of about 1,0 m or less. The blowing winds clearly influence the surface currents.

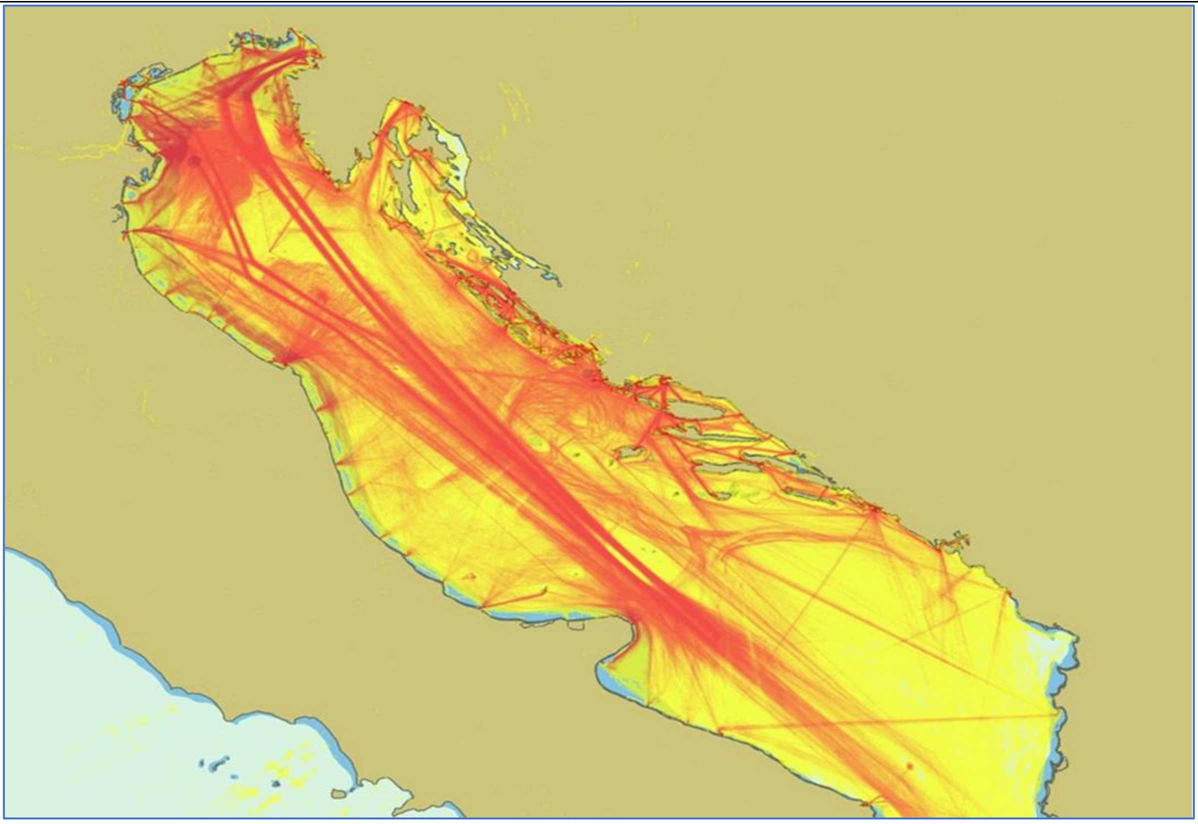


Figure 14 Adriatic Sea marine traffic density[3]

Maritime traffic in the Adriatic includes transport routes for tankers with crude oil to the northern Adriatic ports, liquefied gas transport to the Rovigo LNG and Omišalj LNG terminals, dry cargo and container ships, chemical tankers, and passenger ships. In addition, fishing vessels, yachts, recreational boats, military and research vessels contribute to the general and heavy local maritime traffic, particularly during the summer season. Such busy shipping traffic increases the risk of adverse effects on the marine environment.

Most merchant's vessels, particularly those carrying oil as cargo or having significant volumes of fuel oil aboard, are heading towards the largest Adriatic ports, i.e. the ports in the northwest Adriatic. These ports include Venezia, Trieste, Kopar and Rijeka. Accordingly, the densest traffic can be found on the routes connecting these ports and the Strait of Otranto. This route extends mainly through the unrestricted, open sea area along the main Adriatic axis. This route is defined by Traffic Separation Scheme "Off North Adriatic", the TSS close to the island Palagruža and the Strait of Otranto. These traffic separation schemes separate opposite traffic, thus significantly reducing the collision probabilities. In addition, there are also several observable transversal routes, branching off the main waterway and connecting the main ports in the Central Adriatic area (Split, Ancona, Zadar).

According to the project goals, the applicable oils spill risk assessment process is a process that provides valuable outcomes concerning the various traffic, geographical and environmental

[3] MMPI

circumstances. In the case of the Adriatic Sea, the oil spill risk assessment needs to fulfil the following requirements:

- The process must allow implementation of different methods, i.e. those that primary stakeholder(s) consider the most appropriate.
- The process must ensure comparability between results obtained using different methods, providing the methods that allow such comparisons. In any case, the process implemented in different areas but using the same methodology must be comparable.
- The process should avoid methods that require complex calculations or simulations, thus requiring extensive external support. Nevertheless, if such methods are found appropriate and supportable by primary stakeholder(s), they should be encouraged to use them.
- The process should be carried out transparently, and outcomes should be made publicly available.

Although highly recommended, it is up to the primary stakeholder(s) to adjust the process if appropriate, primarily according to their needs and resources.

The process is founded on the following principles:

The oil spill risk assessment process and outcomes should be relevant for the geographic scope, use and circumstances.

Accordingly, the risk assessment process will use different methods, depending on the local context, from the preparatory stages to the final conclusions. Attention should be paid to the local communities and interests (commercial, public, users),

The oil spill risk assessment process should be tailored to actual needs.

The form and effort of risk assessment should be appropriate to match the extent and significance of the risk under consideration. The scope must be broad enough to capture the essential factors but still efficient. It must be fit for purpose.

When selecting the most appropriate method or steps of risk assessment, one should consider the priorities, the experience of those undertaking the process, stakeholder engagement and available resources.

The oil spill risk assessment outcomes should be a result of collaborative efforts.

Risk assessments and decisions should involve people with the skills, experience and knowledge of the subject matter and risks under consideration. For different scopes, different stakeholders or subject matter experts will add value to the process.

The risk assessment outcomes should be evidence-based.

Although heavily based on heuristic knowledge and experience, risk assessments should use timely, relevant, and trusted (best available) information and make the most of quantitative and qualitative data sources.

Based on the analysis of the circumstances and state-of-the-art methodologies, the process that combines different approaches/methods is accordingly developed and presented in the attached flowchart diagram.

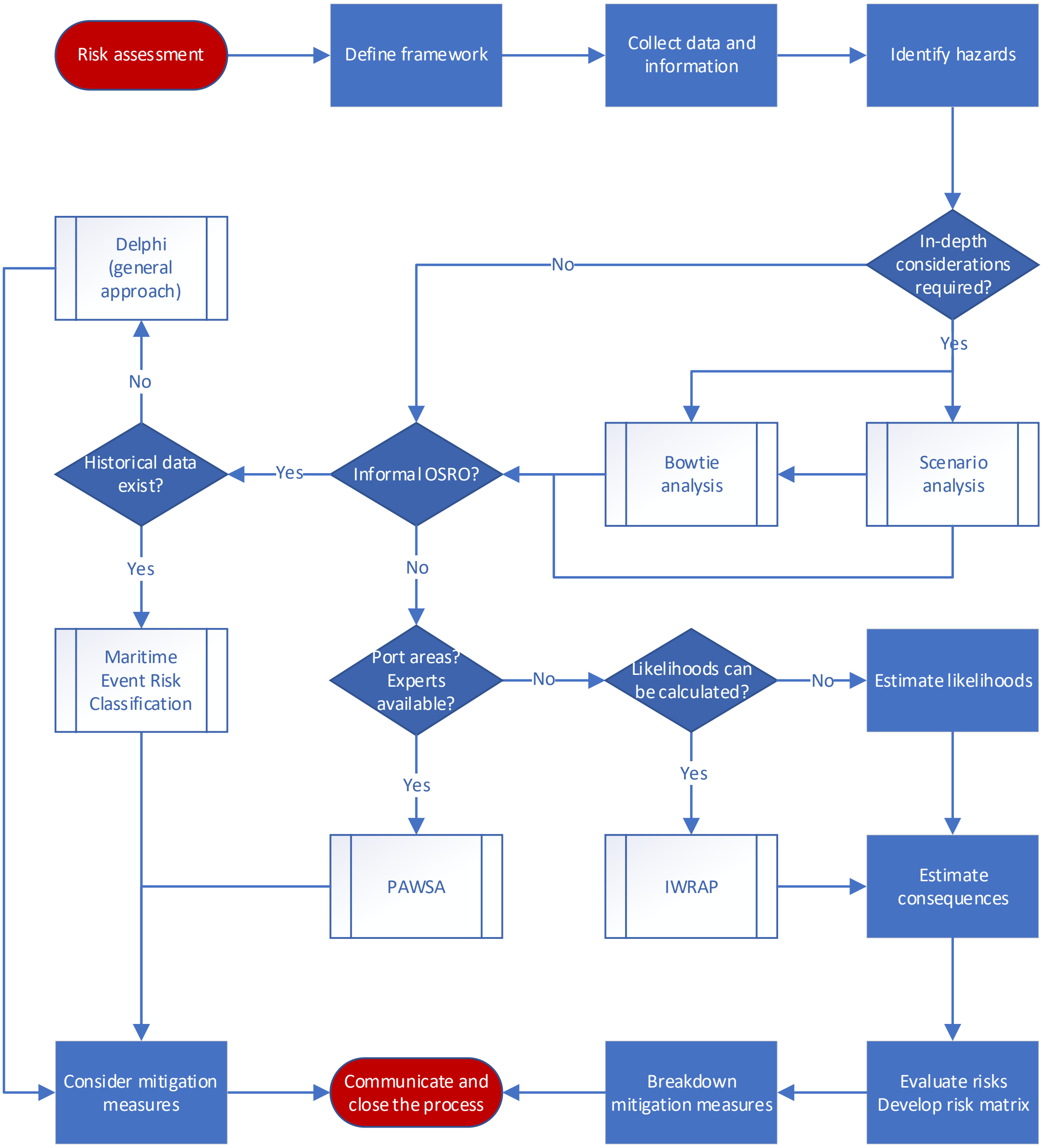


Figure 15 The oil spill risk assessment process

5.1. Framework characterisation

The oil spill risk assessment framework may be understood as a set of ideas, conditions, or assumptions that determine how the assessment will be approached, perceived, or understood. It may be understood as a Terms of Reference for those who will assume responsibility for the process and those who will only participate.

In case of the oil spill risk assessment within the project area, the framework should contain all main components, i.e.;

1. Purpose
2. Stakeholders
3. Timeframe
4. Scope
5. Context
6. Criteria

An explanation of each component and its recommended form and content is given in the following paragraphs.

5.1.1. Purpose

The purpose of the oil spill risk assessment should be defined by the primary stakeholder. In the case of the oil spill risk assessment for the Adriatic Sea region, it is recommended to express the purpose in the form of the general objective and a list of questions the risk assessment process should answer.
The process objectives should be defined as follows:

> *"The general objective of the risk assessment process is to estimate the oil spill risk level in the area under consideration."*

In addition, the goal may be outspoken in the form of the questions to be answered. In that case, the following questions may be used:

> *"What are the most important hazards existing in the area under consideration that may cause oil spill?"*
> *"Where, along the coastline or on the waterway, the hazards likely to cause oil spills may be expected?"*
> *"What hazards may cause the worst-case oil spills? How large these oil spills may be?"*
> *"How often the hazards that may cause worst-case oil spills are likely to occur?"*
> *"What are the environmental and societal consequences of the oil spills caused by the identified hazards and within the area under consideration?"*
> *"What control options are effective against identified hazard?*
> *"What control options minimise identified risks?"*

As a general recommendation, it is assumed that oil spill risk assessment will be carried out using quantitative techniques, i.e. the entity assuming responsibility for the process should identify risk associated with a specific hazard as a numerical value. If it is not viable (for example, due to extreme efforts required or cost incurred), the risks should be determined using semi-quantitative methods (for example, by calculating collision risks and estimating oil spill quantities).
Qualitative methods, i.e. methods where risks are only described or approximately estimated, are recommended for use only in areas where large or medium-scale oil spills are highly unlikely (there are no previous records of such cases, or no ships are carrying significant quantities of oils).
Accordingly, qualitative methods should be limited only to areas where no more than 50 metric tons of oil (as a fuel or as cargo) are carried onboard ships sailing in the area under consideration.

It is assumed that clean-up operations outside confined (port) areas in case of said amounts are not practical.
The above limit should not be used in oil spill risk assessment for confined areas, including port areas.

