RESPONSE

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OpenRisk Guideline

for Regional Risk Management to Improve European Pollution Preparedness and Response at Sea

Response to spills

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Executive Summary

Effective risk management for pollution preparedness and response is an essential aspect for ensuring a clean marine environment, and other important interests of states, such as functioning power plants, tourism and fishery. In the European Union (EU), national authorities are responsible for managing the risks in their jurisdictions. In addition, regional cooperation initiatives have been established between EU member states and neighbouring states to improve pollution preparedness and response over larger sea areas. In context of these cooperation agreements, several regional risk assessment initiatives have been implemented, representing important milestones for establishing risk-informed pollution preparedness and response decision making processes.

Despite the progress made to date, several shortcomings have been identified in the existing practices in risk-informed decision making, including i) lack of transparency in the methodological basis of the tools used in the risk assessments, ii) lack of comparability of risk assessment results across geographical areas and over time, iii) high costs of implementing regional risk assessments, iv) challenges in implementing the risk assessment results, both at the member state and regional cooperation level, especially when different authorities are involved.

The OpenRisk project addresses the above shortcomings by focusing on two aspects of effective risk management: i) providing guidelines for implementing regional risk management for pollution preparedness and response authorities, and ii) providing a set of open-access risk analysis tools to facilitate transparency and comparability of risk assessment results.

In the first line of work, a coherent approach for regional pollution preparedness and response risk management is described, based on the widely applied ISO 31000:2018 standard. Starting from generic risk management principles, frameworks, and processes, OpenRisk focuses on defining a set of linked risk management processes applicable to different risk management contexts. These contexts differ in the objectives and types of envisaged decisions, the time frame and periodicity of implementation, and required resources. This work aims to provide guidelines for establishing decision making processes within and between authorities. In the second line of work, a set of existing and newly developed risk analysis tools are described, which are openly available. These tools focus on accidental risks of maritime transportation, and in particular on the risks of marine oil spills.

Ship in the ocean. © Pixabay (CC0 Creative Commons)

Background

Despite the increased focus on maritime safety, the risk of ship accidents and related spills remains a cause of concern in Europe and worldwide. On an intergovernmental level, these risks are addressed by two strands of interrelated work: safety of navigation (prevention of accidents) as well as preparedness to respond to maritime incidents (preparedness and response to incidents).

Whereas reducing the number of accidents is often considered the most cost-efficient option of risk mitigation, accident prevention is a complex issue involving the activities of many actors. Even though progress can be made by implementing preventive measures, a complete elimination of maritime accidents remains a utopian vision. Hence, effective preparedness and response to marine pollution remains an essential aspect of ensuring clean marine environments and other interest of states. This means that authorities will need to retain a sufficient level of response capacity. This sufficient level needs to be somehow defined, which includes decisions regarding the dimensioning of response resources, their placement, the mechanical response capacity (e.g. booms, skimmers and brushes to collect oil), application of dispersants (aircraft, vessels, dispersant types), and the degree of inter-reliance on resources of neighbouring countries, as well as sub-regional, regional and international resources.

Several authorities have indicated that traditionally, such decisions have been made based on a mix of common sense, institutional memory, practical hands-on knowledge of the national experts involved, as well as principles of existing commitments and regulations. However, there is a clear trend that during the recent decades, an increasing number of maritime authorities rely on risk assessment results, which provide a more comprehensive, transparent, and systematic basis for decision making concerning maritime risks. This is evident e.g. from the implementation of national [1] and regional risk assessments [2] in the Baltic Sea area, as well as from recent activities in the Arctic Council Working Group on Emergency Prevention, Preparedness and Response (EPPR), see [3]. Such trends can also be identified in the EU in the field of civil protection, where risk-informed decision making is an important element in disaster risk reduction policies [4].

The Amoco Cadiz, a very large crude carrier (VLCC), ran aground off the coast of Brittany, France on 16 March 1978, causing one of the largest oil spills ever from a ship. © NOAA (public domain)

Regional cooperation on preparedness and response

Major maritime accidents such as Torrey Canyon (1967), Piper Alpha (1976), Amoco Cadiz (1978), Erika (1999), and Deepwater Horizon (2010) have clearly shown that maritime oil spills can be well beyond the capacities of even the most well-equipped nation. Recognizing this, countries in Europe and worldwide have adopted a dense network of mutual aid agreements on responding to maritime incidents and accidents. These agreements may be bilateral or multilateral and cover various sizes of sea areas - from single bays to entire regional seas such as the Baltic Sea. This kind of cooperation is widely agreed as an effective way to optimize response activities by sharing both resources and best practices. Broadly, such agreements specify how to initiate joint response operations, what joint command and control procedures to execute, which assumptions to adopt, and how the financial dimensions are handled. Frequently, these agreements create also a regular cooperation framework with annual meetings, expert groups as well as joint exercises where joint approaches are practiced in live-like situations.

In the EU, regional agreements on pollution preparedness and response include the Helsinki Convention (www.helcom.fi) in the Baltic Sea, the Copenhagen Agreement, the Bonn Agreement (www.bonnagreement.org) in the North Sea, the Lisbon Agreement (www.dgpm.mm.gov.pt/lisbon-agreement) in the north-east Atlantic, the Barcelona Convention with the Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC) (www.rempec.org) in the Mediterranean Sea and the Bucharest Convention (www.blacksea-commission.org) in the Black Sea. EU-wide similar functions are provided by the European Maritime Safety Agency (EMSA) (www.emsa.europa.eu) and the Emergency Response Coordination Centre (ERCC) (erccportal.jrc.ec.europa.eu). Some countries are also part of the Agreement on Cooperation on Marine Oil Pollution Preparedness and Response in the Arctic.

From accident statistics to regional risk assessments

A traditional way to quantify maritime accident risks nationally and regionally is to collect accident data and to derive accident statistics from those. The results are then used as a basis for intergovernmental discussions on the need of joint measures. However, accident data can be misleading and commonly suffers from under-reporting and other biases. Statistics also lack the proactive, forward looking perspective, which is commonly desired when considering new measures. Another way is to share the results of national risk assessments with neighbouring countries. However, such risk assessments are often produced with very different methodologies and with the specific national context in mind. Hence, these are often difficult to combine into overviews of larger areas.

For achieving a common understanding on the likelihood of incidents, the adequacy of the joint response capacity and the need for improvements, several joint regional risk assessments have been carried out. Recent regional risk assessments in Europe include: HELCOM BRISK and BRISK-RU in the Baltic (2009-2012), BONN BE-AWARE I and II in the greater North Sea (2012-2014) and REMPEC MEDESS-4MS in the Mediterranean (2012-2015).

The successfully completed regional risk assessment initiatives represent a considerable investment in terms of funds as well as effort, expertise and time within national preparedness and response authorities and in their regional cooperation structures. However, despite the promise and successful implementation of national and regional risk assessments, the full benefits of a dynamic risk management are yet to be achieved. One issue is that the results of risk assessments are typically applicable only for a limited period of time, because the world changes constantly and new risks emerge. Another issue relates to the fact that national and regional risk assessments have also been largely one-off projects, implemented with heterogeneous, and partly undisclosed, methodologies.

Hence, past regional risk assessment activities are rarely comparable across time or space, causing difficulties in sharing results across borders. Another main limitation is that large investments lead to large time periods between assessments, so that the evolution of how the risks of maritime accidents and marine pollution develop over time and how efficient policy measures are, cannot be effectively monitored. Lack of full access to the details of the

Figure i.
EU Regional Pollution agreements on Pollution Preparedness and Response [6, 7, 8, 9, 10, 11, 12] *

*) The limits of the Lisbon Agreement geographical scope on this map have not been subjected to any validation on the part of the Lisbon Agreement Secretariat and are the sole responsibility of HELCOM.

risk analysis models makes it also sometimes difficult to justify the high costs of safety measures even within national decision making processes. These limitations are important reasons why risk-informed decision making is still more the exception than the rule in the maritime community. These issues are exacerbated in risk assessments covering maritime prevention and response, where preparedness and response authorities need to convince safety of navigation authorities about implementing certain risk reduction measures, or vice versa.

Considering the above, there is a great need for guidelines for implementing integrated risk management approaches in organizational practices. Similarly, there is a need for a coherent toolbox of jointly agreed risk analysis methods and tools to enable systematic and proactive risk assessment and management. Such jointly agreed baseline methods, if necessary, implemented with articulated national or regional adjustments, would be the first necessary step to use the full potential of risk assessments for pollution preparedness and response decision making. Such tools would enable systematic management of maritime risks nationally, regionally as well as EU-wide and even globally, to the degree desired by the involved countries.

OpenRisk: Aims and report structure

This OpenRisk project report serves two aims. First, a guideline is provided for implementing risk management in organizational processes of pollution preparedness and response authorities, based on the ISO 31000:2018 International Standard on Risk Management [5]. While these authorities are the primary end users, the guidelines can also be useful for other stakeholders, e.g. through communication and consultation processes. Second, the report outlines a toolbox of open-access methods for joint use in national and regional risk analyses, supporting the execution of the risk management processes.

The report is structured as follows. Chapter 1 provides a brief overview of the ISO 31000:2018 standard. In Chapter 2, the risk management processes for pollution preparedness and response are concretized, based on ISO 31000:2018, and an overview is given of the methods included in the OpenRisk toolbox. Finally, Chapter 3 presents the methods in more detail, outlining their aims and use, implementation basis, required inputs and obtained outputs, and how they are obtained in practice.

Response vessels in the Baltic Sea in icy conditions. © Jouko Pirttijärvi/SYKE

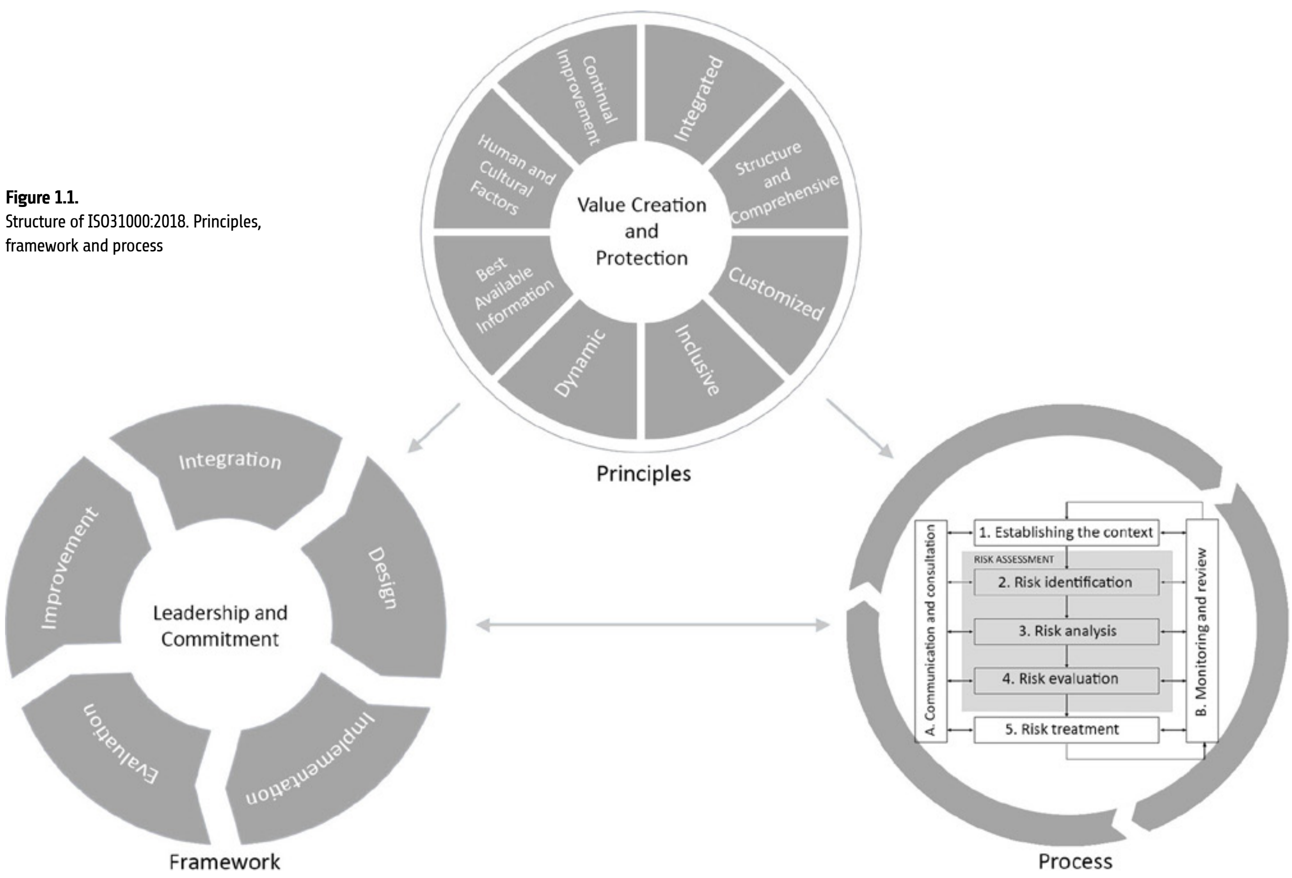
1. An Overview of Risk Management according to ISO 31000:2018

Risk management can be defined as 'the process of analysing, selecting, implementing, and evaluating actions to reduce risk' [1]. In other words, we can analyse and evaluate the activities which entail a risk of significant loss. Several generic standards and risk-based approaches are used, e.g. the Formal Safety Assessment (FSA) adopted by the International Maritime Organization (IMO) for supporting rule-making related to ship construction and design. IMO has also published a manual on oil spill risk evaluation and assessment [2]. This guideline provides a generic basis for assessing oil spill risk, adopting the idea of a tiered response. However, it does not focus on the implementation of risk management into organizational processes, and provides little guidance on which tools can be used for assessing risk for different decision purposes.