5.1.2. Stakeholders

As a rule, in the case of oil spill risk assessment, the role of the primary stakeholder, i.e. the stakeholder who will have direct responsibility for actions agreed or recommended, will be assumed by the responsible maritime administration. In most EU countries and abroad, the maritime administration is responsible for developing and implementing measures to reduce the probability and consequences of accidents involving oil spills. Consequently, the oil spill risk assessment should be understood as an essential tool to design those measures in a way that will secure a high level of environmental protection.
It is important to note that maritime administrations are also the only entity responsible for legal enforcement and international cooperation, mainly through the International Maritime Organization (IMO) and other regional cooperation arrangements and programs.
Subsequently, the representatives of the maritime administrations should be those who, as the employees of the respective ministries and, among other duties, bear responsibility for the safety of navigation and marine environment pollution prevention.
In cases when the oil spill risk assessment deals with events whose consequences may threaten two or more countries, it is possible to have two or more maritime administrations sharing the primary stakeholder's role.
In addition to the representatives of the maritime administration from the headquarters, the significant role as the primary stakeholders may be assumed by the local representatives of the maritime administration, e.g. Harbour Masters or his/her representatives. Although not having the same authorisation level, the local representatives often have extensive knowledge and experience regarding the local circumstances. Such expertise is of the utmost importance, mainly when the oil spill risk assessment deals with coastal or port waterways.
The role of the primary stakeholder may also be assumed by private or public entities when they are responsible for operations that may pose a risk to the environment. For example, in case of developing a new oil or LNG terminal, the entity responsible for the process may act as a primary stakeholder, with an obligation to deliver the outcomes of the process to the responsible maritime administration for approval and subsequent implementation (in a part where there is a public responsibility).
In general, the secondary stakeholders are those who:

- understand the factors that create the risk, including likelihood, variations and monitoring tools,
- are or will be involved in the implementation of risk controls,
- are familiarized with the legislative responsibilities,
- are directly influenced by changes or new practices or measures,
- already have experience with a relevant event,
- have a direct interest in the outcome of a risk assessment,
- may provide refreshing, alternative perspectives.

A list of potential (secondary) stakeholders is quite extensive and may include representatives of:

- VTS authorities operating in the area under consideration,
- the national accident investigation board, as a body responsible for accidents analysis and events statistics,
- emergency response organizations, both public and private,
- pilots, serving ports or areas under consideration,
- tug companies operating in the area,
- local shipping companies, particularly those maintaining local regular lines,
- seafarers unions or organizations,
- maritime universities,
- research institutions, particularly those having expertise in the oil fate development or environmental sensitivity,
- non-professional users (i.e. leisure boats),
- meteorological and hydrological institutions/service providers,
- freight forwarders, charterers, and shipping agencies,
- port authorities,
- equipment manufacturers,
- classification and insurance societies.

Although not a stakeholder in a full sense of the word, experts who support the risk assessment implementation may be considered stakeholders. By guiding the whole process, they may impact the results, both in a positive and negative direction.

It should be noted that persons who only provide data or information but do not participate in analyses or conclusion developments are not considered stakeholders.

It is the role of the primary stakeholder to carefully select the stakeholders and data providers, aiming to ensure appropriate coverage and balance of all areas of expertise while maintaining the size of the group within manageable margins. Considering the variability of the methods used in the oil spill risk assessment, the optimal size of the team participating in the process should not be less than six participants and no more than twelve.

5.1.3. Timeframe

In the case of the oil spill risk assessment, the term “timeframe” refers to two different concepts:

- period within which the data and patterns identified during assessment remains valid, and
- period within which the outcomes of the risk assessment outcomes remains valid, assuming no significant changes occur.

In the first case, it is assumed that all data and patterns identified within the last ten years before the oil spill risk assessment are valid and may be used in the process. This assumption is particularly valid for AIS data or other data or information provided by real-time sources. Information relating to previous oil spill cases may be used even if more than ten years have passed since the actual case occurred if the causes are mostly related to the human element. If it is not the case or if cases are older than twenty years (for example, as a basis for the scenario analysis or in the Maritime Event Risk Classification process), then attention must be paid to the recent technology changes that may address the cause(s), thus making the analysis of the specific case inapplicable. For example, the oil spill following the fire on the tanker not equipped with the Inert Gas System is not a valid scenario after all tankers are required to be equipped with such a system according to the SOLAS Convention amendments.

Figure 16 Timeframe delineation

Regarding the validity of the outcomes, it is assumed that the foreseeable trends will be considered in the process. Consequently, the risk assessment outcomes should be valid for the next ten years or so, assuming there are no disruptive changes in used technology or traffic patterns. In case of such changes, it is assumed that the oil spill risk assessment process will be updated or reiterated using more advanced tools.
In any case, before the oil spill risk assessment takes place, the stakeholders should agree on the validity of data to be used and on the target validity of the risk assessment outcomes. They should communicate their decision to all other stakeholders and participants.

5.1.4. Scope

Due to required practicability, the oil spill risk assessment process could not cover vast sea areas. Therefore, it must be restricted. Several criteria may be used as a delineation criterion. Based on the analysis of the target outcomes, the following delineation criteria have been designated as the most important:

Geographical range

Maritime traffic in the Adriatic Sea follows four main patterns. The main route is along the central axis of the Adriatic Sea, between the Strait of Otranto in the south and the Gulf of Venice and the Bay of Trieste in the north; this route is used by most large merchant ships. The second group of routes includes the crossing routes between the ports on the western and eastern Adriatic coasts. The third group of routes includes the routes connecting ports along the east and west coast of the Adriatic Sea, which in the case of the western coast is domestic traffic only, while along the eastern Adriatic coast can be international. And the fourth group includes various irregular routes used by large cruise ships, yachts, fishing ships, and other small boats.
The oil spill risk assessment may be targeting the oil spills having a reasonable probability to occur in:

- unrestricted waters,
- near-coastal waters,
- port areas.

Open (unrestricted) waters are characterized by only a few natural or artificial obstructions that may influence the traffic flow. The Traffic Separation Schemes mainly define the traffic pattern (if they exist). Such waters are waters along the main traffic route (from Otranto to North Adriatic ports) and central parts of the cross-Adriatic routes. The main hazard is collisions. The traffic load is well known, with only minor discrepancies in data. Numerical modelling of the traffic flow is relatively simple and provides highly reliable data.

Near-coastal waters include mainly routes close to the east and west Adriatic coasts. The routes along the east coast are more demanding due to numerous islands. The complexity of the routes and hazards that may cause oil spills are much more emphasized. The traffic load, particularly along the east coast, is highly variable during the year and in different areas. Numerical modelling can provide reliable data only within the restricted areas, with recognizable statistical parameters.

Port areas include areas within port limits and approaching waterways. The traffic flow in those areas is complex, and the numerical modelling is highly demanding (due to the much higher resolution required). Large oil spills are less probable due to restricted sailing speeds. However, there are increased probabilities of collision, allision and grounding due to increased traffic load. Managing the traffic flow in the port areas requires substantial knowledge of local restrictions and customs.

In all cases, the geographical range should be limited to areas with similar numerical traffic flow characteristics. It should be noted that a too extended range may result in the highly complicated and demanding oil spill risk assessment procedure, decreased outcome reliability and extended costs.

Substances

The oil spills are, in the narrow sense, spills of crude oil. Such definition does not include several frequently carried liquids that may significantly impact the marine environment in case of a spill. Consequently, in this Guideline, the oil should be understood as any oil defined as such in Appendix 1, Annex I of the MARPOL 73/78 Convention, whether carried in cargo tanks or fuel tanks or any other containment on board. Although such characterisation includes numerous quite different substances, it is not recommended to narrow the scope.

In addition, the scope in respect of the substances under consideration may be further extended by adding liquids categorised as noxious liquid substances in accordance with Appendix 1, Annex II of the MARPOL 73/78 Convention. However, such extension should be avoided (unless the primary stakeholder explicitly introduces it) due to the highly complex characterisation of the consequences.

5.1.5. Context

The oil spill risk assessment process needs to respect the external and internal factors, i.e. context, in which it occurs. Consequently, it is assumed that before the oil spill risk assessment begins, the stakeholders will collect sources and familiarize themselves with the legal and regulatory framework valid in the area under consideration. It is specifically essential in all cases where mitigation measures might require amendments to the navigation regime, directly or indirectly described in the regulatory framework in force.

Additional attention should be paid to financial and social issues that may occur because of estimated risk. The most notable case involves hazards having low-risk value due to infrequent occurrences but catastrophic consequences. In such cases, social perception may significantly

overcome the importance assigned to the risk value. In addition, the costs of the mitigation measures in related cases may be unjustifiably high regarding the assigned risk value.
In any case, stakeholders should agree whether a proposal to amend legal or regulatory framework is acceptable as a mitigation measure or outcomes of the process should be in accordance with the existing regime.

5.1.6. Criteria

For oil risk spill assessment in the Adriatic Sea area, the "As Low as Reasonably Practical" principle is recommended to be followed in all cases.
As a level of significance, oil spill risk should be considered significant if the spill causes persistent, observable or harmful effects on the environment within 30 days after it occurred, lasting more than 24 hours.
However, if the primary stakeholder considers it appropriate, other approaches may be used. The examples include quantified criteria, such as the maximum allowable risk level for one or more considered hazards.

5.1.7. Risk assessment team

After the framework is outlined, a key decision of any risk assessment process is appointing an appropriate risk analysis team and assigning roles and responsibilities to its members.
The team leader is a member responsible for organizing and facilitating the analysis. He or she will have to be knowledgeable in the analysis technique being employed and possess good people and meeting skills. A good team leader should be:

- independent of the subject activity or system; it is not required to be the activity or system expert,
- able to organize and negotiate,
- communicates well with a diverse group,
- able to maintain focus group energy and build consensus,
- impartial, honest and ethical,
- experienced with the risk assessment techniques.

The team leader need not be a representative of the primary stakeholder or any other stakeholder.
The administrator is responsible for recording the analysis meeting proceedings. It is assumed that the administrator must be detail-oriented and understand the risk assessment technique. In addition, he or she should be attentive to details, understand technical terminology, summarize discussions and understand the risk assessment techniques.
Subject matter experts are responsible for identifying hazards, postulating causes, estimating consequences, identifying safeguards and suggesting ways to address loss exposures. They should understand the design, operation and maintenance of the systems or activities being analysed. Having subject matter experts with appropriate knowledge and experience is key to the risk assessments' quality and accuracy. The stakeholders should propose subject matter experts.
It is assumed that all team members will honestly participate in the process from the beginning until the end.

5.2. Data and information management

The oil spill risk assessment should be based on the information as much as possible and on expert opinions as much as necessary.

In the following paragraphs, the terms *data* and *information* are understood differently. Data contains raw figures and facts, while information represents data collated to derive meaningful inferences according to its contextual requirement. Information is structured, processed, and presented with assigned meaning. Consequently, information cannot exist without data, but data does not rely on the information.

Necessary data and information can be gathered from different sources such as observations and measurements, literature reviews, databases, and expert opinions. In addition, insights may be collected or derived from experiments, interviews, surveys, and simulations.

For each source of data or information, the following should be considered:

- the sources of information and their reliability,
- type of data (e.g. qualitative, quantitative or both),
- data quantity and quality,
- level of confidentiality.

Data and information from unreliable sources or whose reliability cannot be confirmed should not be used.

When the data to be analysed are obtained from sampling, the collected data should ensure the statistical confidence level equal to 95% or more. Lower confidence levels may be accepted with due regard if there are no other available sources.

Good practice in the use and collection of information requires that those responsible:

- consider the limitations of data and alternative perspectives (including of experts),
- share evidence in a timely fashion,
- conduct peer review of data and associated risk assessments,
- consider the external risk sources on incidents and responses, not just evidence for the causation,
- collect and describe evidence in a way that enables comparisons across time and in different circumstances,
- engage experts and external audits where appropriate.

If the data and information collected or derived during previous assessments are available, the team members should verify whether there have been any changes in the context and, if so, whether the earlier data or results remain relevant.

It is assumed that one team member should be responsible for information management, i.e. to control the data flow, sources, storage, and dissemination. His responsibilities should include caring about externally collected data and information developed during sessions or as a product of performed analyses.

It is assumed that, for the oil spill risk assessment in the area under consideration, at least data and information describing the following are required:

Data on traffic flow

It is assumed that the larger the number of ships sailing into or out of an area or a port, the greater the potential for accidents and, hence, the spilling of oil. Specifically, if a particular port is

used by the larger ships[4], the more prominent traffic is expected, resulting in a more significant oil throughput in a port. The higher the traffic volume, the greater is the chance for one of the ships to be involved in an accident.
In addition, large ships are generally less able to avoid an imminent accident (compared to smaller ships) because of the high momentum and inertia associated with the size. For example, in collisions, a large ship will be unable to change course if the colliding ship is very close. In the case of a grounding, the energy of hull tearing will be directly proportional to the size (and hence, mass) and the square of the ship's speed. Also, large ships have large drafts and therefore have a higher probability of encountering submerged objects or grounding.
Lastly, in a collision, the masses of both ships and their relative speed determine whether the tank will be punctured or not. Therefore, the release probability will depend on the ship size and mix, among other parameters.