The guidelines presented here are based on the ISO 31000:2018 International Standard on Risk Management (here after referred to as ISO 31000:2018) [3]. This standard is selected as it is a collection of best practices, developed based on very extensive consultation and expert input. It is widely used in many industries, and is very flexible to account for specific organizational needs. It has been suggested in the context of strengthening the cooperation between different European states with respect to Pollution Preparedness and Response (PPR) [4], and also in the academic literature it has been found to be a suitable basis for supporting PPR risk management [5]. Furthermore, the need to strengthen the link between risk assessment and risk management, and to harmonize the terminology used, has been recognized in the Inter-Secretariat meetings with the Regional Agreements, and European Civil Protection and Humanitarian Aid Operations (DG ECHO) and the European Maritime Safety Agency (EMSA), as well as in the OpenRisk Workshops.

In order to understand the concept of risk management in ISO 31000:2018, it is important to consider three fundamental aspects: the **principles** underlying risk management (Section 1.1), the **framework** under which risk management is conducted in a given organizational setting (Section 1.2), and the generic risk management **process** (Section 1.3). These aspects are illustrated in Figure 1.1. The principles are underlying commitments, values and considerations which are commonly taken as best practices in risk management activities. The framework concerns how the risk management processes are embedded in a particular organizational setting, aimed to ensure that the results of the risk assessment are acted upon and that the appropriate resources, skills, and other boundary conditions are in place to facilitate risk-informed decision making. The process is a specific set of steps taken to define the scope and focus of the risk management questions, and to provide answers to these.

Figure 1.1.
Structure of ISO31000:2018. Principles, framework and process



1.1. Principles of Risk Management

ISO 31000:2018 defines eight core principles of risk management, aimed to create and protect value in line with the organization's objectives and mandate (Figure 1.1.1). These principles should be considered when developing the risk management framework and in executing the risk management processes. Accordingly, risk management is:

1. **Integrated**, i.e. it is part of all organizational activities;
2. **Structured and comprehensive**, aimed to lead to consistent and comparable results;
3. **Customized**, i.e. it is tailored and proportionate to the organization's context and objectives;
4. **Inclusive**, i.e. it involves internal and external stakeholders, to consider their knowledge and views, and to facilitate awareness and information;
5. **Dynamic**, i.e. it anticipates, detects, acknowledges and responds to changes in the organization's internal and external context;
6. **Based on the best available information**, i.e. historic and current information is used, and future expectations are considered, accounting also for associated limitations and uncertainties;
7. **Considerate of human and cultural factors**, as human behaviour and culture influence all aspects of risk management at each level and stage;
8. **Continuously improved**, through learning and experience.

In the remainder of this guideline, these general principles should be kept in mind. Recognizing the specific context of PPR authorities in different states - e.g. relating to the division of competences at the national level, the available resources, and commitments to different regional cooperation regimes - the principle that risk management processes should be customized to specific organizational needs is of central importance. In particular, the processes described in Section 2 provide an integrated approach to PPR risk management, along with a set of state-of-the-art open source tools which can be used to provide information in these processes, described in Section 3. Nevertheless, different PPR authorities may have good reasons to decide on using different tools or apply only some of the processes. It is, nevertheless, hoped that the guideline can support authorities in further developing risk management processes where this is necessary, and can facilitate harmonization of risk management practices especially with respect to regional cooperation activities.

1.2. Risk Management Framework

The risk management framework aims to assist the organization to integrate risk management into its activities and functions. This includes the design, implementation, evaluation, and improvement of risk management, customized to the needs of the organization. These components and their interrelations are illustrated in Figure 1.2.1, and are outlined next.

As a basis for the framework, the top management requires leadership and commitment to integrate risk management into the organizational activities, together with oversight bodies, as applicable. Top level managers should define the risk management policy, and align management objectives and strategies with this policy, whilst ensuring legal and regulatory compliance. Managers should also assign responsibilities within the organization and ensure that necessary resources are allocated for risk management. In addition, managers should ensure that the risk policy and processes are up-to-date. Lastly, managers should communicate the benefits of risk management to all stakeholders, and ensure that all stakeholders are adequately represented.

The integration of the risk management requires an understanding of the organizational structure and context, as risk is managed across the organization with shared responsibilities. The integration of risk management is dynamic and iterative, and should be part of the organizational purpose, governance, leadership, strategy, objectives, and operations.

The first step in the design of the risk management framework consists of attaining a thorough understanding of the organization and its context. This includes an analysis of internal and external stakeholder interests and influences. It also includes an analysis of legal, policy and regulatory influence which govern the organization – as well as an understanding of the mandate of the organization. The responsibilities and resources available within an organization should also be well defined.

The next step consists of articulating a risk management commitment by top managers and oversight bodies, through developing policies setting out the risk management objectives and commitments. This includes for example developing procedures for integrating risk management in work practices and decision-making, making resources available, and setting up systems for measuring and reporting.

Next, organizational roles, authorities, responsibilities, and accountabilities are assigned and communicated throughout the organization. The allocation of resources is another element in the design of the framework, including the skills and competences of people, implementation of methods and tools for risk management, and of information and knowledge management systems.

Finally, communication and consultation processes should be designed and integrated, to share information with target audiences, and receive feedback from relevant stakeholders.

Once the design is complete, the implementation of risk management within the organization should take place. This involves developing specific plans with linked resources (staff, tools, finances, time), identification of who, when, and how different decisions are made, and ensuring that the organizational risk management arrangements are understood and practiced. This also involves stakeholder engagement, as appropriate.

The evaluation of the risk management framework involves periodically measuring its performance against its purpose and implementation plans, determining whether it remains suitable to support the organizational objectives. Based on this, the improvement of the framework is performed. This involves adapting to internal and external changes, and continuously improving the framework and its integration throughout the organization.

1.3. The Risk Management Process: five stages and two parallel activities

The ISO 31000:2018 risk management process is comprised of a number of stages, as shown in Figure 1.3.1. There are five main stages in the generic risk management process: 1. establishing the context, 2. risk identification, 3. risk analysis, 4. risk evaluation, and 5. risk treatment. Steps ii) to iv), i.e. risk identification, analysis, and evaluation, are usually referred to as risk assessment, as indicated in the figure. In addition to these five stages, it is also important to

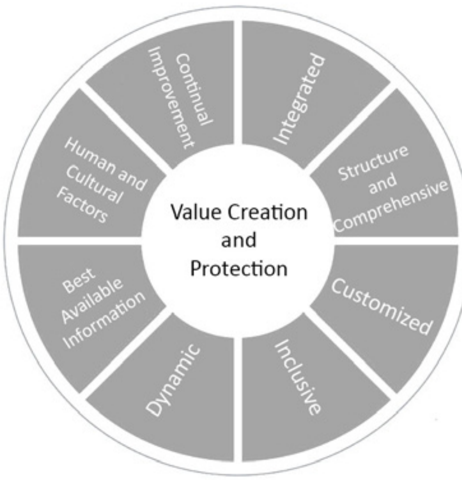


Figure 1.1.1.
Principles for Risk Management, based on ISO 31000:2018

Figure 1.2.1.
The Risk Management Framework, based on ISO 31000:2018

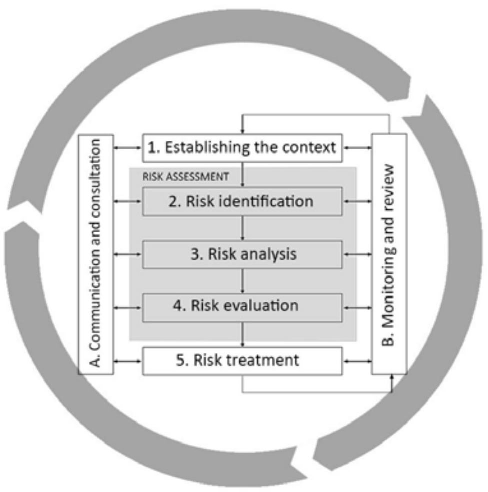


Figure 1.3.1.
The Risk Management Process as described by ISO 31000:2018

undertake two parallel activities: A) communication and consultation with relevant stakeholders, and B) monitoring and review of the adequacy of implementation of the five stages.

Stage 1: Establishing the context

It is of primary importance to set out the aims and objectives of the risk management. Stakeholders should be able to answer why they are conducting the process, what are the questions that require answers, what decisions need to be made, and what they hope to achieve.

To facilitate the further risk assessment, one must define the so-called limits of the system being assessed. Modern socio-technical systems are complex, with internal and external interactions between various components. The risk associated with one system can also influence the risk associated with other related systems. Given this, it may not be obvious where one system ends, and another begins. If the system limits are not clearly defined, the risk assessment process can thus be unfeasibly complicated and resource-intensive. Defining the system limits helps one to clearly identify the components and processes that need to be assessed. Indirectly, setting system limits can also help users to determine the sources and types of data that are needed for the assessment.

The timeframe of the risk management process should also be considered, as well as the required resources and expertise. Usually, the expended resources are proportional to the importance of the decision which needs to be made.

Another key aspect to consider when establishing the context is external stakeholders, and the extent to which these should be involved in the risk assessment process. A consideration of external stakeholders includes an assessment of the legal, regulatory, financial, and social factors which can influence the risk. External stakeholders also help to define key trends and drivers which can have an influence on the system under consideration. The perceptions of external stakeholders towards a system may also be considered.

Equally important when establishing the context is defining an internal context. This primarily concerns the overall objectives and aims of an organization, which may have a profound impact on the risk management process. Governance strategies, role and responsibilities, reporting guidelines should be understood during this step. The internal context also involves an understanding of the capabilities of the persons who will conduct the risk identification and analysis, as well their knowledge and skills, and possible training needs.

When commencing a risk management process, it is common to set out certain risk-acceptance criteria or decision making principles, and to formulate objective procedures for reaching consensus in the risk evaluation phase. This is necessary because different individuals may have different perceptions of risk, and varying acceptance of undesirable events. In formulating the risk evaluation process, it is important to define how the risk analysis is reported based on the adopted tools (qualitative or quantitative), how the risk level is determined, and which decision criteria are used.

Stage 2: Risk Identification

In step 2 of the risk management process, users need to establish what risks can arise in a system or process. Thus, after establishing the context, the hazards, possible failures and unwanted events associated with the system or activity are identified.

Evidence is vital in order to successfully identify risks. This evidence usually comes from a variety of sources, such as databases of past incidents or accidents, models and simulations. Risk identification often also involves expert judgement of knowledgeable stakeholders.

Accident investigations can provide an important 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 to gain insights in failure processes, and in 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 particular cases cannot necessarily be generalized 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 exactly the same system or activity under consideration, relevant data from an equivalent system may serve as a good starting point to delineate possible hazards and failure mechanisms.

Risks can also be identified through expert judgment and stakeholder consultation, or through such means as simulator trials. Simulations are particularly useful when the system or process being analysed is particularly novel.

Stage 3: Risk Analysis

Not all the identified risks may be of concern to decision makers and stakeholders. Some combinations of hazard and failures may present an almost negligible risk to a system, either by having a low occurrence probability, low consequence severity, or both. In the risk analysis stage, users determine why and how risks arise, and their impacts both internally and externally to 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.'

In other words, the risk analysis stage is used to determine the relative probability and consequences of the identified risks. The collection of adequate evidence (data from various sources, expert judgment, models or simulation results) is vital for this stage, as well as awareness of the limitations of the available evidence, similarly as in the risk identification stage.

Considering the principles underlying risk management introduced in Section 1.1, and especially the explicit assessment of uncertainty, risk analysis consist of four steps:

Step 1. Estimating the probability of the event occurrence;
Step 2. Estimating the severity of the consequences in case of event occurrence;
Step 3. Assessing the strength of the evidence for the probability and consequence estimation;
Step 4. Combining probability, consequence, and strength of evidence in a risk scale.

In some applications, step 3. can be omitted if the evidence is overall considered to be strong, but in contemporary risk analysis, it is commonly included [6].

It is also occasionally possible to skip either steps 1 or 2, if the probability or consequences of certain risks are below a certain threshold. The ISO 31000:2018 guideline states that if either the consequences of a risk are likely to be insignificant, or its probability is expected to be extremely low, end-users may use a single parameter to decide on whether or not to treat that particular risk, and how to go about doing so.

Step 1. Estimating the probability of the event occurrence

If a risk analysis tool allows quantification of the occurrence probability, the assessor can calculate the frequency or probability (P) of undesirable events. This often relies on past system and accident data, and modelling techniques. To calculate the probability of undesirable events, the failure rate of various individual system components (human and technical) in hazardous environments can be determined and aggregated over a set of failure scenarios.

For probability estimation, it is not necessary that a quantity-oriented tool is used. Instead, some tools rely on qualitative scales which indicate the relative likelihood of occurrence of particular events. This is usually based on stakeholder consultation or expert judgment.

Step 2. Estimating the severity of the consequences in case of event occurrence

The determination of the consequence severity (C) of undesirable events can be based on different evidence types, including accident data, stakeholder consultations and expert judgements, and model-based simulations. Understanding the underlying sources of the hazards, possibly considering the system's ability to mitigate the effects of the event occurrence, allows an estimation of the consequence severity. The estimation can be on a qualitative scale or using a quantitative numeral.

Step 3. Assessing the strength of the evidence for the probability and consequence estimation

Two generic principles underlying risk management is that the analyses are based on the best available information, and that uncertainties are explicitly considered, see Section 1.1. Due to possible inherent limitations of the data, the simplifications in the models, or possible disagreements between experts or stakeholders, this means that it is important to carefully consider how good the evidence is for making the probability and consequence estimations. This also considers the appropriateness of the assumptions made in the probability and consequence estimation. This process is known as assessing the strength of evidence, for which several methods have been proposed.

Step 4. Combining probability, consequence, and strength of evidence in a risk scale

In the application of some risk analysis tools, and for some risk management processes, a further sub-step is performed to combine the ratings of probability (P) and consequences (C) obtained in sub-steps 3.1 and 3.2 to attain an overall risk value. There are different ways in which the overall risk value for hazardous events is obtained in practice. Tools for supporting analysis methods may:

- Directly assign a combined risk rating as the result of an integrated calculation method;
- Assign a combined risk rating as the result of the judgment(s) of (an) assessor(s) based on specific evidence using a particular tool;
- Assign a risk rating based on the judgment(s) of (an) assessor(s) based on specific evidence obtained using different tools, e.g. one for building scenarios and their probabilities, and another one for estimating the severity of the consequences.

The strength of evidence assessment, which should also be part of the risk analysis, can be combined as well in the risk rating, or left as a separate assessment, depending on which method is used.

Modern risk analysis tools enable the calculation of the probabilities and consequences in an increasingly integrated manner. Nevertheless, it is important to differentiate between these two components when deciding on risk control options, as well as appropriately considering the strength of evidence underlying the analysis (see Stage 5).

There is a need to display the risk information, so that the different risk events can be visually compared. Some risk analysis tools can display the risk information spatially, i.e. on maps of where the risks have their effects. A common generic tool is the use of risk matrices, or more generally probability-consequence diagrams. Such diagrams can be used to integrate the information about the different risk events (probabilities, consequences, and corresponding strength of evidence) in one graph, which can then be used as a basis for the risk evaluation stage (Stage 4).

Stage 4: Risk Evaluation

Following the risk analysis process, one can evaluate whether the risk values are acceptable or not, whether risk control options would need to be implemented, and which ones. To do so, 'acceptable' or 'routine' levels of risk can be determined as part of the establishment of the context in Stage 1. One simple but often applied criterion for implementing risk control accounts for the number of exposures of the hazardous event. If, for instance, a certain barrier is tested daily and seems to be working, it should be ensured that this will also be the case in the future. For barriers which are tested on an infrequent or ad hoc basis and fail the test, corrective actions should be implemented.

Another method to support risk evaluation and decision making is the use of risk metrics, which can be used to determine whether the risk falls within these acceptable levels or not [7]. One example where (especially quantitative) risk metrics are important, is in the application of the ALARP principle, which denotes that the system risks should be made "as low as reasonably practicable". Thus, in cases where the risks are not acceptably low, new risk control options should be implemented, unless it can be demonstrated that the costs involved are disproportionally high compared to the risk-reduction effects. This principle is often applied in practice in such a way that risk control measures are implemented even if risks are low, if the risk control option can be easily implemented at low costs. Another criterion-based method, used especially in risk management decision making where major investments are considered, is Cost-Benefit Analysis (CBA). In this method, the relative risk reducing effects and the associated costs are determined for each risk control option, which allows decision makers to select the most feasible option.

An approach strongly supported by the ISO 31000:2018 standard, useful especially for processes and tools which allow risk estimation over several relatively short time periods, is to 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 found, or sustained incremental changes over an extended time period, this may be taken as a sign that additional risk treatment is warranted.

In contemporary risk management approaches, it is recommended to evaluate the risks and determine the appropriate further actions in a managerial review process [6], or in an analytic-deliberative process [8]. The managerial review means that the results of the risk analysis are presented to a (group of) decision maker(s) and considered along with other decision-relevant information. This can include the costs of the risk treatment options, social factors such as creation or loss of employment, or other legal, political, or cultural factors. The decisions are made on a risk-informed basis, following a discussion. There may be justified reasons to consider other issues than costs when selecting which risk control options to implement in practice, such as previous experience with similar systems, the maintainability of the new system elements, or the preferences of decision makers or stakeholders. It is also essential to carefully consider the legal constraints regarding the risk control options, as often the locus of control of making certain modifications to system designs or operational procedures is under the authority of another actor or stakeholder in the system. The analytic-deliberative process is similar, but the additional stakeholders can voice their concerns in the decision making process, and are typically also more closely involved in the risk identification and analysis stages.

Stage 5: Risk Treatment

If, after Stage 4, the risk level is deemed to be too high or unacceptable, appropriate risk control and mitigation measures should be implemented. The purpose of these measures is to reduce either the probability or the consequences of undesirable events, and as such, they are examples of 'barriers'. At this stage, it is also important to ensure that new risk control and mitigation measures do not lead to the emergence of new hazards, or at least that those new hazards are appropriately managed.

There are several principles underlying the risk control options, and it should be decided on a case-by-case basis, using the results of a sufficiently thorough risk assessment, which options are to be implemented. Approaches for risk control include the elimination of the hazard through inherent safe design (e.g. segregated ballast tanks), risk reduction through implementing safety devices (e.g. technologies for ships collision avoidance), warning devices (e.g. alarms), or procedures and training (e.g. oil response coordination exercises).

It is imperative that the risk evaluation stage (Stage 4) is appropriately linked to the organizational decision making processes of the risk management framework, to ensure that the results of the risk analysis stage are actually used, and that the selected risk treatment options are actually implemented (Stage 5). It is also imperative to carefully consider who is responsible for implementing, operating, and maintaining the risk control options, and this should be linked to communication and consultation processes as appropriate.

Parallel Activity A: Communication and consultation

Good communication and consultation is usually crucial for effective risk management. As shown in Figure 1.3.1, ISO 31000:2018 indicates that stakeholders may have an important role in all stages of the risk management process. Understanding the needs, interests, and influence of stakeholders, including their risk perceptions, and their legal and social context, can greatly affect the effectiveness of the definition of the context, the risk assessment, and risk treatment. Stakeholder communication and consultation is often also critical in sourcing funding for risk control options.

It is rather common that certain risk analysis techniques produce information and lead to risk assessment findings where other actors have the authority to implement changes in the system. This is especially the case in large-scale, distributed systems where legal and operational responsibilities are divided between private actors and public authorities. In such cases, communicating the findings to relevant actors should be appropriately considered. Risk matrices and probability-consequence diagrams are often applied in risk communication activities, for decision makers and stakeholders to obtain a common understanding of the relevant risks. Depending on the application, also maps displaying the risk levels over spatial areas, or diagrams showing the evolution over time, are used.

Parallel Activity B: Monitoring and review

Monitoring and review in the risk management process is another important parallel activity, which cuts across the various risk management stages. Focusing on the implementation of an ongoing risk management process, quality management activities ensure that the information processed in the five stages is adequately utilized to establish the context, perform the risk assessment, and implement appropriate risk control options. Such monitoring and review is critical to ensure high-quality, timeliness, and useful risk assessment for making good risk management decisions. This monitoring also concerns the consultations and communication with the stakeholders.

Another aspect of the monitoring and review activity addresses the fact that systems, as well as the nature of the activities and processes within the system, and their environment, change over time. It is, therefore, vital that risk management is up-to-date, which requires a periodic re-evaluation of the adequacy of the applied tools and information sources. This aspect aligns with the continuous improvement of the overall risk management framework, see Section 1.2.

Deploying booms in the Baltic Sea © Jouko Pirttijärvi/SYKE

2. Risk Management Processes for Pollution Preparedness and Response

The generic risk management process described in Section 1.3 is adapted to risk management activities for Pollution Preparedness and Response (PPR), focusing on the risks of marine oil pollution, primarily those caused by maritime transport accidents. Recognizing a variety of reasons for executing a given risk management process, the types of envisaged decisions, and the available resources, three PPR risk management processes are distinguished: screening, intermittent, and strategic.

In the light of the different decision contexts, these processes have different risk identification, risk analysis, and risk evaluation tools associated with them. An overview of the three processes is given in Section 2.1. In Section 2.2., a number of characteristics of the processes are listed, to further facilitate understanding the distinction between them. This section also outlines how these processes can be linked to one another. In Section 2.3., the OpenRisk Toolbox is introduced. This is a set of open-source methods and tools which can be used as part of the different PPR risk management processes. This section also outlines some characteristics of these tools, and provides insight which tools are intended for which processes.

2.1. PPR Risk Management Processes: Overview

2.1.1 Different decision contexts as a basis for distinguishing three PPR risk management processes

As shown in Figure 1.3.1, all risk management processes are embedded in an external and an internal context, which drive the kind of risks to be addressed and the decisions which need to be made, while setting objectives, policies, information flows, and decision making processes, subject to choices on adopted risk assessment methodologies and constraints on the available resources.

The external context consists of legal, economic, social, and technical aspects. The legal context consists of the rights and responsibilities set by the applicable legal instruments related to pollution preparedness and response, e.g. the Convention on Oil Pollution Preparedness, Response and Co-operation (OPRC 1990). The economic context concerns for instance the development of new oil terminals in a given sea area. The social context for instance considers issues related to the perceptions by stakeholders (e.g. the general public), which e.g. may voice concerns about pollution preparedness in a given sea area in the wake of a recent oil pollution incident elsewhere, following media reports. The technical context concerns, e.g. engineering developments in the maritime transportation system, e.g. changes in vessel structural design or in the autonomous operation of certain vessel types, or the increasing sizes of container vessels.

The internal context consists of the organizational characteristics relevant to the execution of the risk management processes. This includes the overall organizational objectives and strategies, the capabilities in terms of the resources and knowledge, policies and applicable standards, management structures, information flows, and decision making processes. The risk management framework described in Section 1.2 embodies these elements of the internal context in an operationally useful set of processes, which support the executing and utilization of the risk management processes.

Within the external and internal contexts, depending on the types of risk related decisions which need to be made, three different processes are defined: screening, intermittent, and strategic risk management processes. In the screening risk management process, the main purpose is to monitor the risk levels and/or to anticipate future emerging risks, and the decision-making focuses on whether there is a need to perform more elaborate risk management activities to guide what needs to be changed. In the intermittent risk management process, the risks are investigated more in-depth, facilitating decisions on (relatively minor) adjustments to the maritime transportation and/or the pollution response system to mitigate the risks. In the strategic risk management process, all relevant marine risks are considered in a holistic manner, facilitating decision-making related to major long-term investments in the maritime transportation and/or the pollution response system.