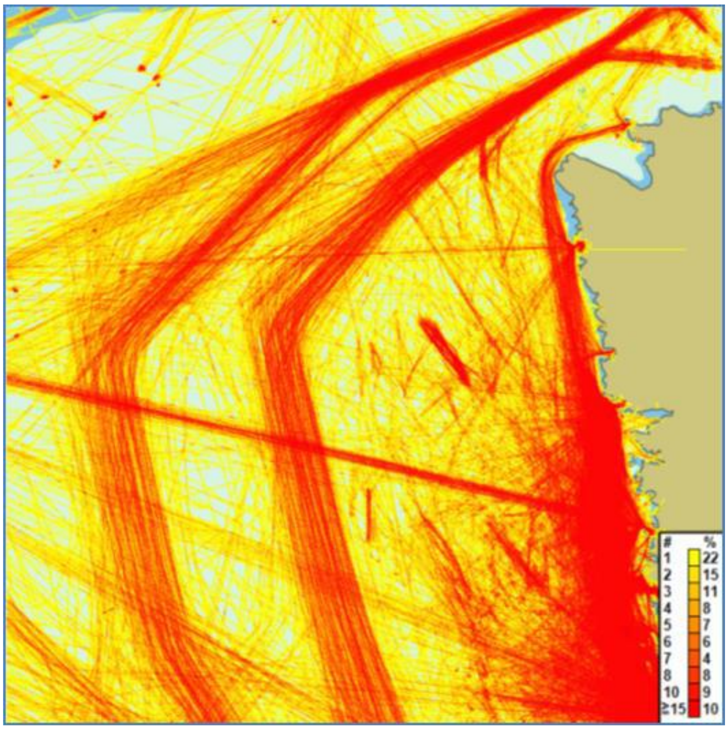


Figure 17 Traffic density plot produced by the Coastwatch system (CVTMIS)

Consequently, the most appropriate dataset is a set consisting of an entry (a record) for each ship entering the area under consideration, containing the following data:

- ship's identification (name, IMO number or MMSI),
- type and size (length, width and draught, GT),
- cargo (type and quantities, hazardous cargoes),
- service speed,
- port, terminal, or berth used,
- arrival and departure times (in or out of the area, at pilot stations or similar recognizable points, alongside).

[4] Large ships are ships, beside tankers, having more than 2.000 tons of marine fuel aboard.

To get accurate statistics on traffic flow, as extensive as a possible data set (track records) is recommended. In any case, a dataset covering at least three years is assumed. Data should be in the form of a spreadsheet or similar form, allowing numerical analysis. It is important to note that only data in the spreadsheet table support the seasonality analysis; other forms, particularly summary data, as a rule, do not enable such analysis. Such data form is crucial for the traffic analysis involving passenger ships along the Adriatic Sea coasts.

If such data are not available, the summary data may be used instead. Examples of such data include weekly, monthly, or yearly data on berth occupancy, number of ships per type, total cargo quantities, average speeds underway, etc.

Summary data in a graphic form, such as traffic densities per ship type (for example, as produced by the Marine Traffic website) or raw AIS data extracted from AIS servers' databases (for example, by the Croatian VTMIS service), are beneficial. However, these graphs cannot be numerically analysed and require local expert knowledge for proper interpretation.

Finally, when preparing traffic flow data, one should also estimate the changes that may be expected within the agreed timeframe. For example, if a new terminal is planned within the area under considerations, the number of ships that will be accommodated at the berth and volume of fuel onboard these ships must be estimated,

Data on local hydrography

The essential hydrographic data describe waterway configuration, channels' characteristics, route options, and sea currents.

The shape of the approaching waterways (traffic routes geometry) and the traffic lane locations within the port area significantly influence the probability of ship accidents. The main types of waterway configurations include an open approach from the sea, the convergence zone, an open harbour or bay, an enclosed harbour, a constricted waterway, and a river. Although not equally distributed, all the mentioned waterway types can be found in the Adriatic Sea area (e.g. navigable rivers, Po and Neretva, have modest traffic). Generally, the wider the waterway, the least probability of accidents.

An essential part of the traffic route geometry is different objects that may influence the flow or behaviour of individual ships. Such objects include isolated dangers (e.i. Galijola), including wrecks and obstructions, undersea cables, military exercise areas, anchorages, fishing grounds, aquaculture, and offshore energy objects.

It is assumed that any passage wider than four miles should be considered as an unrestricted sea area and should not be considered as a channel.

The channel width and depth are essential parameters. The wider the channel, the less is the probability of collisions with other large ships. In general, the channel depth (minimum safe depth or chart Datum) should be enough to accommodate the largest ships calling at the port. However, from the point of view of grounding risks, the off-channel depth and the type of water bottom are equally important. The shallower the off-channel depth is, the greater the probability of grounding if ships veer off course (for example, due to mechanical problems, instrument errors, or operator failures). Groundings could lead to significant ship damage and potential oil leaks depending on the nature of the channel bottom, the ship's speed, and the off-channel depth variation.

The potential for deviating off course becomes higher if the waterway or channel has several turns (especially near right-angle turns); i.e., the number of course changes from the open water to the inner harbour is an essential parameter that may influence both collision and grounding risks.

The nature of the ground at the water bottom, especially in off-channel locations, influences the groundings and the potential ship tank breaches. If the bottom is silty, one can expect a low probability of a leak for a given speed of grounding compared to when the bottom is rocky or has reefs.

Lastly, one should consider the effects of sea currents, mainly if sea currents exert high variability in direction and speed. However, these factors have a lesser influence on the accident probabilities because, in general, the details of currents are known to pilots. Notably, the currents generated by sudden floods into the channel (for example, following an extended rainy period) can pose problems.

It is important to note that data on local hydrography are mainly presented as descriptive or qualitative information. Even if there is numerical data (for example, long-time datasets of current measurements), extracting valuable information for an oil spill risk assessment is tedious and with no clear connotations. Therefore, it is recommended to generate information on hydrographic parameters using qualitative approaches (for example, by interrogating experienced local pilots using questionnaires and interviews).

Other hydrographic parameters, such as tides, tidal currents, or salinity, have minor effects on oil spill risk assessment or no effects at all. Consequently, they are excluded from further analysis.

Data on local weather

The local weather is mainly described with factors that affect the visibility and winds and waves, Reduced visibility is an important parameter contributing to collision accidents or groundings due to the ship going off course. The leading causes are fog and heavy rains (showers), although the second one is much less frequent than the first one. However, heavy rains may affect visibility, particularly electronic visibility, i.e. the effective use of radar devices.

Even though the availability of radar and other electronic navigational instruments on modern ships is mandatory, thus decreasing the influence of this parameter on potential oil release accidents, the parameter needs to be considered.

Data on the visibility at sea are generally given in days per year for relevant points along the coast or islands. Therefore, a broad understanding of the effects must be generalised from the dataset covering at least ten years and as many measuring stations as available. Data should cover not only the area under consideration but also the neighbouring areas.

Although not having the same significance level, data on precipitations in the area under consideration should be collected. One should bear in mind that heavy showers affect the ship's navigation and manoeuvring performances, mainly within the confined port areas or in narrow channels. These datasets should be preferably in the form of spreadsheets.

The local winds and resulting sea states bear utmost importance for the safety of navigation. Although these two effects are interrelated, there are areas where significant winds may occur without accompanying high waves and vice versa (swell). For example, the strong NE wind along the northern Croatian coastline may reach extreme forces not producing commonly expected wave heights. The effects of winds and waves may impact safety, particularly for boats, yachts, and smaller ships.

Both winds and waves may have an extremely negative impact if the integrity of steering and the ship’s stability is compromised. A ship's steering loss can render it impotent and subject to drifting and grounding, shoaling, or colliding with rocky outcrops. Therefore, the frequency of occurrence of high wind and corresponding high sea states influence oil spill probabilities. One should bear in

mind that the maritime traffic is continued in these conditions and reduced significantly only in cases of extreme weather.
Datasets describing winds should be collected in the form of a spreadsheet, allowing further numerical analysis. Measuring stations providing data should be carefully selected, ensuring that local peculiarities (shadowing) do not significantly affect the data's reliability. If raw data are unavailable, the preferred minimal dataset should, for each cardinal direction, include at least:

- 30-minutes averages,
- 10-minutes averages,
- 10-seconds gusts,
- frequencies and durations of constant winds (22 knots or more, and 34 knots or more).

Datasets describing waves should preferably be measured data (generated by wave buoys or similar devices). These data should be correlated with wind measurements obtained at the same spot and same time. Data should include the average values (heights, directions, and periods) and analysis of extreme values.
If measured data are not available, directions, heights, and periods may be estimated using one of the available methods (numerical models) or expert estimations. Values obtained by these methods should be verified by consultations with experts having local knowledge.
Data on winds and waves should cover at least three years, or preferably five or more.

Data on previous accidents

In general, data directly or indirectly representing past losses or describing circumstances (factors) leading to the losses are highly valuable data for the oil spill risk assessment. Examples include statistical data on different types of accidents occurring in the area under consideration, near-misses, significant deficiencies (for example, on the steering systems), health or environmental impacts, injuries, fatalities, etc.
Additional information might also include the causes of failures, the consequences (both financial and legal), the nature of injuries, etc.

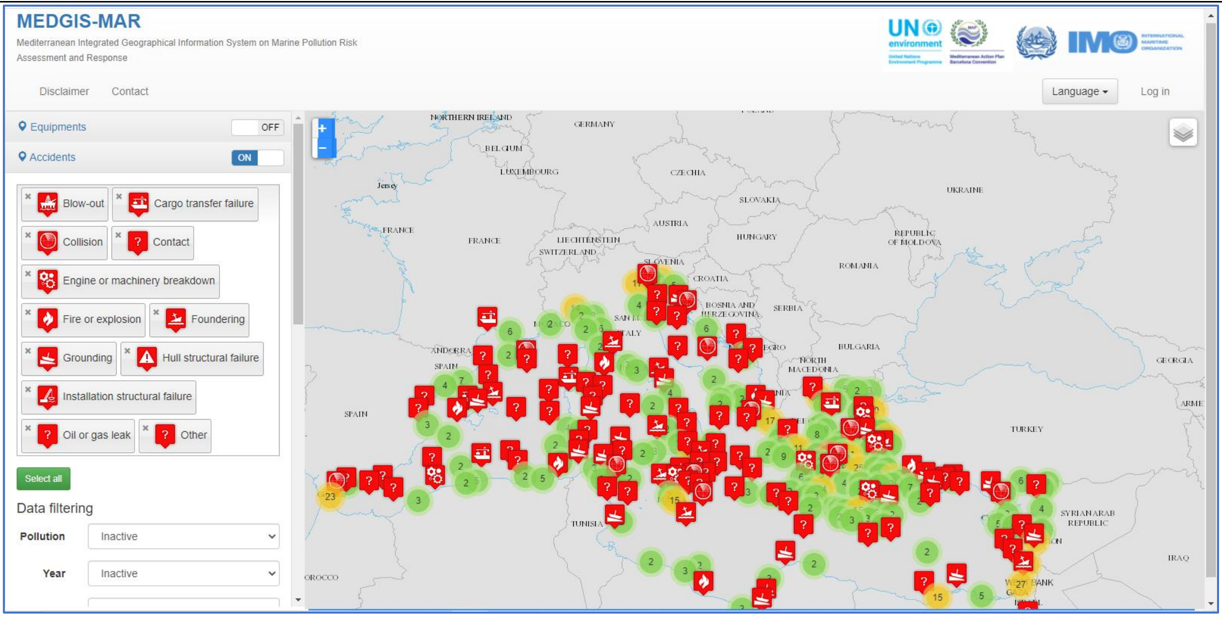


Figure 18 MEDGIS-MAR main screen

The primary sources should be the national databases maintained by the national institutions responsible for the maritime accident investigations. Since these databases may have too few cases, one can consult international databases, for example, those maintained by REMPEC[5] and ITOPF.[6]

It must be emphasised that accidents involving oil spills are rare events. Subsequently, data on previous accidents may be used only to identify possible events or as a basis for scenario development. From the statistical point of view, these data have no significance due to a small sample of relevant cases. It is a case for the Adriatic Sea area, where, despite numerous ships carrying oils, no significant accident takes place up to date.

5.3. Hazard identification

There are many definitions of hazard and associated hazard events. Based on the analysis of different sources, the structure of the hazards that may cause maritime oil spills identified by IALA [44] is considered appropriate. Consequently, it is used in the proposed methodology.

According to the IALA risk assessment procedure, hazards can be grouped into the following main categories: natural, economic, technical, human, operational, or caused by waterway complexity. Natural hazards include minimum safe depth (m) proximity of danger (NM), tide, wind, wave and current effects, ice conditions, restricted visibility (NM), low sun issues, background lighting, loss of positioning, navigation, timing (geographical obstruction) and earthquake and tsunami effects. Economic hazards include legal action problems and insufficient AtoN funding issues.

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5 Data can be found at https://medgismar.rempec.org/. The database contains accident data, including location, type, ship name, ship type, cargo type, release status, a product released, form of release, pollutant name, release quantity.

6 See https://www.itopf.org/knowledge-resources/data-statistics/statistics/

Technical hazards include shipborne navigation equipment failure, quality and validity of charted information, loss of ship control, loss of communications, loss of connectivity, cyber interference, aids to navigation failure, loss of positioning, navigation and timing (PNT), and substandard ships. Human hazards relate to crew competency, fatigue, safety culture, the influence of alcohol and drugs, availability, and competency of VTS, other AtoN provider competency, availability and competency of pilotage, piracy/terrorism, political issues, culture and language issues, crew medical issues and crew distractions.

Operational hazards include the impact of smaller ships navigation, fishing activities, seasonal activities, poor passage planning, inadequate routeing guidance, poor route monitoring, poor promulgation of maritime safety information (MSI) and poor response to marking of new danger. Hazards related to the waterway complexity include the existence of wrecks and new dangers, crowded waterway issues, the existence of restricted areas (e.g. ammunition, fish farms), sharp bends, narrow fairway, limited manoeuvring space, traffic considerations, limited available depth of water, new or existing obstructions, mobile seabed, or channel siltation.

The list presented in previous paragraphs can be used as an initial list of hazards to be considered within the oil spill risk assessment. Therefore, it can be extended with other, more specific hazards, or existing hazards may be changed to reflect better the actual situation. Accordingly, not all hazards should be used in every case. Hazards characterised with an extremely low probability of causing an undesired sequence of events may be omitted from further considerations.

If oil spill risk assessment aims to consider mitigation measures, then hazards that cannot be counteracted by mitigation measures available may be excluded from further considerations. The most notable example is human hazards, which are in most cases beyond the reach of the coastal authorities and should be addressed by shipping companies or indirectly by Port State Control Officers in each case.

It is assumed that hazard identification will be carried out as a first step and involve subject matter experts since few individuals have expertise on all hazards. Group interactions are more likely to stimulate hazards considerations that even well-informed individuals might overlook. The hazard identification process should be as comprehensive as reasonably practicable; events identified as hazardous will form the basis for subsequent analyses and the selection of oil spill scenarios. Although hazards listed at the beginning of this chapter seem well-known, they may become diverse and have unexpected outcomes. Consequently, it is not necessary or desirable to specify which approach should be adopted in particular cases. The methodology should be chosen by the primary stakeholder (or a team leader, if it is appointed as recommended). Hazard identification may follow a standard technique, following an established protocol, modified one, or combining several, supposing the objectives are met as efficiently as possible given the available information and expertise.

As a rule, the hazard identification should be carried out as a structured group analysis of possible hazards for each route leg subject for the analysis. Brainstorming should be allowed as appropriate. However, the team leader should control the discussions and take care not to lose the focus of the discussion. In that respect, the list of hazards attached to this document is recommended as a guidance document.

Notwithstanding the previous deliberations, the Bowtie method is recommended if more in-depth hazard analysis is required (for example, if team members cannot agree on causes or consequences of one or more proposed hazards). It may help the team agree on the common

grounds or provide valuable insights on causes, consequences, and interrelations among different hazards.
The following features of the process are essential:

- The interactions should promote creativity to encourage the identification of hazards not previously considered.
- A structured approach should ensure comprehensive coverage of relevant hazards without skipping less obvious problem areas.
- Accident experience should be used, where available, to capture the lessons from the past.
- The outcome of the hazard identification should be clearly defined to clarify which hazards should be included and which have been excluded.

The outcome of the process should be the list of hazards that can cause releases of liquid hydrocarbons to the surrounding environment.
Lastly, hazard identification should consider all spills, no matter how significant they may be, particularly in terms of the oil volume spilt. However, those spills that are considered insignificant, for whatever reason, should be distinctly marked as such.
When all hazardous events have been identified and characterised, an assessment is undertaken to select those events to be taken forward and to define the oil spill scenarios.

5.4. Risk appraisal

The oil spill risk assessment may deal with two broad categories of oil spills: operational and accident. Operational spills (discharges) are spills from ships or other sources and occur because of non-compliance with regulations or as deliberate discharges of waste oil and water containing oil residues (spills of oily water with less than 15 ppm of oil content). Regarding ships, such operational discharges are regulated through the MARPOL Convention.
Spills of oily water having more than 15 ppm of oil are considered illegal discharges. They are caused mainly by poorly designed or poorly maintained equipment or human errors. Since being frequent but small in the amount of oil spilt per release, such discharges can be relatively easily prevented. Responsibility for risk assessment lies on equipment producers and port operators since, in most cases, spills take place in ports.
Consequently, the essential methods of risk assessment in case of operational spills are techniques for identifying hazards (for example, Failure Modes and Effects Analysis, Failure Modes, Effects and Criticality Analysis, and Hazard and Operability Studies), and techniques for understanding consequences and likelihoods (for example, Event Tree Analysis, Fault Tree Analysis, and Human Reliability Analysis). In any case, a steady decrease in operational discharges of oil has been recorded in the last few years. Consequently, the focus of this document is not on oil spills categorised as operational.
Accidental oil spills, although relatively rare events, may cause much larger oil spill releases, thus causing substantial environmental damage in a relatively short time. Oil tanker spills are considered a major ecological threat due to a large amount of oil spilt per accident and numerous routes passing close to the sensitive areas. In addition, by ever-increasing ships, oil spills caused by the accidental breach of the hull and fuel tanks are getting into focus, mainly due to large quantities of fuel aboard large ships (measuring in thousands of tons of fuel oil).
Numerous, highly variable causes may trigger accidental oil spills. Consequently, the preventive measures, as well as control options, are numerous. Furthermore, various external impacts can

significantly change the course of events, making different actions appropriate to different circumstances. Due to these characteristics, particularly to limit the number of variations the team has to deal with in a limited time, in most cases, the oil spill risk assessment is based on a set of hazardous scenarios describing a possible course of events as its starting point.
Consequently, although it is not required, it is strongly recommended that oil spill risk assessments under consideration be based on the number of preselected scenarios, no matter what method will be used. Nevertheless, the role of the preselected scenarios and thoroughness of the subsequent analysis will be different in the case of different circumstances and methods.

5.4.1. Delphi

Delphi method is appropriate for oil spill risk assessment in cases where there is no previous experience and data that can be used for a more systematic approach. In such cases, the unbiased view of experts can provide initial insights that could be later expanded using more sophisticated methods.
The process is appropriate within the project area if:

- AIS track records are not available or not reliable to allow statistical analysis.
- Detailed data on marine traffic are not available or will be changed soon in an unpredictable way.
- Local expertise is available and easily extracted.
- Hazards cannot be identified without a doubt, for example, due to previously non-existing traffic.
- Stakeholders have conflicting interests, or they do not reveal (intentionally or unintentionally) what their interests are.
- Quick results of the process, even without specific and substantiated outcomes, are appreciated.

The approach is advantageous if the main reason for the process is new installations, especially if there is no previous experience (for example, offshore oil terminals), and risks are unknown (for example, if complex equipment never used before is going to be used).
Bearing in mind that the Adriatic Sea is an area already characterised with heavy tanker traffic (40 million tons or more per year) for quite a few years, where additional capacities in terms of terminals or production sites are highly improbable, and where all major and plausible technologies are in place for numerous years, a need for a Delphi method is not considered realistic.
Such an approach might be appropriate mainly in the case of new facilities in non-industrialized areas (for example, bunker stations at outer islands). There are no data available in such cases, and developing simulation models or gathering several subject matter experts for several days seems unnecessary. Consequently, in such cases, structured but simplified consultations with selected experts may offer the solution.
All principles applying to the standard Delphi method should be followed to ensure effective implementation, with a strong emphasis on anonymity.

5.4.2. PAWSA

As already pointed out, the PAWSA method is a modification of the Delphi method with dedicated structure and formal development ("Books"). The method is appropriate for areas where highly complex navigation patterns exist, where highly mixed traffic structures are recognized, and significant volumes of dangerous cargo are underway. The implementation guidelines are available publicly.[7]

It is very appropriate for areas where port traffic is mixing with traffic on the nearby approaching waterways, thus preventing the efficient use of simulations or numerical determination of likelihoods. An example of the question that may be made in such a case is: "Determine the influence of passing ships on the ships moored along the quays facing the channel (mooring safety)." Such influences can be numerically determined, but such an approach requires extensive modelling, efforts and resources, and results are still not sufficiently generalised to cover all possible situations (due to the extreme variability of numerous variables). Consequently, the sufficiently accurate answer may be more effectively obtained by examining the problem by subject matter experts. All other methods are too costly or too demanding, and time-consuming. Although the method provides answers to specific questions more efficiently than some other methods, it still requires many subject matter experts from different subject areas.

The process is appropriate within the project area if:

- There is significant local expertise available for the area under consideration.
- Detailed data on marine traffic are not available or will be changed soon in an unpredictable way.
- Complex navigational situations may quickly arise within the area under consideration, i.e. situations never before faced by pilots, masters, or other stakeholders.
- Methodology support is available and affordable.
- The main target area of the oil spill risk assessment are port areas and approaching waterways.

In the Adriatic Sea area, such complex traffic patterns with significant traffic of different types of ships exist only in the Bay of Venice area, together with the Marghera port facilities (although the port of Marghera is, in terms of cargo volumes, the mid-sized Italian port).

The port consists of four main areas:

- Marghera, the largest port section, extended over an area of 14.500.000 m² with 12 km of quayside, where most of the port's commercial and industrial activities take place,
- Marittima (including San Basilio-Santa Marta), the passenger port section, with a 290.000 m² total area, 3.4 km long quaysides and passenger terminals that can handle up to 10 large cruise ships and several high-speed crafts,
- Fusina, a ro-pax terminal covering a 360.000 m² area,
- San Leonardo, an oil products pipeline terminal.

[7] See https://www.navcen.uscg.gov/?pageName=pawsaGuide

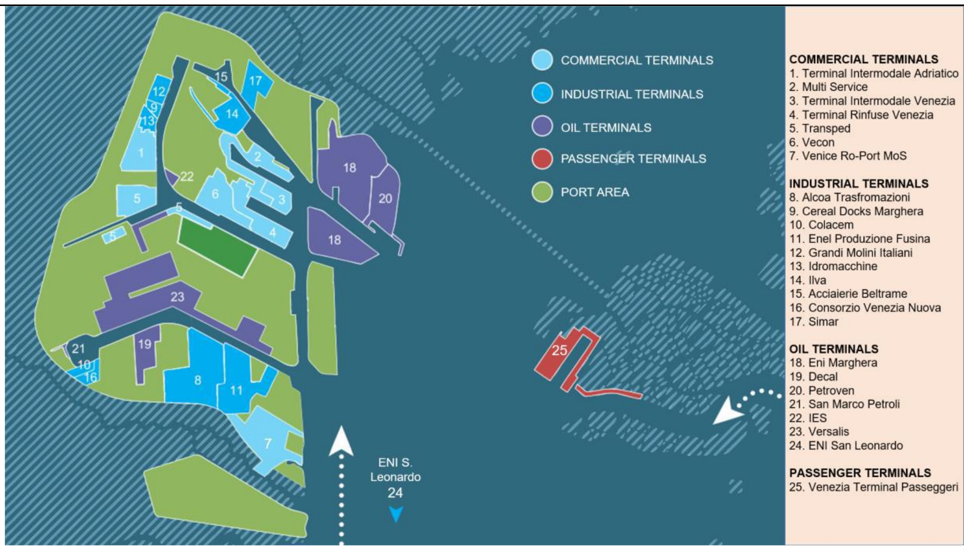

Figure 19 Map of the Port of Venice's terminals [37]

One should bear in mind that, due to environmental considerations, the number of ships regularly using the facilities is decreasing, particularly the number of large passenger cruisers.

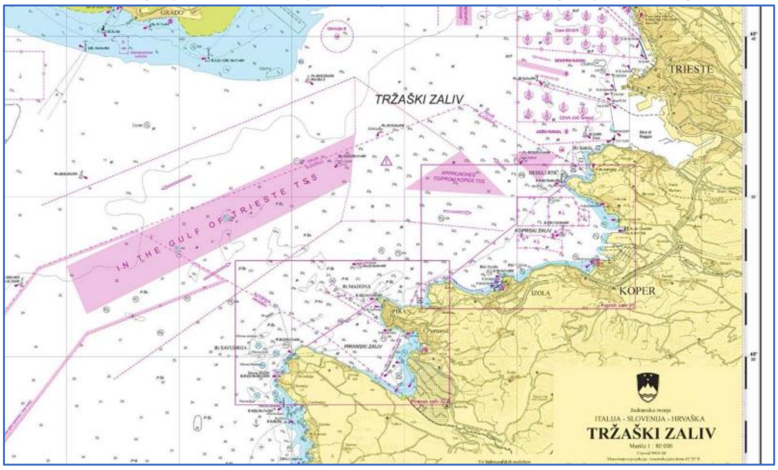

Figure 20 Gulf of Trieste TSS (source: Tržaški Zaliv 03)

The second candidate area is the area in front of the port of Koper and Trieste. Suppose the density of traffic increases in the future, the implementation of the PAWSA method may be considered. The decisive argument supporting such an approach is the large oil tanker terminal (TAL) located within the port area in the Gulf of Trieste (Bay of Muggia). The terminal consists of two piers with double berths and can accommodate up to four vessels simultaneously. The terminal can receive tankers with a maximum displacement of 280,000 metric tons. If such an approach is selected, it should cover all ports in the area and include stakeholders from both Italy and Slovenia.

However, experience so far does not suggest a need to implement the PAWSA method in the area. If circumstances change, particularly in the case of the significant increase in marine traffic in the area, the method should be seriously considered. It is worth emphasising that there are no indications that tanker traffic in the area will increase. Nevertheless, if it occurs, it should be a reason to consider the revalidation of the actual measures and implementation of the PAWSA method.