Each process requires the establishment of a defined context in terms of a defined set of accountabilities and responsibilities, specifications of which activities are executed, over what time frame and with what resources, and how these relate to other organizational processes. The utilized risk assessment methods and tools are defined, as well as the scope of the analyses, and the principles and/or criteria used in decision making. For the preliminary, intermittent, and strategic risk management processes, all these procedural characteristics can be very different.

2.1.2 Screening risk management process

The screening risk management process aims to monitor the risks in a given sea area, in order to determine whether there are significant changes in the risk level of maritime transportation activities. Hence, this process essentially focuses on whether, based on the risks of the maritime transportation system, further risk management activities are required (i.e. the intermittent or strategic risk management process), or whether the risks are considered acceptable and no additional action is needed. In other words, the risk treatment consists of three options: i) business as usual (no particular further action), ii) execution of the intermittent risk management process, or iii) execution of the strategic risk management process.

To facilitate monitoring and detection of changes in risk levels, the basic screening risk management process requires relatively short time intervals in the risk identification and analysis stages (e.g. variations in risks over months or one year). Tools and procedures in this process should require only small commitments in terms of organizational resources, and hence are driven by historic data sources which are analysed in a highly automated manner. The risk evaluation and treatment can be done, e.g. on an annual basis, e.g. in conjunction with already existing coordination meetings, which also limits the resource commitments. The outcome of the basic screening process is a decision whether or not to execute a further risk management process, in particular the intermittent risk management process. In exceptional cases (e.g. if sudden large changes in risk levels occur, or if continued risk increments over an extended period are observed), also the strategic risk management process can be executed.

This basic process can be extended to also consider if current or future technical, social, economic, or legal developments affect the maritime transportation system so that new and emerging risks associated with those changes need further consideration in terms of pollution preparedness and response planning. Also significant changes to the response system (e.g. decommissioning of certain response vessels, new legal requirements) can be considered in this extended screening risk management process. Such an extended screening process requires more resources as it should account for a wider information and knowledge base, to obtain a more thorough understanding of the external and internal context with relevance to PPR activities. While it is important to anticipate such system changes, the frequency of performing this extended screening process can be lower than the basic screening, e.g. in cycles of a few years or in conjunction with more high-level regional coordination meetings.

2.1.3 Intermittent risk management process

The intermittent risk management process aims to analyse certain risks in more detail, to support medium-term decision making related to the capacity and organization of the current response fleet in the light of the maritime oil pollution risks (focus on preparedness), and to assess the performance of the response system (focus on response). Decisions concerning the PPR activities focus on relatively small adjustments to the organization of the current response system, e.g. reviewing/updating operational or training procedures. Such decisions require relatively limited resources, typically within already available organizational budgets.

This intermittent process thus focuses on gaining a better understanding of the risks in the maritime transportation system from a pollution preparedness viewpoint, i.e. the likelihood of different accident scenarios in various marine areas, and the severity of their consequences in terms of oil outflow, oil drift, and ecosystem impacts. Other tools can be used to analyse the operational performance of the response operations, e.g. focusing on the adequacy of procedures (e.g. communication lines, authorizations), and organizational capabilities (e.g. training, human resources). Combining the information of these marine risks with the available response resources gives a basis for decision making concerning risk treatment for pollution preparedness and response.

The risk identification and analysis stages rely on a set of tools which require somewhat more resources and skills than in the screening risk management processes, but significantly less than in the strategic risk management process. This process is intended to be conducted only if so decided in the risk evaluation stage of the screening process, but can also be executed on an ad hoc basis.

Response vessel in the Baltic Sea in icy conditions. © Jouko Pirttijärvi/SYKE

2.1.4 Strategic risk management process

The strategic risk management process aims to obtain an overall picture of all marine oil pollution risks, to support long-term decision making related to the capacity and organization of the response fleet in the light of the maritime oil pollution risks (focus on preparedness), and to assess the performance of the response system (focus on response). Decisions concerning the PPR activities can have more far-reaching implications to the response fleet or operational procedures (e.g. commissioning of new response vessels, new equipment types). As the related decisions have long-term impacts, it may be advisable to extend the analysis scope to include other stakeholders in maritime risk management (Maritime Administrations, Vessel Traffic Services, etc.). Depending on the findings of the extended screening risk management process, the scope of pollution preparedness and response can be extended to pollution prevention, preparedness, and response. This can, e.g. consider the need for structural investments necessary to prevent unwanted events from occurring (e.g. new technologies for traffic monitoring and routing) or operational changes (e.g. changes to vessel reporting schemes).

The strategic risk management process is resource intensive, requiring specific technical skills which would typically be commissioned from external consultants, and hence is performed infrequently. This process is intended to be conducted only if so decided in the risk evaluation stage of the extended screening process, but can also be executed on an ad hoc basis.

2.2. PPR Risk Management Processes: Characteristics and Interdependencies

A summary of some essential characteristics of the screening, intermittent and strategic risk management processes is given in Table 2.2.1 to Table 2.2.3, in order to make the differences between the different decision contexts clear.

How exactly these processes are implemented in the overall risk management frameworks of different PPR authorities is beyond the scope of these guidelines, but some tentative suggestions are considered useful as a basis for further reflection and discussion. The basic screening processes could be implemented within organizational practices of PPR authorities and the processes executed by its staff, or at the level of regional response secretariats. The intermittent process, which focuses on more specific sea areas, could be implemented within organizational processes of PPR authorities, and either be executed by its staff or by external consultants. In some cases, bilateral or sub-regional collaborations may be useful. The strategic process, which needs additional high resources, could be undertaken either as a national project, or through an international collaborative project, and would usually require the involvement of an external consultant to execute the analysis. In collaborative projects, proper planning and commitment of all involved parties are prerequisites for useful outcomes.

Figure 2.2.1 illustrates how the processes can be linked to one another. The basic and extended screening processes are periodically and continuously executed, with different frequencies. Depending on the outcome of the risk evaluation in these processes, the risk treatment consists of executing an intermittent or a strategic risk management process, or only keeping monitoring the risks through the basic screening process. In contrast, in the intermittent and strategic risk management processes, the risk treatment consists of making actual modifications in the maritime transportation system, or in the pollution response system.

Table 2.2.1.
Characteristics of the PPR Risk Management Processes: Screening

Screening risk management process *Basic screening*	
Aim and purpose	Monitoring the evolution of risk levels of shipping activities in sea areas based on historic data
Type of decisions	Determining whether or not further risk management processes (typically extended screening or intermittent, possibly also strategic) need to be executed
Periodicity	Periodic and relatively frequent, e.g. annually or in conjunction with planned regional coordination meetings between PPR authorities
Decision makers	Pollution Preparedness and Response authorities
Typical stakeholders	Regional response secretariats, maritime administrations
Required resources	Low: analysis of historic data can be automated, reporting requires little effort, so very limited financial and staff commitment is needed
Required competences	Low: familiarity with setting up the tool and how to interpret it is needed
Screening risk management process *Extended screening*	
Aim and purpose	Anticipating the evolution of risk levels of shipping activities in sea areas based on the evolution of historic risk levels, as well as by systematically investigating changes in the external and internal context which may lead to future changes in risk levels, or lead to new and emerging risks
Type of decisions	Determining whether or not further risk management processes (typically strategic, possibly also intermittent) need to be executed
Periodicity	Periodic but relatively infrequent, e.g. every three to five years, or ad hoc depending on the findings of the basic screening process
Decision makers	Pollution Preparedness and Response authorities
Typical stakeholders	Regional response secretariats, maritime administrations, vessel traffic services, shipping companies, seafarers representations, pilot organizations, maritime industry cluster, voluntary response organizations
Required resources	Medium: analysis of historic data can be automated, but the systematic stakeholder consultation processes, especially the risk identification and analysis, require moderate resource commitments (time, funds, personnel). Reporting is more extensive
Required competences	Low-Medium: experience with the stakeholder consultation process and running the corresponding workshops is needed

Table 2.2.2.
Characteristics of the PPR Risk Management Processes: Intermittent

Intermittent risk management process	
Aim and purpose	Understanding the pollution risks of shipping activities in sea areas, i.e. where what kinds of accidents are likely to happen, what would be the possible oil spills from those, where spills would drift to, what effects those would have to marine and coastal areas, and how effective the response is to those risks.
Type of decisions	Determining whether adjustments in the preparedness planning and/or response organization is needed, typically limited to relatively small adjustments to the fleet or operational procedures, within already available budgets.
Periodicity	Ad hoc, based on the outcome of the screening risk management process.
Decision makers	Pollution Preparedness and Response authorities
Typical stakeholders	Regional response secretariats, maritime administrations, vessel traffic services, voluntary response organizations
Required resources	Medium: some tools allow a certain level of automation, and while most tools require little resource commitment, the value of the process comes from applying several tools in sequence. Information gathering and processing requires moderate resources commitments (time, funds, personnel). Reporting is more extensive.
Required competences	Medium: experience with the toolbox for the intermittent process is required, in terms of execution and interpretation

Table 2.2.3.
Characteristics of the PPR Risk Management Processes: Strategic

Strategic risk management process	
Aim and purpose	Obtaining a holistic understanding the pollution risks of shipping and other ma-rine activities in sea areas, i.e. where what kinds of accidents are likely to happen, what would be the possible oil spills from those, where spills would drift to, what effects those would have to marine and coastal areas, and how effective the response is to those risks.
Type of decisions	Determining whether changes in preparedness planning, response organization and/or traffic organization, are needed in light of risks, typically associated with major developments in the maritime transportation system. These changes may include large-scale investments in infrastructure or equipment, with possibly very large funding requirements, exceeding available operational budgets.
Periodicity	Ad hoc, based on the outcome of the screening risk management process (typically the extended screening process).
Decision makers	Pollution Preparedness and Response authorities, maritime administrations, ministries
Typical stakeholders	Regional response secretariats, vessel traffic services, shipping companies, seafarers representations, pilot organizations, maritime industry cluster, voluntary response organizations
Required resources	High: all risk management stages require relatively high resources (time, funds, personnel), especially the establishment of the context, the risk analysis and the cost-benefit analysis. A lot of data needs to be gathered from various sources, extensive expert consultations may be needed, and often many simulations us-ing several models need to be performed and integrated. Extensive reporting is needed.
Required competences	High: specialized knowledge of and expertise with risk analysis tools and pro-cesses are needed; typically this process is executed by external consultants.

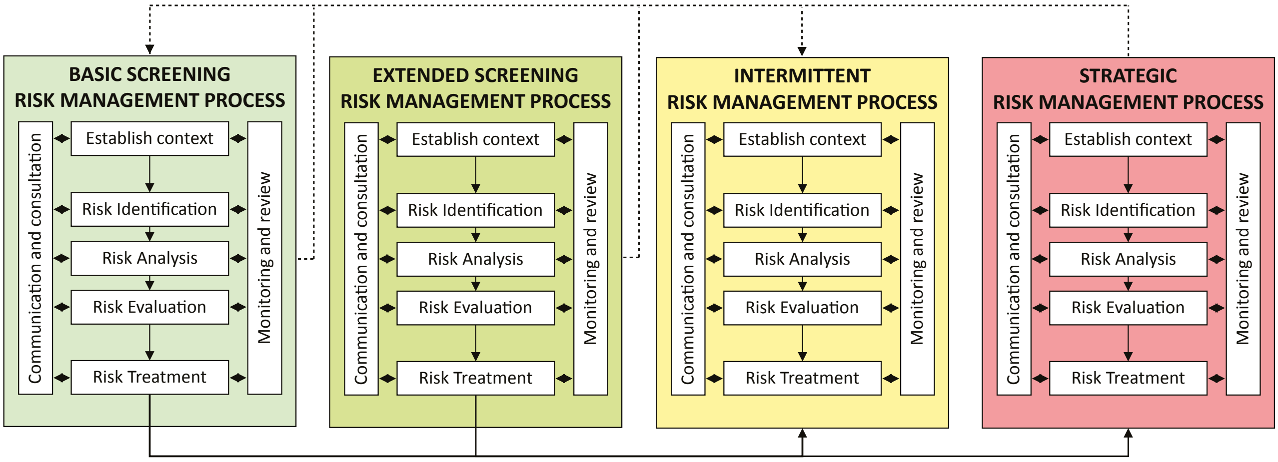


Figure 2.2.1.
Relations between the PPR risk management processes

2.3. Tools in support of PPR risk management processes: Overview of the OpenRisk Toolbox

For supporting the PPR risk management processes defined in Section 2.1 and Section 2.2, a set of techniques, models, and tools is available, known as the OpenRisk Toolbox. The toolbox is populated with several methods which are freely available to PPR authorities, many of which have a proven track record in maritime risk management. This includes for instance the Ports and Waterways Safety Assessment (PAWSA) and the IALA[1] Waterway Risk Assessment Programme (IWRAP Mk II) risk management toolbox [1], SeaTrack Web which is the system recommended by HELCOM for tracking oil drift in the sea area, and the set of tools used in well-known sub-regional risk assessments [2]. Other tools are more generic, e.g. Bow-Tie or Cost-Benefit Analysis, are used for many activities in different industries, and are recommended in the ISO 31010:2009 standard on risk assessment techniques. Some tools have been specifically developed in the OpenRisk project, given the lack of open access methods for supporting decisions in some PPR risk management processes, e.g. the MarinRisk tool, the Maritime Event Risk Classification Method and the Accidental Damage and Spill Assessment Model for Collision and Grounding.