5.4.3. Maritime Event Risk Classification

The method, although only recently developed, seems appropriate for implementation in areas where:

- the process needs to cover a multitude of aspects, i.e. environmental damage, loss of life or injuries and economic losses,
- enough data on accidents and their severity (consequences) exists or can be estimated with consistent accuracy.

Although well developed, the method has a limited potential for implementation in the Adriatic Sea area following the mentioned prerequisites. The major drawback is that the number of accidents and incidents in the area does not provide a sufficiently large dataset for structured analysis and identification of the Safety Issues. In fact, the number of accidents recorded by coastal states is relatively high, but the vast majority of these accidents involve boats and yachts and do not relate to the oil spill risk assessment.
In addition, the method, being only recently developed, requires specialized knowledge that may not be available at the time.
However, the method should be kept in mind, particularly if all coastal states decide to undertake such exercise for the whole Adriatic Sea area. In that case, the method seems the most appropriate, and even the authors' support may be sought.

5.4.4. Scenario analysis

Scenarios typically deal with the most adverse event developments. Hence, the efforts are concentrated on the most prominent developments, minimizing the waste of resources.
Such an approach offers numerous benefits:

- Scenarios are much more apprehensible to subject matter experts; therefore, knowledge extraction is much easier.
- The number of options to be considered is reduced; thus, the problem is much more manageable in the given time.
- Uncertainties, both in likelihoods and consequences, are significantly reduced, thus causing more reliable outcomes.

The process is appropriate within the project area if:

- Detailed data on marine traffic, including AIS data, are not available or will be changed soon in an unpredictable way.
- Subject matter experts could not reach a consensus on event developments, so a more detailed analysis of hypothetical developments is needed.
- Detailed data on marine accidents are not available.
- The pool of subject matter experts is not large enough, or experts for some subject matter areas are not available.

Based on the previous observations and following the analysis of the conceivable course of events, the list of possible hazardous scenarios is developed:

1) Collisions
    a) Head-on
    b) Overtaking
    c) Crossing
2) Groundings
    a) Full speed groundings
    b) Drifting groundings
    c) Touching bottom (Touch-and-Go)
3) Allisions
    a) Windfarms
    b) Oil rigs
    c) Wave and tidal energy structures
    d) Breakwaters
    e) Aquaculture objects
4) Foundering
    a) Capsizing
    b) Sinking
5) Structural failures
    a) Structural failure of the ship
    b) Structural failure of other objects (bridges, cranes, etc.)
6) Other
    a) Engine fire
    b) Cargo fire
    c) Accommodation fire

For cases dealing with simple traffic patterns, only a few scenarios may be identified. However, for larger areas and complex traffic patterns, the team may identify numerous scenarios, in which case a well-rounded, representative set of hazards will need to be selected.
Scenarios may be used for:

- scenario analysis, requiring a selected but a limited number of scenarios to be analysed by the team members to get deeper insights into accident dynamics and its consequences,
- estimation of likelihoods and consequences.

In case of scenario analysis, the team members are given an initial set of data, and they are required to interrelate hazards with a scenario, recognize the possible course(s) of events, causes, barriers, control options, and outcomes (consequences). The data used as a basis may include some or all of the following:

- characteristics of the ship: size, type, cargo, oil quantities (per tank and total quantity), flag, crew composition, previous port(s),
- position and time of the initial event, the primary cause of course of events,
- weather, at the time of the initial event and 3-day weather forecast,

- characteristics of other ships participating in the course of events,
- discharge characteristics: oil type, release dynamics,
- any other information that may help to estimate outcomes in respect to barriers and control options.

In case scenarios are used to estimate likelihoods and consequences, the level of description is significantly lower. The fundamental idea is to provoke subject matter experts to estimate likelihoods of discharge regarding the position (or the ship's voyage leg) and consequences (the volume of oil discharged). In this case, the scenarios should only indicate the cause and position of discharge. The discharge position may be given precisely or only indicated (within a specific area or while the ship follows a route leg). The other information should be assessed by the subject matter experts using their local knowledge and data and information accumulated during previous phases of the process.

When estimating consequences, it is assumed that experts will be required to estimate the maximum possible damage to the environment (worst case scenario) and the most probable damage to the local environment (damage that would be caused by the median ship under consideration in terms of oil quantities aboard). In other words, the worst credible case represents the scenario with the most severe consequences and which is still considered plausible. A median ship in terms of oil volumes aboard is a ship carrying a larger volume of oil than found on 50% of all ships.[8]

In both cases, it is recommended that external experts identify and describe scenarios, i.e. experts who do not evaluate the scenario outcomes. For this purpose, the form attached to this document may be used as it is proposed or may be amended as external experts consider suitable.

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5.4.5. Likelihoods

Likelihood refers to the chance an event might occur. The objective of the likelihood analysis is to characterise the identified hazardous events in terms of likelihood, event duration and location, potential volumes of oil discharged, and the type of oil released.

Likelihoods can be determined:

- in general terms (qualitative analysis, "expert guess"),
- based on the available historical data,
- numerically estimated, based on the measurements (sampling), mathematical or simulation models.

Although likelihoods estimation should be evidence-based, i.e. based on the measurement of sufficiently large samples, such an approach when oil spills risk assessment is in question is not viable.[9] There are two reasons: oil spills are extremely rare events, on the one hand, and in many cases not comparable, thus preventing any generalization in the form of the statistical analysis, on the other. Consequently, the estimation of the historical data is not reliable. Due to these

[8] If all ships are sorted by volume of oil aboard, the ship in the middle position on the list is median

[9] The excellent source of data was published in Lloyd's World Casualty Statistics. The statistics published, among other data, the number of the accident per 1.000 ship-years. Such data representation provides the number of events concerning the exposure on the global scale, providing statistically-based probabilities. Unfortunately, the publication is discontinued, and no other publication, as known to authors, provides comparable statistics.

characteristics, the likelihood is estimated using numerical modelling and simulations in most cases. If such an approach is not viable qualitative analysis is used.
The degree of detail to be achieved for the likelihood analyses will depend on the type of oil spill risk assessment to be carried out: a high degree of detail and use of modelling and statistics based on available and relevant historical events would typically be required for quantitative analysis. In contrast, fewer details would be required for qualitative analysis.
For implementation within the project area, it is assumed that likelihoods will be calculated whenever it is reasonably practical, i.e. the required data are obtainable, and software solutions are available. Consequently, for the major hazards scenarios, i.e. collisions, groundings and allisions, likelihoods should be numerically estimated for all navigable waters using IWRAP Mk II software (or better, if available).
For other scenarios, historical data may be used (for example, those provided by IMO[10] , EMSA[11] or other commercial sources).
The following likelihood categories are recommended for application within the project:

Table 1 Likelihood categories

	Category	Frequency per year	Number of events
6	Frequent	One or more	1 event per year
5	Occasional	0.1 – 1.0	1 event over 10 years
4	Probable	10^{-2} - 10^{-1}	1 event over 100 years
3	Improbable	10^{-3} - 10^{-2}	1 event over 1.000 years
2	Rare	10^{-4} - 10^{-3}	1 event over 10.000 years
1	Remote	10^{-5} - 10^{-4}	1 event over 100.000 years
0	Incredible	$<10^{-5}$	not known

According to the proposed likelihood categories, all events with a probability of less than 10^{-5} per year are considered incredible and excluded from further considerations. Although the probability is not zero, such events are so rare and unpredictable that further efforts are not justified.
Following the same line of reasoning, it is expected that hazardous scenarios having likelihood designated as *Very Frequent* are unacceptable. Therefore, their occurrence is not expected. Bearing in mind the general attitude on spill events today, the same applies to the *Frequent* category.
If it seems appropriate, the subject matter experts may assign non-integer likelihood values (for example, 3.5) to a scenario. It is applicable if two scenarios fall within the same category (having similar probabilities), but one seems slightly more probable. One should note that the recommended scale is not linear.
The main feature of the proposed likelihood categorisation is that likelihoods estimated by subject matter experts may be compared with those calculated, for example, using IWRAP Mk II software or some other equivalent software (likelihoods are expressed in same units).
The IWRAP Mk II process is appropriate within the project area if:

- Reliable AIS data are available, and the track records cover at least five years.

[10] IMO Maritime facts and figures: CASUALTIES https://imo.libguides.com/c.php?g=659460&p=4655524
[11] EMSA Annual Overview of Marine Casualties and Incidents, 2020

- Traffic densities are known or could be extracted from collected data for a sufficiently long period (at least one year).
- Primary concerns are collisions and groundings and oil spills caused by collisions or groundings.
- Data on vessels types and sizes, including types and volumes of cargo, are known.

If IWRAP Mk II is used, based on the previous experience with the software, attention must be paid to the following characteristics of the software:

- Based on the predefined causation probability, the probabilities of collisions and groundings expected to occur in the Adriatic Sea area seem too high. The causation probability used in the software is defined as a probability that the officer on watch would not react in time when the ship is on a collision course with another ship or a grounding course. Its numerical value is not uniform but varies for different geographical locations and navigation conditions. Default values are available from IALA. It seems that default values should be decreased primarily due to the much better weather in the Mediterranean area, thus directly decreasing the collision and grounding probabilities. Therefore, it is recommended that these values should be verified using actual data, if possible, particularly with those collected using the AIS system or based on the actual collisions and groundings, if the large enough dataset exists.
- The system assumes a standard distribution of ships across waterways, although it is known (thanks to the AIS) that in most waterways, ship passages are densest on one side of the waterway width (the distribution across the waterway is not symmetrical). Therefore, the actual distribution should be adjusted if the summative AIS data are known (for example, using the CoastWatch system).

All the identified hazardous scenarios may be considered for further analysis, but, as a minimum, all scenarios that potentially have a significant risk value should be considered.

5.4.6. Consequences

Consequence analysis involves analysing the potential of hazardous scenarios to cause oil spills that would damage the environment. Consequence analysis should be based on the worst-case scenario, or it may consider the most probable outcome. At this stage, there is no detailed information concerning the possible environmental consequences of the identified hazardous events. However, experienced risk assessors or local environmental specialists should be able to make an initial estimate of events that have the potential for high consequences and categorize them accordingly.

For each of the selected scenarios, the effects on the environment should be estimated. Analysis should be accurate and realistic as much as possible.

Unfortunately, in the oil spill risk assessment, a realistic approach, i.e. approach based on the statistics and probabilities, is not possible in most cases. The variability of the factors that may significantly change the outcomes is such that any numerical generalisation of the outcomes (based on the models or simulations) is questionable.

The approach based on the worst-case consequences requires the subject matter experts to assume circumstances producing the worst outcomes. In the case of oil pollution, it may mean:

- the maximum realistically possible release volume and discharge rate,
- the most unfavourable weather,
- the most ecologically sensitive coastline receptors,

- the most demanding part of the coastline regarding clean-up operations.

Release volume can be established by knowing the volumes carried out by the ships transiting the area under consideration. The value can be estimated by presuming the instantaneous release of 100% of a fixed volume due to containment failure. However, based on the experience, such release is highly unlikely (a particular volume of oil will always remain aboard). Better estimates may be reached if engineering calculations are used. For example, it is more realistic to assume that, in a collision involving a large crude carrier, the maximum discharge oil is a certain percentage of the oil stored in the two largest tanks. Government regulations or international industry standards should always be consulted on this subject as calculations for determining volumes and release rates are often prescribed.

The most unfavourable weather may be defined as winds and waves, including the effects of sea currents that will bring the largest volume of the released oil ashore as quickly as possible. To assess the effects of wind, waves, currents, temperatures, etc., the assessors need to understand how the anticipated oil type will behave in the environment into which it may be spilt, including how it will weather or change over time. The base properties of oil spilt will drive the physical and chemical changes that occur when it may be spilt onto the water. Oil characterisation is used to describe the unique properties of an oil brand and its weathering profile under certain environmental conditions and can be used to predict persistence in the environment and toxicity. It can be done using dedicated software, such as ADIOS or similar. If data are not available or applicable, one should choose an analogue oil based on the best available data.

The spill trajectory and fate modelling also may provide additional information, enabling more accurate assumptions regarding circumstances leading to the worst-case outcomes. The computer simulation of oil spill fate and trajectory aims to estimate the physical changes that spilt oil undergoes (i.e. weathering processes) and its potential pathways, travel times, areal distribution, and associated volumes under the prevailing wind and current conditions.

An oil spill trajectory model should use wind and three-dimensional current data based on in-situ monitoring and modelled oceanographic or meteorological data fields. The data should cover all seasons and be specific for the region where the activity will take place. The oil spill modelling should be stochastic, allowing for simulations based on historical wind and current data variations. It should ensure the necessary number of spill simulations to reflect the metrological and oceanographic input data variations. The stochastic analyses should be paired with the most relevant deterministic cases that can be utilised to support response planning.

The modelled fate and trajectory of the spilt oil may be presented as maps and tables showing the probability of the distribution of oil both at sea and on shorelines. The limitations and resolution of the modelling should be understood and documented together with the quality of input data. Although such software provides valuable data to subject matter experts, their implementation value is limited. In fact, these tools are more valuable for response strategy planners than for the oil spill risk assessment teams. Therefore, their use is recommended if in-depth mitigation measures analysis will follow the oil spill risk assessment. If it is not the case, the effects of such analysis may be unjustified regarding efforts to build and run such simulation models

Table 2 Types of oil behaviour

Oil category	Description
Light evaporator	Less dense than seawater; highly volatile – prone to evaporation Examples – jet fuel, gasoline
Medium evaporator	Less dense than seawater; volatile – prone to evaporation Examples – light grade crude, freshly diluted bitumen (with 30% condensate)
Medium floater	Less dense than seawater; marginal volatility Examples – diesel fuel, fuel oils, medium-grade crude
Heavy floater	Marginally less dense than seawater; limited volatility Examples – heavy grade crude, heavily refined oils
Heavy sinker	Seawater density or heavier, especially in high sediment environment Examples – heavy grade crude

The event location and knowledge of local biological and socio-economic sensitivity should be used as a base to estimate the worst-case scenario causing the most extensive environmental damage. Although detailed environmental and socio-economic sensitivities are not required, local knowledge, environmental/social impact assessments, and existing sensitivity maps are precious. They can help experts highlight events with the potential for severe consequences, which may be given priority for further analysis or proper categorization.

Lastly, the most demanding part of the coastline is the part whose natural characteristics prevent efficient clean-up operations. It is usually the low-level wetlands, where spilt oil can deeply penetrate behind shorelines or rocky parts of the coastline, where natural obstacles prevent clean-up workers from collecting oil and oily debris. In any case, this factor is the least important and, in most cases, does not prevail, compared with other, previously mentioned factors influencing the consequence severity.

Previous considerations show difficulties preventing straightforward measurement of the accident consequences. Accordingly, the following scheme is selected based on the oil spill quantities as a measure of consequence severity.

The following consequence scale is recommended for application within the project:

Table 3 Consequence categorization

	Category	Oil quantity	Description
6	Catastrophic	>50.000 tons	A significant length of the coastline is polluted, including distant areas not connected with the impact point. Clean-up operations require international involvement. Damage to the environment is long-term (longer than five years) or even irreparable.
5	Extremely large	5.000 – 50.000	A significant length of the coastline is polluted. Large-scale clean-up operations may require international involvement. Recovery after clean-up will last at least five years.
4	Large	500 – 5.000	The area affected extends significantly beyond the primary impact point. Large-scale clean-up operations are required. The negative impact on the tidal and sub-tidal species is notable and expected to last three months at least.

3	Noticeable	50 – 500 tons	The area affected extends beyond the primary impact point. Extensive clean-up operations are required. The negative impact on the tidal and sub-tidal species is notable and expected to last at least three months.
2	Minimal	5 – 50 tons	The only area close to the impact point is affected. Clean-up operations are required. The negative impact on the tidal and sub-tidal species is notable.
1	Almost negligible	0.5 – 5 tons	Clean-up operations may be required. A negative impact on the tidal and sub-tidal species is visible.
0	Negligible	< 0.5 tons	There are no visible effects after 24 hours. Clean-up operation is not viable or required.

Because the scale is not linear, the subject matter experts may assign non-integer consequence values (for example, 3.5). It is applicable if two scenarios fall within the same category (having similar consequences), but one is estimated as having a potential for larger spills.
The consequence categories are developed based on the average qualities of oil and its impact on the coastline. The categorization may not be appropriate for sensitive parts of the coastline. In that case, the evaluation and ranking of environmental resources' sensitivity need to consider their ability to tolerate and recover from acute exposure to oil during a spill.
There are three main elements to consider when ranking the sensitivity of the environment to oil:
Sensitivity of biological features: This is a species- or group-specific sensitivity that is a combination of individual sensitivity to oil pollution (e.g. toxicity, smothering effects, a behavioural pattern that affects the likelihood to be exposed to the oil pollution) and the population's sensitivity to the disturbance in terms of its recovery ability.
Coastline sensitivity: This describes the different shoreline substrates having different oil holding capacities and how effectively natural mechanisms clean them.
Socio-economic sensitivity: Socio-economic sensitivity is derived from the economic importance of the resource (e.g. fisheries, recreational beaches, marinas etc.) and the likelihood that oil pollution will impact the socio-economic activity in the event of a spill.
The assessment, in this case, should, as a minimum, be based on the sensitivity of the impact indicators and the potential exposure to oil pollution. A qualitative categorization can be expressed as a relative ranking of consequences, such as a relation between the Environmental Sensitivity Index (ESI) and the estimated oil amount or oil concentration that can pollute the area. A more detailed assessment of consequences can be performed based on established relations between oil exposure volumes or concentrations and the impact indicators such as habitat, seabird populations, or fisheries. Such quantitative relations can, for example, be expressed as a relation between the extent of oil exposure

(volume/concentration), the effects of the oil in terms of ecological damage or economic loss, and the potential duration of the environmental impact in terms of recovery time.
If an assumed oil spill impacts the sensitive area (for example, area where endemic species, susceptible to substances commonly found in oils under consideration), the category of the consequence should be increased. If such possibilities are permanent (for example, if a port regularly accommodates ships with highly toxic or polluting cargoes), the team may agree to modify the whole scale and implement different values as a category range.

5.5. Risk evaluation

Risk is established by combining the likelihood and the potential consequence of each scenario. Once the risk has been established, the primary objectives are to evaluate the risk of an activity or scenario logically and understandably to secure that the risk level is tolerable and that adequately informed decisions can be made regarding the implementation of risk-reducing measures to achieve a risk level that are as low as reasonably practicable (ALARP).
Use of the ALARP principle is recommended, i.e. activities not meeting risk tolerability criteria shall be subject to risk reduction regardless of cost and that the residual risk is tolerable, supposing that it is as low as reasonably practicable.
For considered oil spill scenarios, a clear and balanced picture of the risk exposure should be presented. Therefore, the method recommended for depicting risks is a risk assessment matrix (RAM). It is used to plot the likelihood and consequence outcomes from each spill scenario and can be presented in various formats. The matrix provides a view of the overall risk profile and compares the risk associated with each potential spill scenario.
The recommended approach is the simplest one. Thanks to that, it is understandable to the broadest number of subject matter experts and other stakeholders. In addition, the method is applicable even by those who have never been familiarized with risk assessment methods or protocols.
One should note that the proposed risk matrix uses categories where each category differs by order of magnitude from the previous one, i.e. the ratio between the bounds (or the quantitative equivalents of those) of the following categories are constant. This approach is estimated as the most appropriate for safety-related studies. The likelihood is expressed as expected frequency (number of expected occurrences per unit time). It is known that these frequencies may vary by order of magnitude. Thus, likelihoods and consequences are represented on a logarithmic scale. More elaborated justification on the use of the risk matrix as proposed can be found in [14].

Table 4 Risk assessment matrix

Likelihood	Consequence					
	Almost negligible	Minimal	Noticeable	Large	Extremely large	Catastrophic
Frequent	6	12	18	24	30	36
Occasional	5	10	15	20	25	30
Probable	4	8	12	16	20	24
Improbable	3	6	9	12	15	18

Rare	2	4	6	8	10	12
Remote	1	2	3	4	5	6

In the proposed matrix, the colours have the following meaning:

Low	A minimal likelihood that significant effects on the environment will happen.
Medium	A medium likelihood that significant effects on the environment will happen.
High	Significant effects on the environment are highly probable.
Extreme	Catastrophic effects on the environment are highly probable.

Accordingly, all events (scenarios) having a risk value of 20 or more are events that result in catastrophic consequences to the environment and thus are not acceptable and require immediate and comprehensive measures.
Scenarios whose risk value is rated 15 or more but less than 20 are scenarios that can cause significant effects on the environment. These scenarios require thorough examination and prompt response in the form of appropriate mitigation measures.
Scenarios with risk values 9 or more, but less than 15, are scenarios requiring further mitigation measures.
Lastly, scenarios with a risk value of less than 9 are considered scenarios that do not present an actual threat to the environment, thus, do not require further measures.
The proposed matrix divides the risk into four categories instead of commonly found three. The reason is an intention to provide more considerable scalability of mitigation measures for different circumstances. However, the subject matter experts may decide to assign different risk value ranges to different categories. In such a case, they should present justification for such change.
The outcome of the process should be the matrix containing all pondered scenarios positioned on the graph. The example of the final matrix is presented here.

Likelihood	Consequence					
	Almost negligible	Minimal	Noticable	Large	Extremly large	Catastrophic
Frequent	6	12	18	24	30	36
Occasional	5	7 10	15 1	5 20	25	30
Probable	4	8 12	12 4	16	6 20 2	24 3
Improbable	3	6	9	12 11	15	18
Rare	2	4	9 6	8	10 10 8	12
Remote	1	2	3	4	5	6

Figure 21 The risk matrix marked with scenario scores (scenarios 01-12)

It is assumed that the final scoring of each scenario will be carried out as a brainstorming session. Participants should be expected to present all arguments that affect the likelihoods and consequences. The goal is to reach a common understanding of the risk represented by each scenario and to scale that risk to all other pondered risks.

It is recommended that, besides risk scoring, the most appropriate control options for each scenario are logged. At this stage, it is not necessary to accomplish a complete analysis of each control option. However, the output of the process in this stage should be the list of control options assigned to each scenario, with an assigned percentage of the control option efficiency. The assigned percentage should be understood as an appraised percentage of hazard occurrences effectively removed by implementing that control option.

Further considerations should be dedicated to scenarios (and, if that seems appropriate, their variations), starting with risks having the highest assigned risk values.

5.6. Risk control options

Overall, risk reduction is achieved with effective prevention (barriers) and mitigation measures (control options). Reducing the likelihood of oil spills through prevention is the primary aim, yet residual risk remains despite best intentions. The risk comparison, together with a review of each scenario's unique influences (e.g. oil type, prevailing conditions, local sensitivities), provide the information needed to formulate mitigation measures.

The number of possible mitigation measures and their variations is countless. Therefore, the team should start with measures to resolve or minimize hazards associated with the scenarios with the highest risk value. After extreme, high and medium risks scenarios are sorted out and mitigation measures identified, the team may consider even those with low-risk values, although, if the method is adequately implemented, already selected measures should minimise overall risks in the area.

The next step is to analyse the residual risks in the area under consideration. It includes revising all risk scenarios in light of all measures selected, including their interactions and analyses of possible negative interactions. If the residual risk for each scenario is estimated as acceptable, the final list of mitigation measures may be developed.

It should be noted that any other measure that may decrease any of identified hazards may be considered and included in the list, although it might not be directly related to the particular scenario.

As a rule, the risk mitigation measures should primarily aim to minimize oil spills caused by the hull's breach. These measures include the following:

Speed reduction

As a mitigation measure, speed reduction aims to decrease the ship's kinetic energy in case of collision or grounding, thus minimising the damage to the ship's hull and sub-sequential pollution.[12]

The measure is implementable in large, unrestricted areas; in port areas, ships' speed is already reduced. When introducing, one should be aware that speed reduction should not be too extensively implemented. In that case, some ships may experience reduced manoeuvrability, thus actually increasing the threat, not decreasing it. Also, sailing with reduced speed means an extension of the exposure time (transit time).

12 The measure should not be confused with slow steaming, where ships intentionally decrease sailing speed to minimise air pollution.

Consequently, the measure should be carefully considered to avoid negative consequences.

Traffic separation schemes

A traffic separation scheme (TSS) is a maritime traffic-management route system developed by the IMO. The traffic lanes indicate the general direction of the ships sailing in the area. Ships navigating within a TSS are obliged to sail in the same direction. If they must cross the lane, it should be done at an angle as close to 90 degrees as possible.

The IMO adopts mandatory TSS in international waters in the form of the Maritime Safety Committee decision. TSS, extending only within the internal or territorial waters, are adopted and promulgated according to the national legislative procedures.

TSSs are used to regulate the traffic at busy, confined waterways or where waterways bend significantly. Most TSS schemes include 'inshore traffic zones' between the traffic lanes and the coast. The inshore traffic zone is unregulated and intended not to be used for through traffic but rather for local traffic, fishing, and small craft. A ship navigating in a traffic lane should sail in the general direction of that lane. The body of water between two opposite lanes must be avoided by ships travelling within the TSS as possible except in certain circumstances such as emergencies or fishing activities.

The North Adriatic TSS already regulates the main sailing route in the Adriatic Sea. In addition, close to the island Palagruža, the Republic of Croatia introduced a TSS within the national waters, thus indirectly regulating the traffic lanes in the central Adriatic area.

The only other TSS in the area is the one introduced in the Vela Vrata strait, separating inbound and outbound traffic to the port of Rijeka.