While the OpenRisk Toolbox contains a comprehensive set of tools and approaches, the principle that risk management should be tailored to organizational needs and requirements also applies here. Other methods and tools exist, and PPR authorities may have reasons to use other tools instead.

Table 2.2.4 provides an overview of the tools and techniques currently included in the OpenRisk Toolbox, focusing on the purpose and knowledge generated by applying the tool. Figure 2.2.2 to Figure 2.2.5 give insight into the applicability of the tools in terms of the different PPR risk management processes, and the stages of a risk assessment. Finally, Table 2.2.5 provides information about some attributes of the tools which are important in the context of planning which tools to use in a given organization. These attributes include the required resources and capabilities for using the tool, the tool's complexity, and whether the tool provides quantitative or qualitative risk information.

1 IALA: International Association of Marine Aids to Navigation and Lighthouse Authorities

Table 2.2.4.
OpenRisk Toolbox: Purpose and knowledge generated by application of the tools

#	Tool ID	Name	Risk management questions
1	**AISyRisk**	AISyRisk	— Where are the historic accident risks in the sea area? — How do the risks develop over time?
2	**MarinRisk**	Marin Risk Index	— Where are the historic accident risks in the sea area? — How do the risks develop over time?
3	**Delphi**	Delphi Method	— What kinds of future hazards should be considered? — What are the associated risk levels?
4	**RiskData Hub**	RiskData Hub	— Where are the historic accident risks in the sea area? — How do the risks develop over time?
5	**IWRAP Mk II**	IALA Waterway Risk Assessment Programme	— What is the accident likelihood in different sea areas? — What accident scenarios are likely? — What is the effect of different risk control options on the risk level?
6	**PAWSA**	Ports and Waterways Safety Assessment	— How important are different waterway factors as contributors to risk? — What is the effect of risk control options on the risk level?
7	**ERC-M**	Maritime Event Risk Classification Method	— What kinds of hazards occur in the sea area? — What is the risk level in different sea areas? — What accident scenarios are likely? — Which issues are contributing factors to the event occurrence?
8	**ADSAM-C/G**	Accidental Damage and Spill Assessment Model for Collision & Grounding	— What size of oil spills can occur in a collision or grounding accident?
9	**SeaTrack Web**	SeaTrack Web	— Where does the oil drift to in the sea area?
10	**NG-SRW**	Next Generation SmartResponse Web	— What size of oil spills can occur in a collision or grounding accident? — Where does the oil drift to in the sea area? — What are the consequences to the ecosystem and human use of marine space?
11	**ERSP Calculator** **EBSP Calculator** **EDSP Calculator**	Response System Planning Calculators	— What is the potential of the response system to recover, burn, or disperse the spilled oil?
12	**BowTie**	BowTie Method	— Which factors contribute to the event occurrence and/or its consequences? — What is the effectiveness of different controls to mitigate risks?
13	**FRAM**	Functional Resonance Analysis Method	— Which system functions are responsible for the variation in the system performance?
14	**KPIs**	Key Performance Indicators	— How important are different system indicators in regards event occurrence and/or consequences? — What is the performance of different system elements compared to target levels?
15	**SBOSRT**	Spatial Bayesian Oil Spill Risk Tool	— What are the oil spill risks in the sea area? — What is the extent of ecological damage in different oil spill risk scenarios?
16	**ISRAM**	Integrated Strategic Risk Analysis Methods	— What are the oil spill risks in the sea area? — What size of spills can occur? — Where does the oil spill drift to in the sea area? — What are the consequences to the ecosystem and human use of marine space? — What is the effect of different risk control options on the risk level?
17	**SoE**	Strength of Evidence Assessment Schemes	— How much can the results of the risk analysis be relied on? — How much evidence is there for the elements in the risk analysis?
18	**RM-PCDS**	Risk Matrices and Probability-Consequence Diagrams	— How do risks compare to one another in the different dimensions of risk?
19	**ALARP**	As Low as Reasonably Practicable Principle	— Are the risks acceptable? — Should further risk control options be implemented?
20	**CBA**	Cost-Benefit Analysis	— How cost-effective are different risk control options?

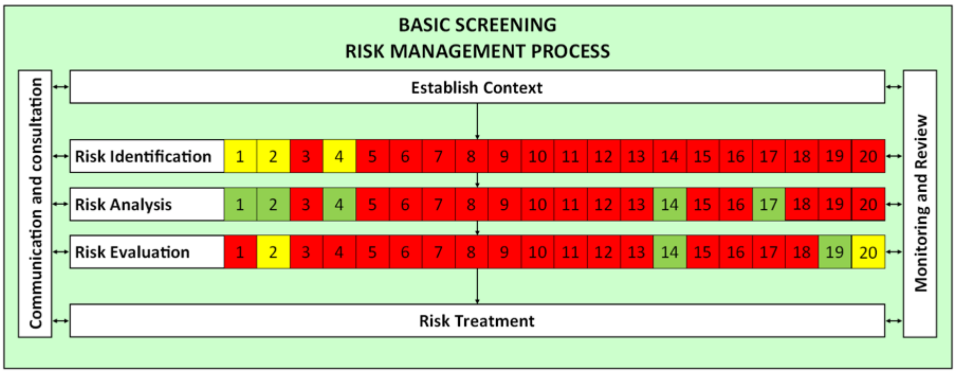


Figure 2.2.2.
Applicability of the OpenRisk Toolbox for basic screening risk management process
(Strongly applicable = Green, Applicable = Yellow, Not applicable = Red)

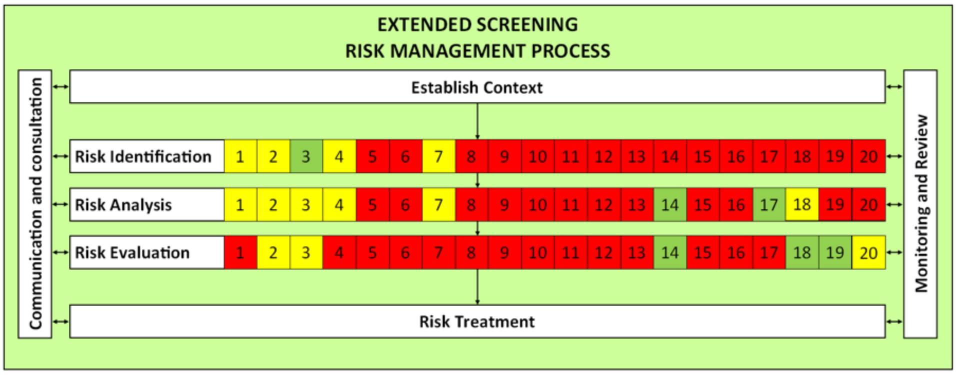


Figure 2.2.3.
Applicability of the OpenRisk Toolbox for extended screening risk management process
(Strongly applicable = Green, Applicable = Yellow, Not applicable = Red)

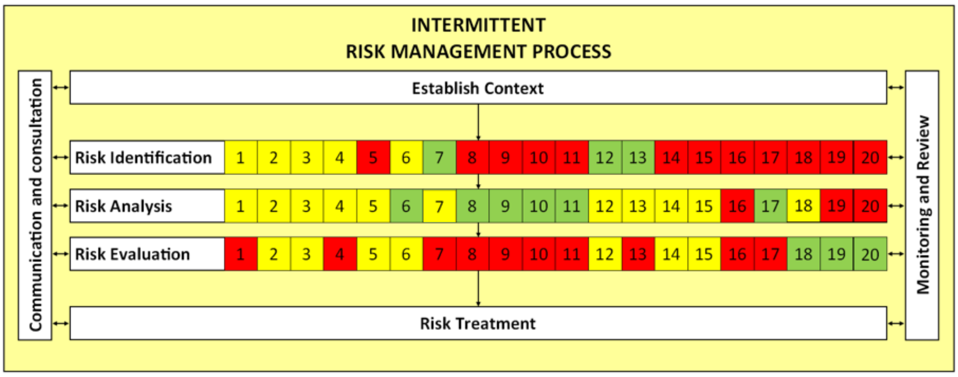


Figure 2.2.4.
Applicability of the OpenRisk Toolbox for intermittent risk management process
(Strongly applicable = Green, Applicable = Yellow, Not applicable = Red)

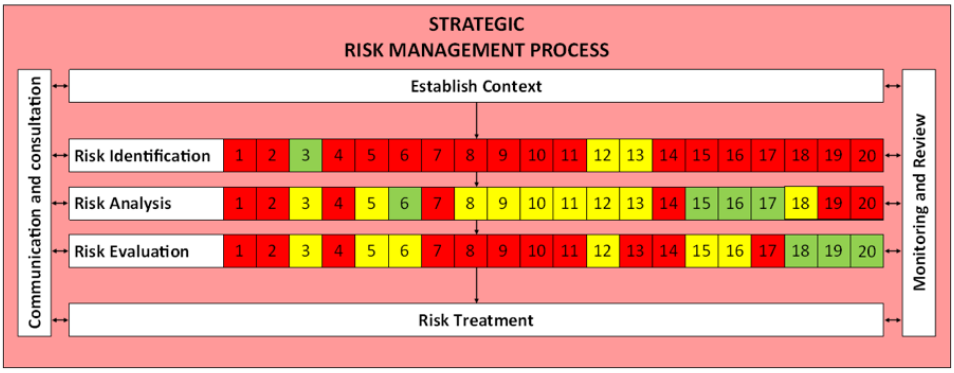


Figure 2.2.5.
Applicability of the OpenRisk Toolbox for strategic risk management process
(Strongly applicable = Green, Applicable = Yellow, Not applicable = Red)

Table 2.2.5.
OpenRisk Toolbox: Attributes of the tools

ID	Tool name	Resources needed	Skill required	Output: Quantitative	Output: Qualitative
1	AISyRisk	★☆☆	★☆☆	✓	
2	MarinRisk	★☆☆	★★☆	✓	
3	Delphi Method	★★☆	★★☆		✓
4	RiskData Hub	★★☆	★☆☆	✓	
5	IALA Waterway Risk Assessment Programme	★★☆	★★☆	✓	
6	Ports and Waterways Safety Assessment	★★★	★★☆		✓
7	Maritime Event Risk Classification Method	★★☆	★★☆		✓
8	Accidental Damage and Spill Assessment Model for Collision and Grounding	★☆☆	★★☆	✓	
9	SeaTrack Web	★☆☆	★★☆	✓	
10	Next Generation SmartResponse Web	★☆☆	★★☆	✓	✓
11	Response System Planning Calculators	★☆☆	★★☆	✓	
12	BowTie Method	★★☆	★★☆	✓	✓
13	Functional Resonance Analysis Method	★★★	★★★		✓
14	Key Performance Indicators	★★☆	★★☆	✓	✓
15	Spatial Bayesian Oil Spill Risk Tool	★★★	★★★	✓	
16	Integrated Strategic Risk Analysis Methods	★★★	★★★	✓	
17	Strength of Evidence Assessment Schemes	★☆☆	★☆☆		✓
18	Risk Matrices and Probability-Consequence Diagrams	★☆☆	★☆☆	✓	✓
19	As Low As Reasonably Practicable Principle	★☆☆	★★☆	✓	✓
20	Cost-Benefit Analysis	★★☆	★★☆	✓	

★☆☆ – Low
★★☆ – Medium
★★★ – High

3. Risk Assessment Methods: the OpenRisk Toolbox

In this Section, the different tools included in the OpenRisk tools, listed in Table 2.2.4, are described. For each tool, the background of its development is briefly outlined. An overview is given of the underlying models, methods, or approaches in the tool. Then, it is described how the tool can be used in pollution preparedness and response risk management. Focus is here on which risk management question(s) can be answered by applying the tool, and in which PPR risk management processes and risk assessment stages the tool can be applied. The applicability of the tools is indicated by three different colours (strongly applicable = green, applicable = yellow, not applicable = red). The process of using the tool is described, with attention to which inputs are required for applying the tool, and which outputs are obtained. Finally, some strengths and limitations of the tool are outlined.