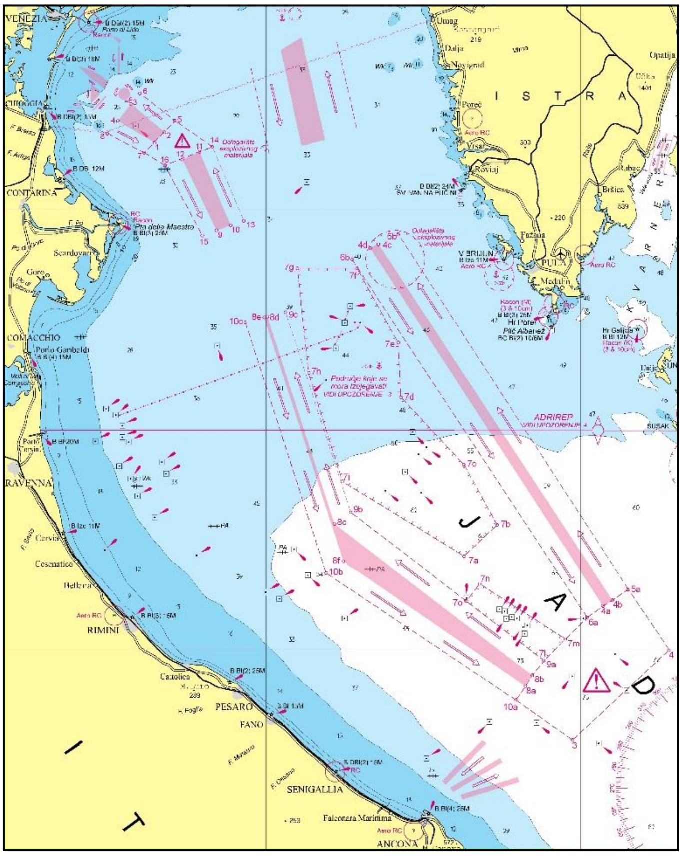

Figure 22 Existing Traffic separation scheme in the North Adriatic

For that reason, the traffic routes to all major ports in the Adriatic Sea area are already regulated by TSS.

Therefore, additional TSSs may be expected only if the level of traffic increases and the complexity of the environment requires so.

Other routing measures

Other routing measures, developed by the IMO, aim to help regulate maritime traffic, supporting associated TSS or as a standalone measure. Measures include:

- Two-way routes: A two-way track for the guidance of ships through hazardous areas.
- Recommended tracks: A route of undefined width for the convenience of ships in transit, which is often marked by centreline buoys
- Deepwater routes: Routes within defined limits that have been accurately surveyed for clearance of sea bottom and submerged articles
- Precautionary areas: An area within defined limits where ships must navigate with caution and within which the direction of flow of traffic may be recommended
- Areas to be avoided: An area within defined limits in which either navigation is particularly hazardous, or it is exceptionally important to avoid casualties, which should be avoided by all ships or certain classes of ships.

It is worth mentioning that these measures are only recommendations. The master may adopt a different route if he considers it appropriate. Some of these measures are already in place (Precautionary areas).
Measures may be used within the project area as mitigation measures.

Exclusion zones

An exclusion zone (no-go area) is a geographic area where, unless explicitly permitted, ships are prevented from anchoring, berthing, or sailing through the area. The area may be established only within the national waters, primarily within the internal waters. Such areas are declared primarily to protect natural sanctuaries from the harmful effects of ships passing through but may be used even for better traffic regulation.
In principle, the exclusion zone area should be kept minimal, as much as necessary to ensure the positive effects.

Sailing permission

Sailing permission is a system used when it is necessary to prevent ships from entering certain parts of the waterway before they are clear for navigation. It may be used in channels but also in much broader sailing areas. The main goal is to decrease the traffic density and minimise the number of close encounters.
The local VTS authorities may implement the measure.
A "soft" version of the measure is already implemented within the Croatian territorial and internal waters.

Mandatory pilotage

Marine pilots are professionally licensed mariners whose role is to board a ship and guide the master along the safest route to its port of call or vice versa. Marine pilots' primary duty is to provide masters with advice regarding local conditions. Pilots provide the local expertise to ensure that the ship sails safely and efficiently. As such, pilotage is commonly compulsory when ships are sailing to or from ports.
However, by declaring the pilotage mandatory for ships sailing between two or more ports (coastal pilotage) or widening the mandatory pilotage area for all or specific ship's types, the local authorities ensure that ships' masters are provided with the required knowledge even outside the port areas.
The measure is highly recommended in the case of ships carrying hazardous or noxious liquids or polluting cargoes.

Mandatory tug escort

Mandatory tug escort aims to assist large ships sailing through narrow channels or passages where increased risk of grounding exists.
The objectives of tug escorting are:

- To ensure a safe passage through the approach channel and apply steering and braking forces to a disabled ship (by escorting tugs) and keep it afloat, or limit the impact of collision or grounding if these accidents are imminent.
- To reduce the risk of pollution in port areas and port approaches due to groundings or collisions caused by technical or human failures onboard a tanker or similar ships with noxious cargoes.

To be effective, the escorting tugs should control the ship over a relatively large speed range, commonly from 10 knots down to zero. Consequently, tugs that can provide the service are large, powerful tugs.

Consequently, mandatory escorting as a measure should be considered only for large ships carrying huge volumes of cargo and being able to pollute large areas in case of grounding or collision.

The measure should be carefully considered since it can result in increased costs and unnecessary delays due to the inability of the port authorities to ensure a fair number of appropriate tugs for every ship arriving at a port.

The measure is commonly applied within the port limits. However, in most cases, it is left to the masters and pilots discretion to determine the number and power of the required tugs. More thoroughly regulating the number and qualities of tugs used may also be considered as a mitigation measure.

Advanced traffic surveillance

The Ship Traffic Service (VTS) is implemented by a competent authority; it is designed to improve the safety and efficiency of ship traffic and protect the environment. The service should have the capability to interact with the traffic and respond to traffic situations developing in the VTS area. It consists of devices and equipment for the automatic identification of ships (AIS), radar devices and equipment, maritime radiocommunications devices and equipment, electronic nautical charts, supervisory cameras, and an integrated maritime information system. It provides typically three different services:

- Information Service (INS),
- Traffic Organisation Service (TOS),
- Navigational Assistance Service (NAS).

The most basic service is the Information service, while the most advanced is the navigational Assistance service. However, even the NAS is provided, as a rule, only upon the master’s request. Advanced traffic surveillance is an advanced service provided to ships sailing in the area under consideration as a mitigation measure. The non-exhaustive list of service provided include:

- mandatory reporting or more frequent reporting by ships,
- navigational advice,
- warning of nearby ships,
- traffic reports, etc.

The scope of services, as well as geographical boundaries, are highly dependable on the circumstances. The measure should be introduced with care since it can create an unnecessary high workload on the VTS personnel and ships’ officers.

Mandatory ship reporting system

Mandatory ship reporting is a formally adopted obligation to report a ship’s position regularly while sailing through the area under consideration. At the international level, IMO may adopt it to contribute to the safety of life at sea, the safety and efficiency of navigation, and the marine environment's protection. In such areas, ships are required to report to a shore-based authority. Such authority shall have the capability of interaction with participating ships.

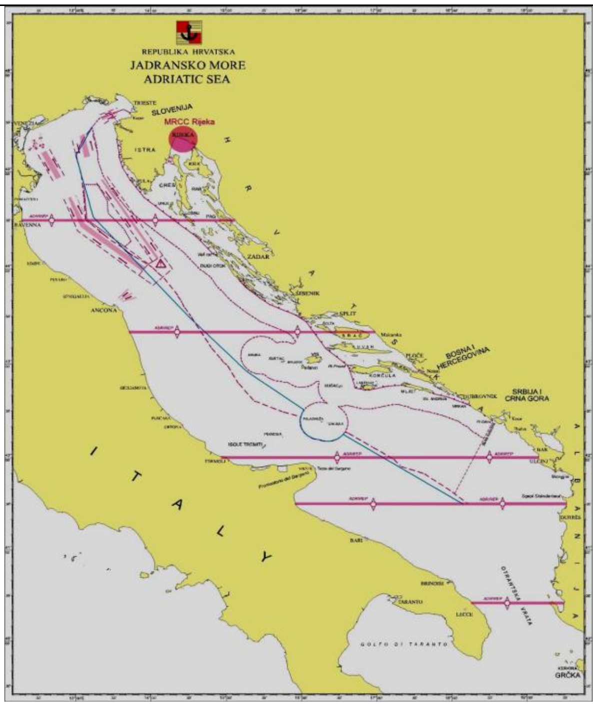

Figure 23 ADRIREP system

In addition to this, the port authorities may require more frequent reporting of ships arriving at their ports. Although the efficiency of this measure is minimised with the introduction of the AIS system, it still may be used to enforce the continual communication and exchange of information with the ship.
Again, the measure should be considered with care due to the possible overuse of communication channels.

Depending on the given framework, the team should consider other systemic or operational measures in addition to the measures listed above (for example, intensified Port State Control inspections). The set of potential operational measures contains numerous measures specific to the circumstances. Consequently, some of these measures may require additional risk assessment methods beyond this document's scope.
After considering all mitigation measures, it is assumed that the team will agree on the final recommendations. Again, the team should try to find a common position on proposed measures in terms of:

- mitigation measures priorities, both in effectiveness and implementation times,
- alternatives, if the initial list of measures is not acceptable due to reason beyond the reach of the team,
- limitations and constraints of the proposed set of measures (i.e. on residual risk).

Finally, the team should prepare the report on activities carried out and recommendations to the responsible authorities. It should contain:

- the agreed framework of the oil spill risk assessment process,
- team members CVs,

- the method selected for the oils spill risk assessment, including the justification for the method used,
- source of data used, with estimated reliability,
- list of hazards identified during initial phases of the process,
- list of scenarios developed as a basis for the risk assessment,
- outcomes of the core process (i.e. likelihood and consequence scales used, risk matrix developed, outputs of the sub-processes, for example, BowTie diagrams, etc.)
- list of mitigation measures considered, including the main implementation constraints,
- recommendations for implementation.

6. Conclusions and recommendations

The main conclusions and recommendations are the following:

1. The oil spill risk assessment should be based on the set of standard risk assessment methods.
2. Before oil spill risk assessment is carried out, the primary stakeholder should outline the overall framework of the process, including the purpose, stakeholders, timeframe, scope, and context, in the form of terms of reference or similar form. If terms of reference also include the criteria, they should be implemented as long as process outcomes do not require revisions.
3. It is recommended to express the purpose of the oil spill risk assessment in the form of the general objective and a list of questions the risk assessment process should answer.
4. The oil spill risk assessment should consist of hazard identification, risk analysis, and risk treatment. Risk treatment may be a part of the process, or it may be started as a separate process based on the outcomes of the risk analysis.
5. In general, risk should be evaluated in accordance with the "As Low as Reasonably Practicable (ALARP)" principle. Other methods are estimated as not as appropriate for the implementation within the Adriatic Sea area.
6. It is recommended that oil spill risk assessment or its part thereof be carried out using quantitative techniques. If it is not viable, the risks should be determined using semi-quantitative methods.
7. It is recommended that oil spill risk assessment should be based on the scenario analysis. Scenarios should cover the identified hazards as much as reasonable and practical.
8. It is assumed that oil spill risk assessment should be based on the following principles:
    a. The risk assessment process and outcomes should be relevant for the geographic scope, use and circumstances.
    b. Risk assessment process should be tailored to actual needs.
    c. The risk assessment outcomes should be a result of collaborative efforts.
    d. The risk assessment outcomes should be evidence-based.
9. Data used as a basis for the risk assessment should be reliable and as up-to-date as reasonably practical.

10. The most appropriate oil spill risk assessment should consistently combine several methods regarding the required outcomes, as defined in the associated flowchart (see Chapter 4).
11. Risk evaluation should integrate all used risk assessment methods' outcomes and provide an initial list of the mitigation measures (risk control options). Unless the outcomes suggest revision, the oil spill risk mitigation measures should be designed according to relevant international instruments and national legal rules and regulations.
12. The oil spill risk assessment should be presented in the standard report form to the stakeholder(s).

7. Annexes

7.1. Maritime traffic in the Adriatic Sea

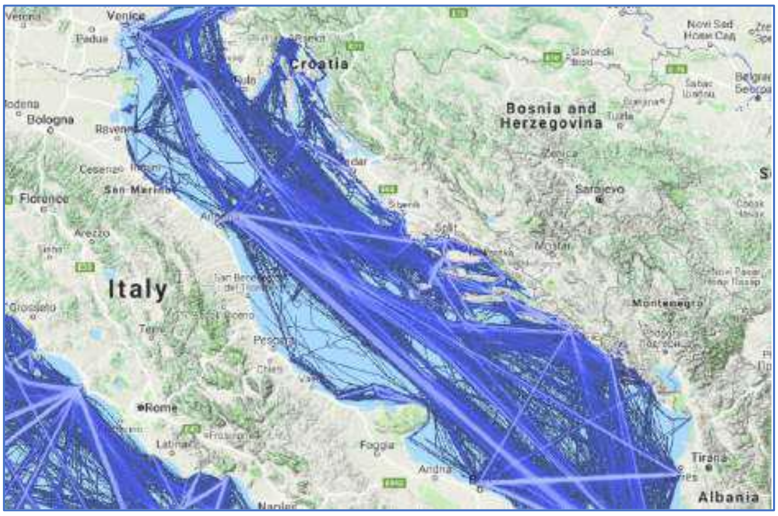

Figure 24 Passenger ships[13]