Booms used for response to spills at sea. © Jouko Pirttijärvi/SYKE

3.1. AISyRisk

3.1.1 Background

The Norwegian Coastal Administration started a project in 2016 to develop a model for automated calculation of risk related to maritime traffic. The reasons for initiating the model development was the increasing complexity and change of ship traffic, lack of full access (transparency) to the previous decision models and costs of repeated manual calculations. Furthermore, the present capabilities in terms of big data processing enable the utilization of high resolution AIS data to develop more dynamic and accurate risk calculation models than before.

The project ends in 2018 and will result in a risk calculation model called AISyRisk, including a long-term data collection on probability of ship accidents and consequences for fatalities and oil spills for the sea areas under Norwegian interest. In addition, the AISyRisk tool is developed, comprising of a data repository with a web application to view and extract information from a data warehouse.

This chapter describes the key points of the AISyRisk tool in accordance with the ISO 31000:2018 Standard. The full project report [1], containing the methodology, will be available for the public.

3.1.2 Overview

The AISyRisk model comprises novel high resolution AIS data based approaches for calculating grounding and collision accident frequencies. Additionally, prior existing models for fire, explosions, and foundering have been adapted for use with AIS data input. The model is inspired by earlier developments such as NavRisk [2], IWRAP [3] and Be-Aware [4].

The AISyRisk model is based on the traditional definition of risk: likelihood x severity. The risk (R) for a given geographical area is defined in Eq. 3.1.1 as the product of the frequency of accidents (F) with ships under navigation, and the consequence of such an accident (C). The calculations can be done for different sea areas, and types and sizes of ships, etc.

$$R = F \times C \qquad \text{(Eq. 3.1.1)}$$

The AISyRisk model output is an accident frequency (number of accidents per location per year). This frequency is determined by combining the modelled frequency of critical situations, with standard values of an accident probability given a critical situation (causation probability). The number of critical situations is modelled based on the AIS derived high-resolution traffic image, in combination with location-specific factors (e.g. topographic data such as proximity to land and bathymetry).

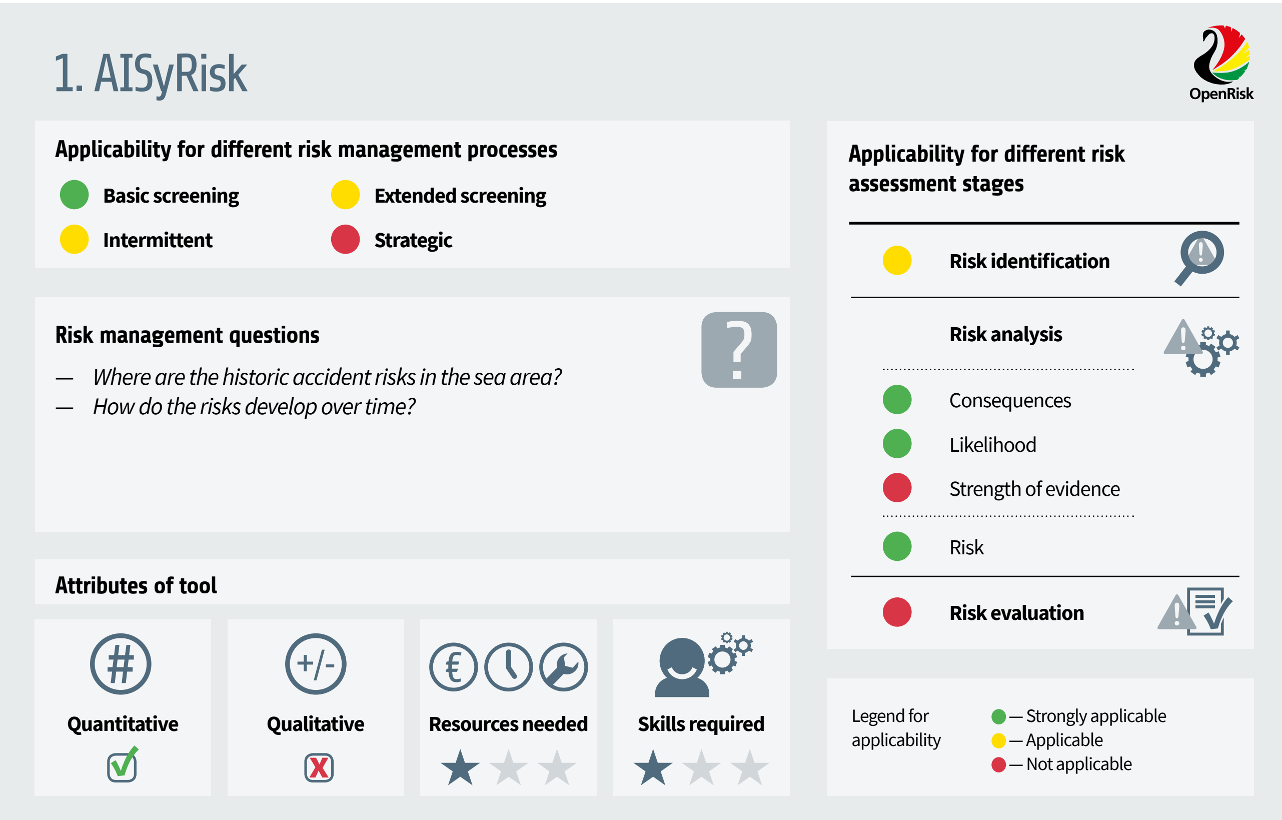


Figure 3.1.1.
Overview of the AISyRisk tool: Risk management questions addressed, tool attributes, and applicability for different risk management processes and risk assessment stages

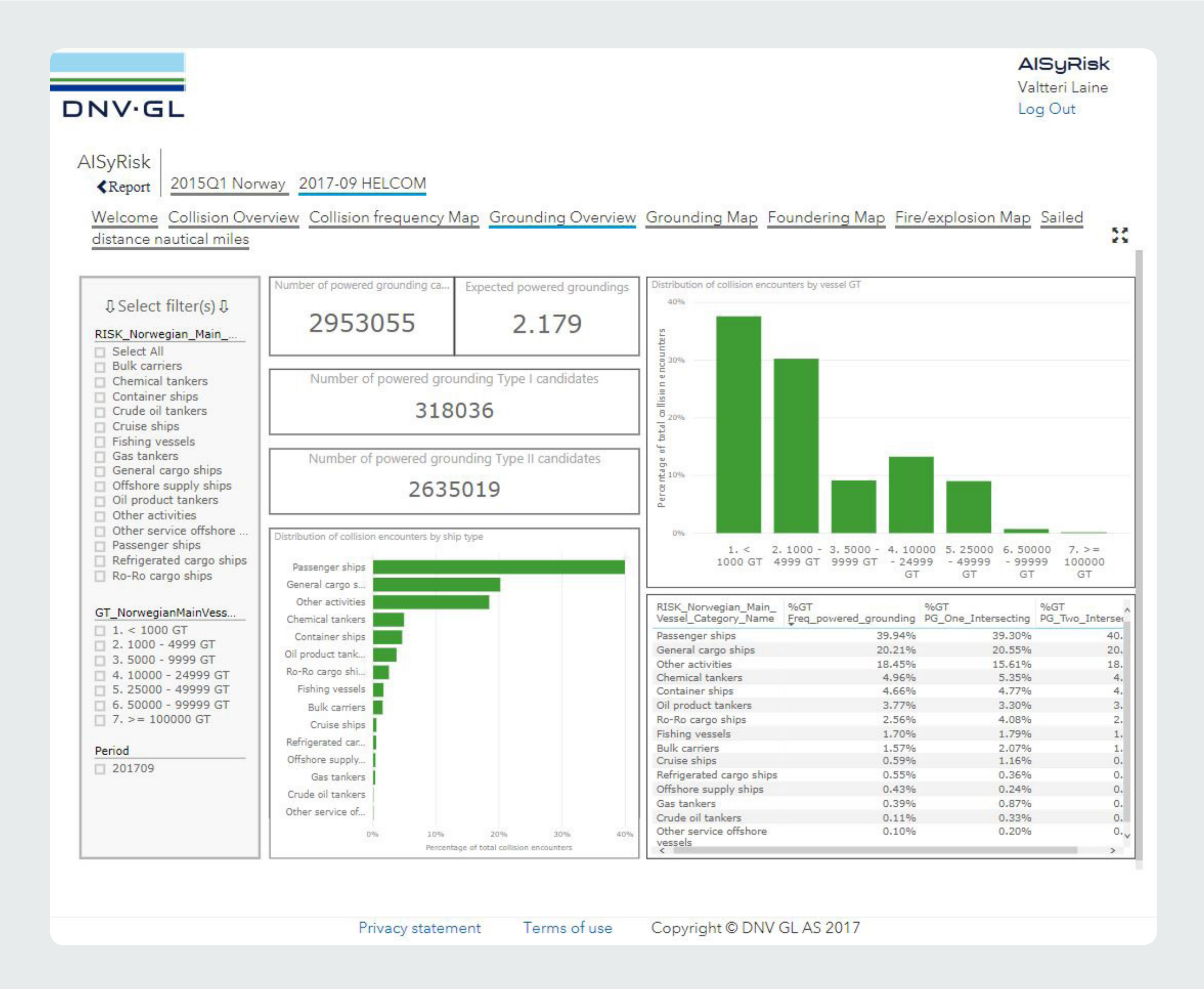


Figure 3.1.2.
Overview of the AISyRisk Web application, [1]

Consequences of ship accidents are divided into two categories: loss of lives and acute pollution. The model for loss of lives gives an estimate of the number of fatalities, while the acute pollution model gives the probabilities for oil spill of different sizes.

3.1.3 Use

The AISyRisk model can be used to answer following risk management questions:

— Where are the historic accident risks in the sea area?
— How do the risks develop over time?

The AISyRisk tool is useful primarily in the risk analysis stage of the basic screening risk management process in the developed PPR risk management framework based on ISO 31000:2018, introduced in Section 2.

It can also be used in the extended screening and intermittent processes. It provides quantitative outputs, and requires few resources and limited skill to execute an analysis.

The AISyRisk model is configured to identify the most significant risks and changes in the risk level of maritime transportation activities. The AISyRisk tool is fully automatic and requires no manual input for execution. From the web application, the user can easily provide overviews and reports in many ways, including GIS-based maps, tables, charts, etc. (Figure 3.1.2). The report [1] includes several use cases for the risk model, including:

— monitoring trends in ship traffic;
— monitoring trends in reported accidents;
— monitoring trends in reported accidents with oil spill;
— monitoring trends in reported accidents with personal injury or loss of life;
— monitoring trends in risk level;
— highlighting rate of change in risk level based on set criteria;
— identifying high risk areas, based on probability of different accident types and consequences;
— identifying reasons for accidents, based on ship manoeuvrings;
— providing an overview of the use of pilot or Pilotage Exemption Certificate (PEC).

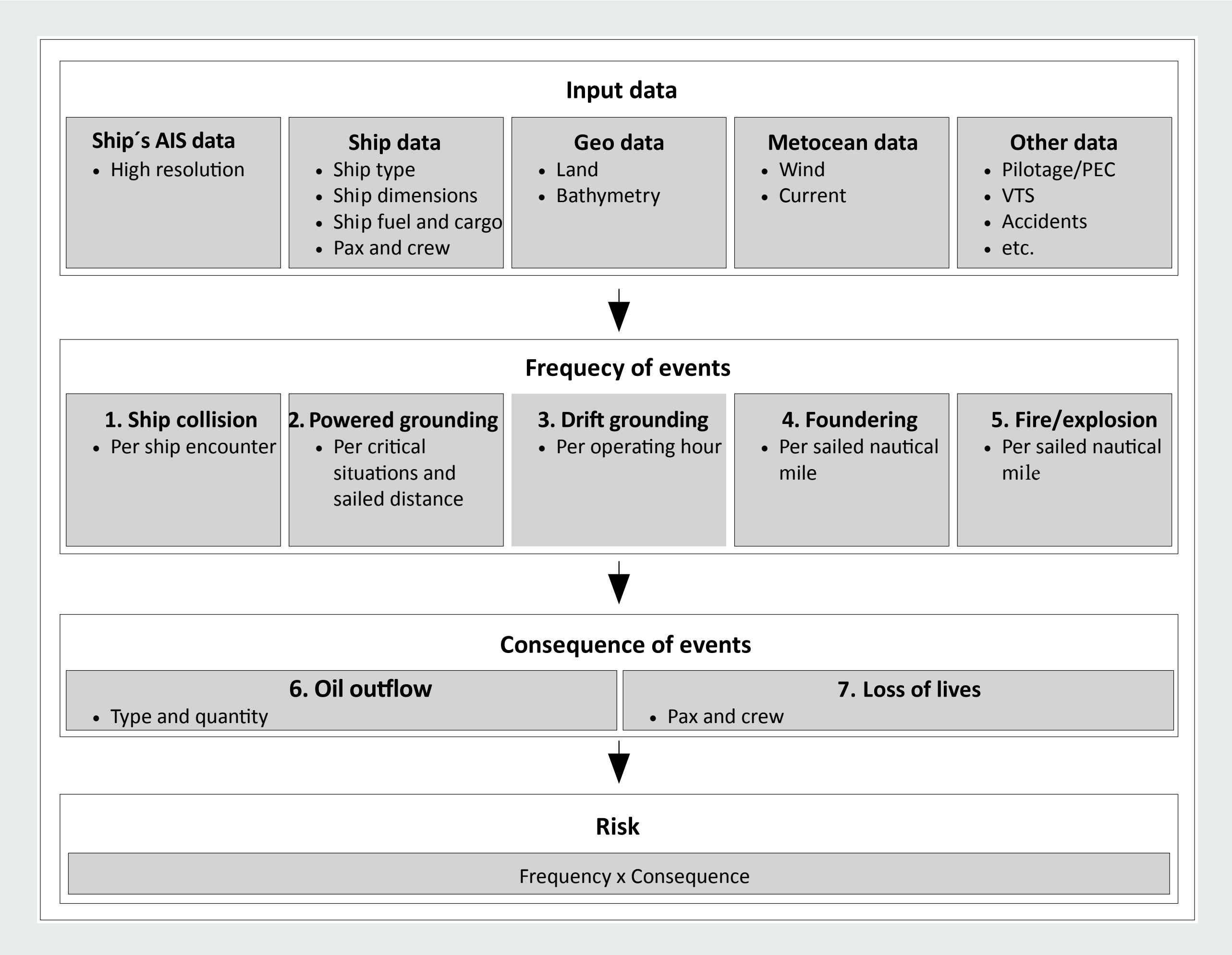


Figure 3.1.3.
Overview of the risk model framework

3.1.4 Input

The input data for the AISyRisk tool comes from a variety of sources. For the model to function properly, it is important to ensure the availability, reliability and usability of each data source. Here are some examples of the data which is used:

— AIS data (high resolution);
— Ship´s register data (ship type, dimensions, number of passengers and crew members, etc.);
— Bathymetry and coastal contours data;
— Local and ocean weather data;
— Pilotage and pilotage exemptions (PEC) data;
— Safe Sea Net data (fuel type and volumes, etc.);
— Accident and incident data;
— Cargo and fuel oil data (quality, type, volumes, etc.).

3.1.5 Process

Figure 3.1.3 illustrates the overall framework of the AISyRisk model. It includes five different types of data inputs for the maritime accident frequency calculations, and methods to calculate the potential consequences of accidents in terms of environmental damages and loss of life. Finally, the model combines the results to calculate the risk.

The risk calculations can be done geographically for a single 1 km2 size grid cell, or for a combination of multiple grid cells to cover larger sea areas. In addition, they can be done, e.g. for different sizes and types of ships. The principles of the methods for frequency and consequence calculations are described in the following sections.

Ship collision

The collision model calculates the frequency of serious inter-ship powered collisions (Figure 3.1.4). The model first estimates the frequency of encounters (critical situations for collision), assuming no collision avoidance actions are taken. This enables the calculation of total encounter frequencies. The model then applies a probability of a collision for each encounter, obtained from statistical analysis, to give the collision frequency. The equation for collision frequency f_c is:

$$f_c = N_c \times P_c \quad \text{(Eq. 3.1.2)}$$

where N_c is the number of theoretic collision candidates and P_c is the causation probability.

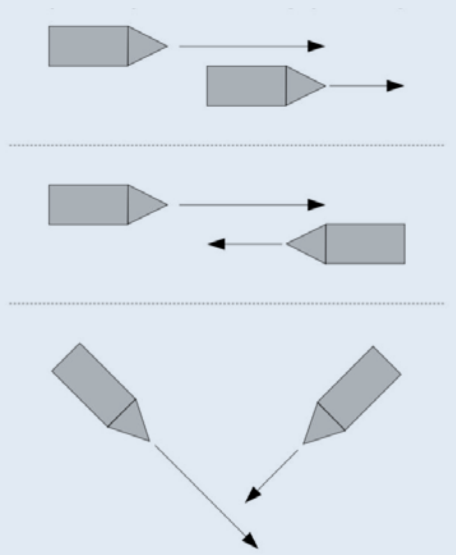


Figure 3.1.4.
The three scenarios defining a critical situation for collision: Overtaking (top), meeting/head-on (middle), and crossing (bottom)

Powered grounding

Two types of critical situations are defined for powered grounding. The first critical situation arises when a waypoint is located so that failure to make the course change would result in grounding within 20 minutes navigation from the planned course change point, if the course change is not made successfully. The model then applies a probability of a grounding for each critical situation obtained from statistical analysis, to give the powered grounding frequency f_{GI}. The equation for powered grounding Type I frequency is:

$$f_{GI} = N_{GI} \times P_{cGI} \qquad \text{(Eq.3.1.3)}$$

where N_{GI} is the number of theoretic powered grounding candidates and P_{cGI} the causation probability for powered grounding (Type I).

In the second type of critical situations, the powered grounding model detects the distance sailed close-to-shore (where coastline overlaps ships' "safety zone") and multiplies this with the probability of grounding per sailed distance. The equation for powered grounding Type II frequency is:

$$f_{GII} = N_{GII} \times P_{cGII} \qquad \text{(Eq.3.1.4)}$$

where N_{GII} is the number of theoretic powered grounding candidates and P_{cGII} the causation probability for powered grounding (Type II).

Drift grounding

The drift grounding model consists of two main elements: First, AIS data is combined with the ship breakdown frequency factor to generate the location and frequency of vessel breakdowns. Second, the recovery probability of control of drifting ships combined with drift speed (wind and current) gives the frequency of drifting vessels hitting the coastline.

The causation probability gives the probability of a critical situation (also referred to as drift grounding candidate) to results in a drift grounding. The frequency of drift groundings per year is calculated as follows:

$$f_{GD} = N_{GD} \times P_{cGD} \qquad \text{(Eq. 3.1.5)}$$

where N_{GD} is the number of theoretic drift grounding candidates and P_{cGD} the causation probability for drift grounding.

Fire/explosion

The fire/explosion accident frequency model applies the accident frequency parameters derived from the accident data with calculations of the ship exposure time (measured in distance sailed) to obtain the accident frequency. The total ship exposure time (corresponding to the vessel's sailed distance) in any area can be calculated from the AIS data.

Frequencies are calculated as the frequency of fire/explosion accidents per nautical mile sailed multiplied by the volume of nautical miles. The base value for fire/explosion accidents per nautical mile is calculated based on accident statistics and traffic volume. The equation is:

$$N_{feNM} = N_{fe} / NM \qquad \text{(Eq.3.1.6)}$$

where N_{feNM} is the number of fire/explosion accidents per nautical mile, Nfe the number of fire/ explosion accidents in Norwegian waters and NM the total distance sailed in the considered area.

Foundering

Foundering (or structural failure) includes ships which sank as a result of heavy weather, springing of leaks, breaking in two, etc. The accident frequency model applies accident frequency parameters (base value) derived from accident data with calculations of the ship exposure time (measured in distance sailed) to obtain the accident frequency. The base value for foundering accidents per nautical mile is calculated based on accident statistics and traffic volume. The equation is:

$$N_{foNM} = N_{fo} / NM \qquad \text{(Eq.3.1.7)}$$

where N_{fNM} is the number of foundering accidents per nautical mile, N_{fo} the number of fire and explosion accidents in Norwegian waters and NM the total distance sailed in the considered area.

Consequence model

The consequences of ship accidents are divided into acute pollution and loss of life. The acute pollution is calculated both for fuel and cargo oil. For each ship type and size the following equation is used to calculate the spill frequency, for fuel and cargo oil:

$$f_S = f_A \times P[S|A] \qquad \text{(Eq.3.1.8)}$$

where f_S is the spill frequency, f_A the accident frequency (i.e. the number of accidents per time unit), and P[S|A] the probability of a spill conditional to the occurrence of an accident.

The calculation of the average spill quantity Q_{Sav} is performed according to the following equation:

$$Q_{Sav} = f_S \times P_{S\_DS} \times DS \times C_{tot} \times R_{tf} \qquad \text{(Eq. 3.1.9)}$$

where fS is the spill frequency per unit time, PS_DS the spill probability per damage severity category, DS the damage severity (i.e. the fraction of the capacity), Ctot the total capacity, and Rtf the tank filling ratio.

The annual accident statistics published by the Norwegian Maritime Authority (NMA) are used to produce the probability of fatality in case of an accident. The formula for calculating number of fatalities Nfat is provided in the equation below.

$$N_{fat} = f_A \times P_{fat} \times N_{fA} \times C_{tot} \qquad \text{(Eq.3.1.10)}$$

where f_A is the accident frequency per unit time, P_{fat} the probability of fatality, N_{fA} the ratio of the fatalities by number of persons onboard, in an accident with a fatality, and C_{tot} the total capacity of persons onboard.

3.1.6 Output

The output of the AISyRisk model is a complete overview related to risks of maritime traffic for all Norwegian waters. This includes GIS maps, charts, tables, etc. Further, it is possible to filter the results to obtain specific information regarding particular ship types, ship sizes, casualty types, damage categories, geographical areas, fuel and cargo types, etc. Examples of outputs of the AISyRisk model are shown in Figure 3.1.5.

3.1.7 Strengths and limitations

Some strengths of the AISyRisk model include:

— Fully automated processing, i.e. no manual input required;
— Based on high resolution AIS data and accurate calculation methods;
— Able to take into account changes in risk level.

Some limitations of the AISyRisk model include:

— Currently only applicable for Norwegian waters. This is because the historic basis of accidents and all risk methodology is tailored for Norwegian waters;
— Following accident types are not included in the current model implementation, but may be added at a later stage:
  — Contact / allision
  — Operational accidents (transfer/bunkering spills)
  — Unauthorized discharge
  — Ice-related accidents (damage to ship because of contact with ice)
— Consequence models are developed for oil outflow and lives lost. Consequences for LNG/LPG, chemical, battery, dangerous goods, etc. are currently not included;
— Following accident categories are neglected, as these are considered not significant in Norway:
  — War loss/damage during hostilities – oil spill due to hostile acts
  — Terror/sabotage – oil spill due to hostile acts

Notes and practicalities

The method used in the AISyRisk model is transparent and documented in the project report. Currently, the model and web application are applicable only for Norwegian waters, but they can be modified to also calculate risk for other sea areas. However, if European regional Pollution Preparedness and Response authorities want to apply the system for their own activities, some investments need to be done.