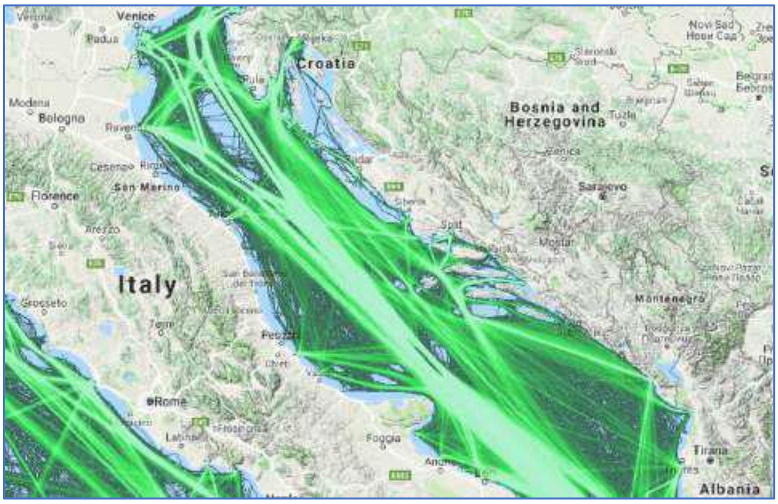

Figure 25 Cargo ships

13 Based on the Marine traffic data for 2017. See [37].

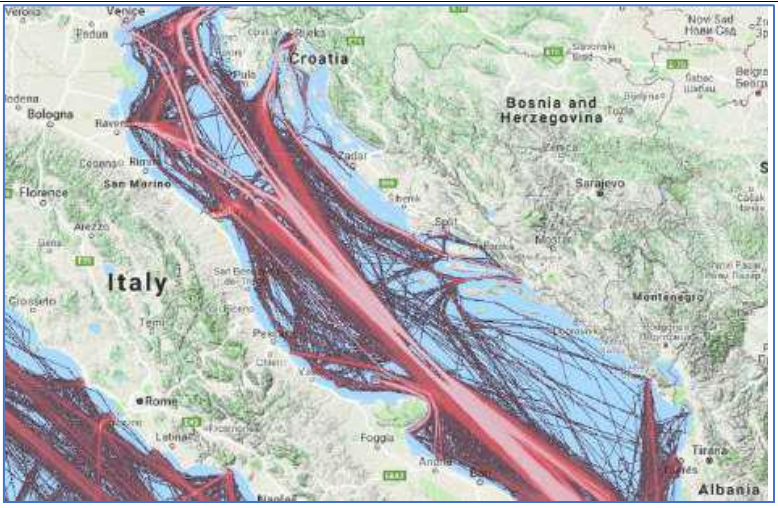

Figure 26 Tankers

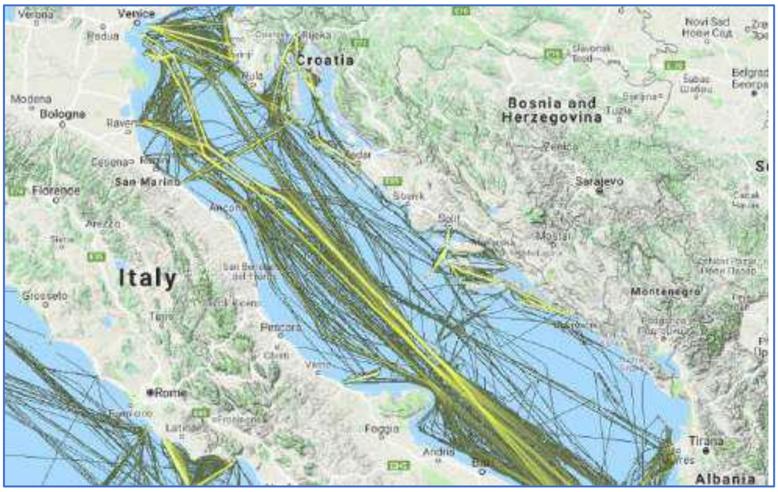

Figure 27 Gas carriers

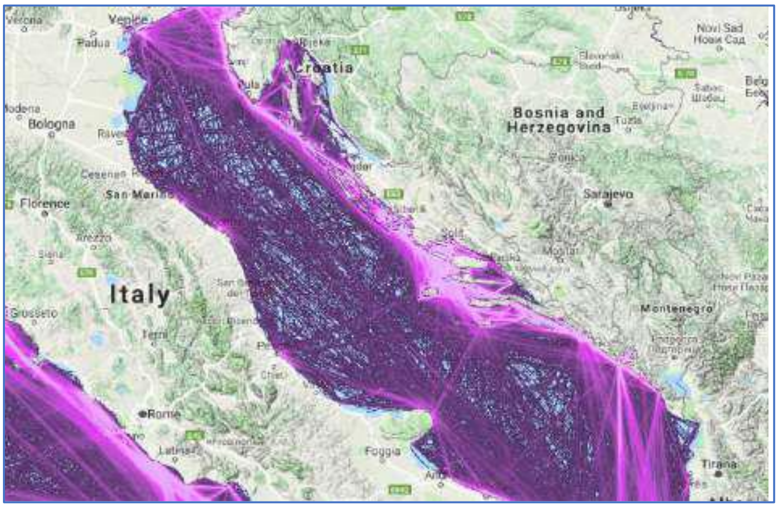

Figure 28 Pleasure crafts

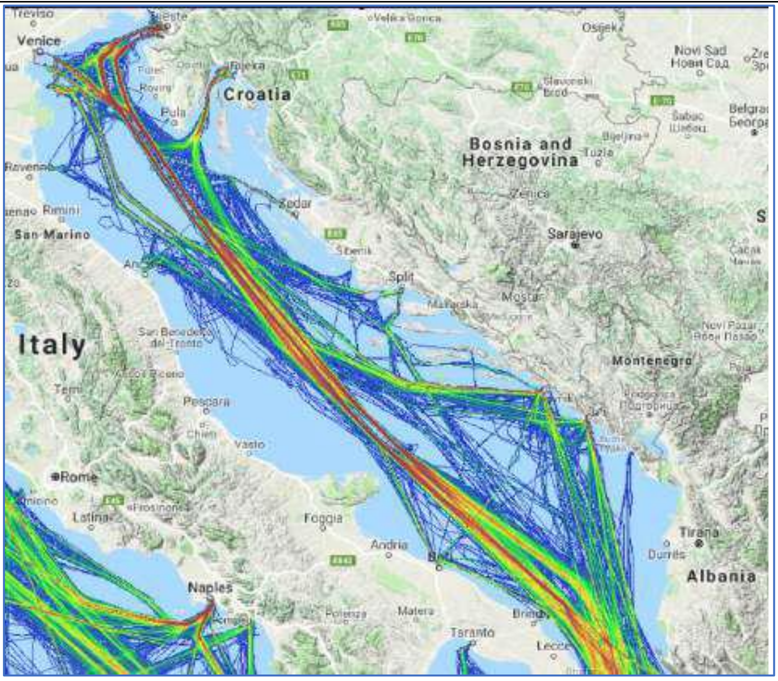

Figure 29 Ships larger than 60.000 GT

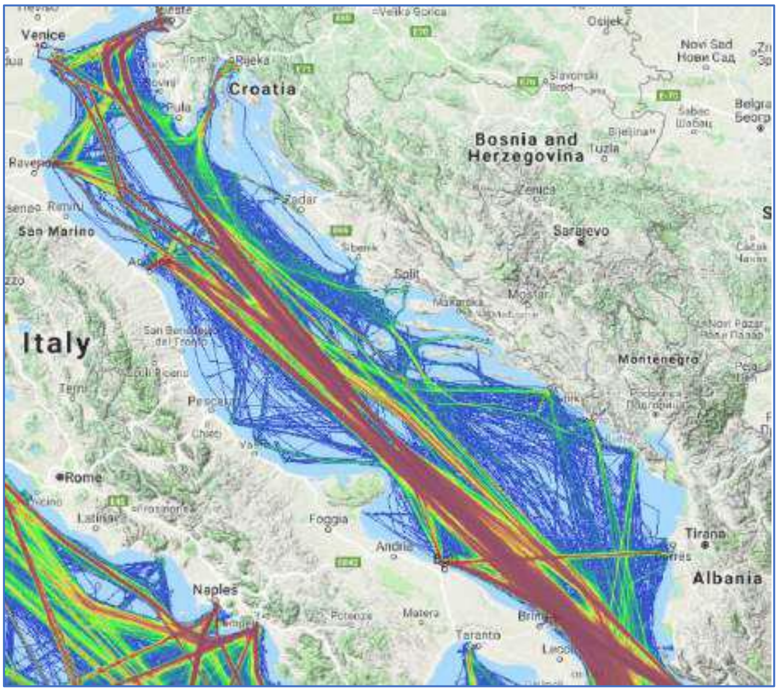

Figure 30 Ships sized between 25.000 and 60.000 GT

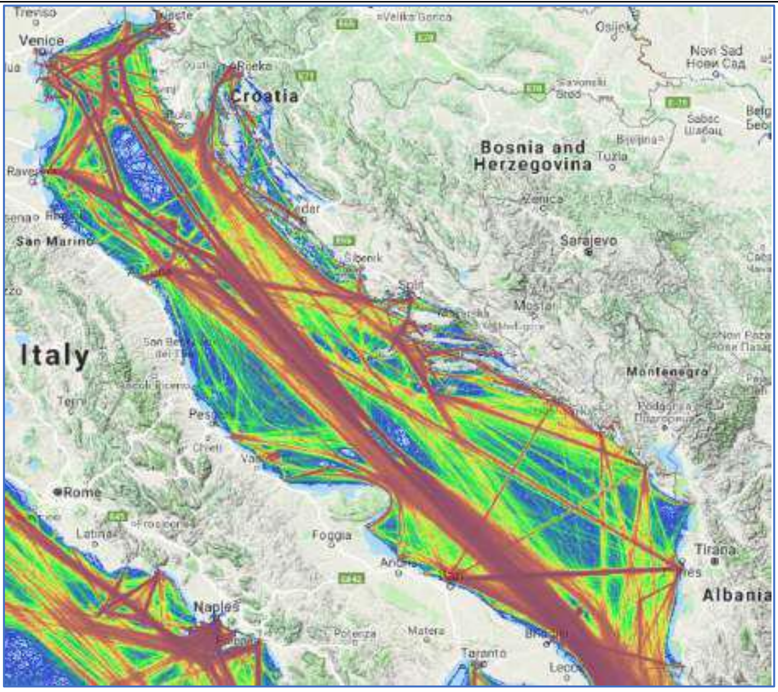

Figure 31 Ships sized between 5.000 and 25.000 GT

7.2. Risk assessment forms

HAZARD IDENTIFICATION

Route leg: ____

Hazard	Description	Location	Remarks
Natural	Safe minimum depth (m)		
	The proximity of danger (NM)		
	Tide, wind, wave and current effect		
	Ice conditions		
	Minimum visibility (NM)		
	Low sun issues		
	Background lighting		
	Loss of PNT[14] (geographical obstruction)		
	Earthquake and tsunami		
Economic	Insufficient AtoN funding issues		
	Legal action problems		
Technical	Shipborne navigational equipment failure		
	Quality and validity of charted information		
	Loss of vessel control		

14 Positioning, Navigation and Timing

	Loss of communications		
	Loss of connectivity		
	Cyber interference		
	Aids to Navigation failure		
	Loss of PNT		
	Substandard ships		
Human	Crew competency		
	Fatigue		
	Safety culture		
	Influence of alcohol and drugs		
	Availability and competency of VTS		
	Other AtoN provider competency		
	Availability and competency of pilotage		
	Piracy/terrorism		
	Political issues		
	Culture and language issues		
	Crew medical issues		
	Crew distractions		

Operational	Impact of smaller vessels		
	Fishing activities		
	Seasonal activities		
	Poor passage planning		
	Inadequate routeing guidance		
	Poor route monitoring		
	Poor promulgation of Maritime Safety Information (MSI)		
	Poor response to marking of new danger		
Maritime space	The existence of wrecks and new dangers		
	Crowded waterway issues		
	The existence of restricted areas		
Waterway complexity	Sharp bends		
	Narrow fairway		
	Manoeuvring space		
	Traffic considerations		
	Limited available depth of water		
	New or existing obstructions		
	Mobile seabed		

	Channel siltation		
Additional hazards			

SCENARIO no. __________

Scenario title ______________________________

Route leg & Position designation ______________________________

Hazard (cause & description) ______________________________

Initial consequences ______________________________

Ship type ____________ **Time** ____________

Ship length ____________ **Ship draught** ____________

Oil spilt (max tons) ____________ **Oil type** ____________

Wind (direction and speed) ____________ **Waves (direction and sea state)** ____________

Currents (direction and speed) ____________ **Sea temperature:** ____________

Weather outlooks ______________________________

Worst case consequences ____________ **RAM designation (1 – 6)** ________

Average case consequences ____________ **RAM designation (1 – 6)** ________

Likelihood (estimated) ____________ **RAM designation (1 – 6)** ________

Mitigation measures

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________
6. ______________________________

Additional remarks

____
____
____
____

RISK ASSESSMENT MATRIX

Likelihood	Consequence					
	Almost negligible	Minimal	Noticeable	Large	Extremely large	Catastrophic
Frequent	6	12	18	24	30	36
Occasional	5	10	15	20	25	30
Probable	4	8	12	16	20	24
Improbable	3	6	9	12	15	18
Rare	2	4	6	8	10	12
Remote	1	2	3	4	5	6

Low	A minimal likelihood that significant effects on the environment will happen.
Medium	A medium likelihood that significant effects on the environment will happen.
High	Significant effects on the environment are highly probable.

Extreme	Catastrophic effects on the environment are highly probable.

LIST OF MITIGATION MEASURES

	Hazard & Scenario no.	Mitigation measure – description and position	Effectiveness (%)	Responsible entity
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				

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