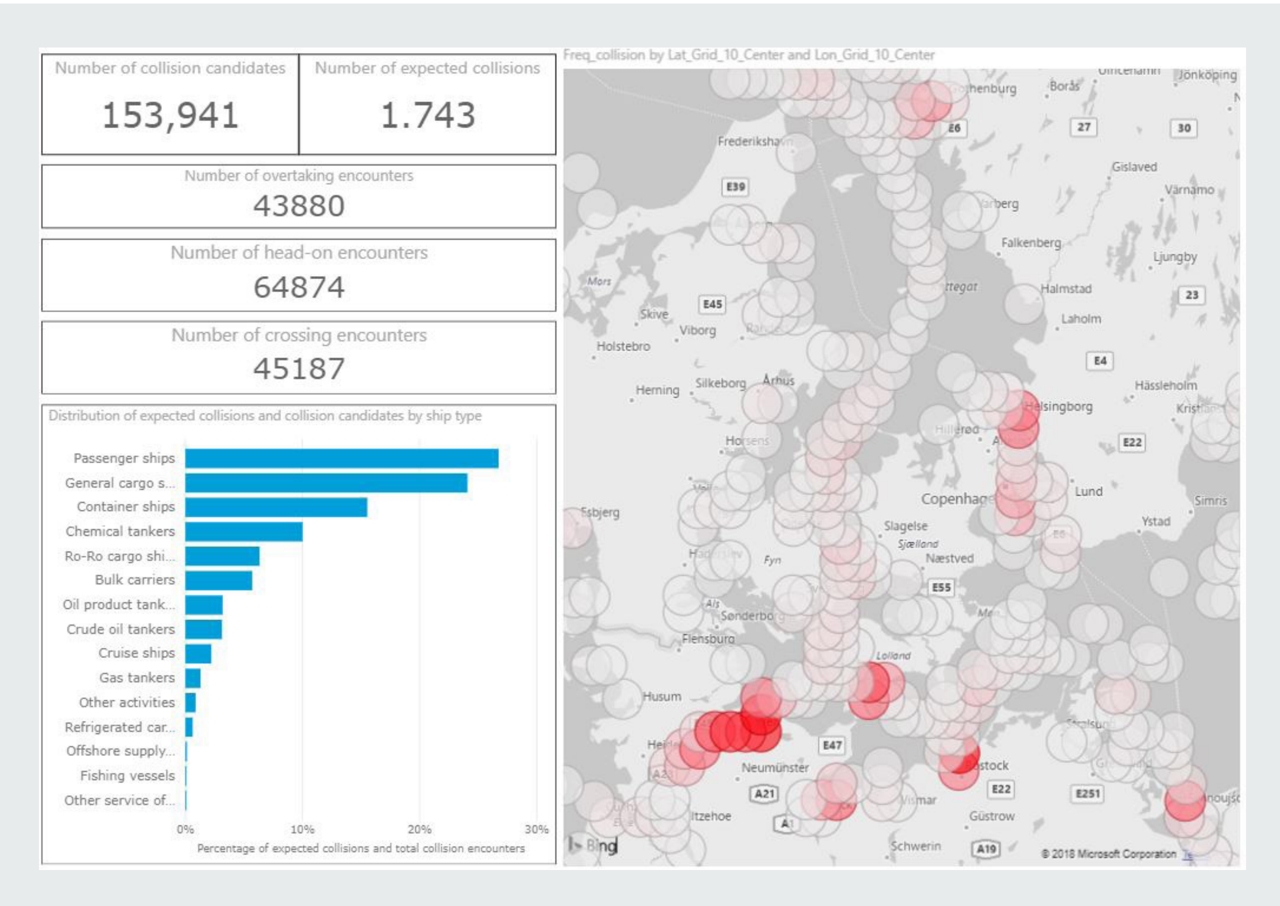


Figure 3.1.5.
Examples of outputs of the AISyRisk model

3.2. MarinRisk

3.2.1 Background

In the MarinRisk model, risk is measured as a combination of the frequency of an unwanted event and the consequences of this event. This means that even a rare event can still result in a high contribution to the risk. On the other hand, an event with very little consequences but with a high occurrence frequency will also have a large contribution. For shipping accidents this means that for example cruise vessels will have a larger contribution to the risk in a sea area than bulk carriers because of the fact that there could be over 3000 people on board the cruise vessel. On the other hand, a very old bulk carrier that sails under a flag of convenience according to Paris MoU can also have a large contribution to the risk, due to a higher expected accident frequency.

In order to make the contribution of each individual vessel to the overall nautical risk visible, a so-called Nautical Risk Index has been developed. Based on expert opinions, mathematical modelling and years of statistical data it is possible to determine the individual nautical risk of a vessel based on the actual weather and traffic conditions. This risk index was first developed in the EU-project EMBARC [4] and was further developed in the EU-project MarNIS [1, 2, 3 ,5], and within the OpenRisk project.

3.2.2 Overview

The aim of the Nautical Risk Index is to determine the contribution of the total risk of an individual vessel. By taking into account the actual traffic situation and some of the characteristics of the vessel, a risk number can be calculated. In context of PPR risk management, the risk index can be used to assess the current or past safety situation in a certain area.

The MarinRisk tool can be used to estimate the total expected number of accidents, oil spills and associate costs, for each ship for each area for which AIS data is available. It could also be possible to determine the risk for vessels based on other traffic data than AIS, provided that this other data set contains the same type of data concerning the type and size of the vessels and the positions. When all risk numbers are aggregated for a certain area, the total risk value of that area is determined. One can also calculate the average value of the risk of the area over a certain longer time period. For example, the risk index can be used in combination with stored AIS-data to assess the nautical risk in the area for different months. This allows the estimation of the risk level over a period of time, which can be used, e.g. to detect changes in periodic assessments.

The results obtained from the MarinRisk tool can also be filtered for specific vessels or conditions, so an understanding can be gained of specific scenarios, e.g. showing the difference in overall risk levels between day and night. It is also possible to create a ranking of the

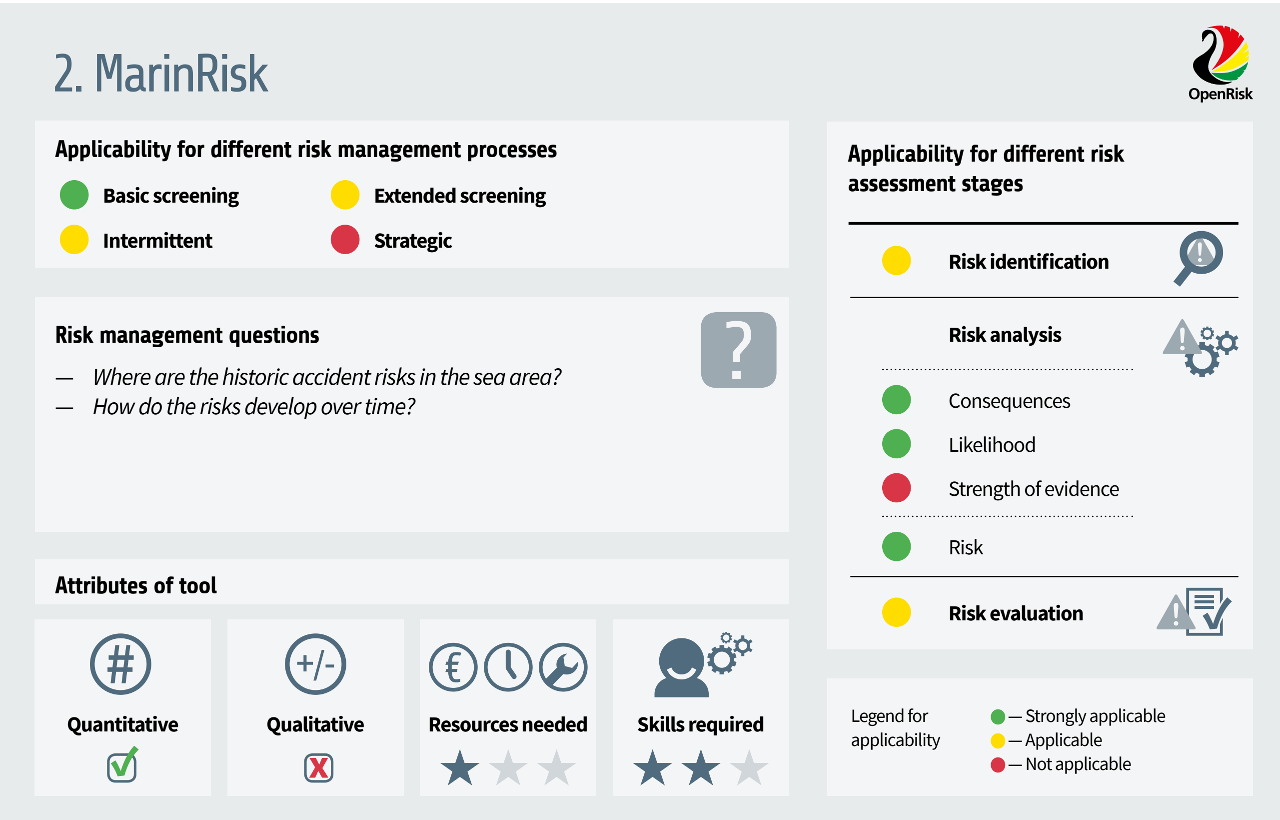


Figure 3.2.1.
Overview of the MarinRisk tool: Risk management questions addressed, tool attributes, and applicability for different risk management processes and risk assessment stages

vessels which most contribute to the risk. This can help to identify additional efficient risk control options.

Since the risk control options are modelled separately in the model, it is also possible to assess the impact of the implementation of these options and see the overall effect in the results. The main restriction in using the index to perform a safety assessment is that the basis of the assessment model is the AIS data, so the actual traffic flows. This means that any risk control options that influence the actual traffic flows cannot be assessed with this method.

For the Dutch Ministry of Infrastructure and Environment, a study was conducted in which the risk index was used to assess the busy traffic flows on the North Sea area [5]. Figure 3.2.2 shows the average risk value for pollution per grid cell based on two weeks data in February.

3.2.3 Use

The MarinRisk tool can be used to answer following risk management questions:

— Where are the historic accident risks in the sea area?
— How do the risks develop over time?

The MarinRisk tool is useful primarily in the risk analysis stage of the basic screening risk management process in the developed PPR risk management framework based on ISO 31000:2018, introduced in Section 2. It can also be used in the extended screening and intermittent processes. Furthermore, it can assist in the risk evaluation process by considering the risk reducing effect of selected risk control options. It provides quantitative outputs, and requires few resources and medium skills to execute an analysis.

The model is configured to identify the most significant risks and changes in the risk level of maritime transportation activities. It can be used to determine risks which require no further analysis, or risks for which a more detailed risk analysis is beneficial.

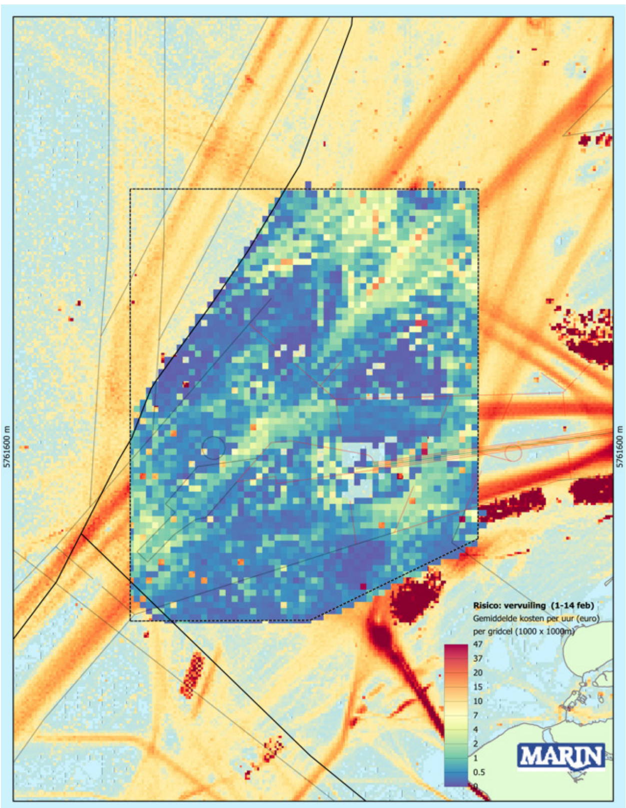


Figure 3.2.2.
Calculated risk of pollution, [5]

3.2.4 Input

The MarinRisk model determines the risk on the basis of the information available in the AIS message of the vessels. Hence, AIS data is the main input for the calculations. However, these messages alone do not contain enough information. Therefore, use is made of an additional database which contains extra information about the vessels, for example the age of the vessel and the flag (based on Paris MoU list). Also, information regarding the weather condition is not included in the AIS message. The user needs to provide this data to the model as well. However, ongoing developments will enable the connection of real-time weather information to the AIS data set in the future, so that this information could be fed into the model automatically.

Furthermore, the model uses basic accident rates that are based on world-wide statistics to create a variation on basic accident rate between different ship types and size. Local accident statistics can also be used as an input to create the accident rates.

3.2.5 Process

The model for calculating the individual risk of a vessel consists of three main parts: i) the probability of a nautical accident, ii) the consequence of the possible accident, and iii) the risk reducing measures that are in place, or could possibly be implemented.

Determining accident probabilities

Based on the actual traffic and environmental conditions of a vessel, the following possible nautical accidents are considered in the frequency part of the model:

— Collision between two moving vessels;
— Ramming contact: a contact with a fixed object or coastline of grounding due to a navigational error;
— Drifting contact: a contact with a fixed object or coastline of grounding due to a machinery failure;
— Foundering: an incident that a vessel sinks due to environmental conditions;
— Fire or explosion on board;
— Hull failure: the probability that a hole will occur in the hull of a vessel;
— Machine failure: the probability of a failure that results in the drifting of the ship.

The probability of each type of accident depends on different influencing factors. The factors that are taken into account in the frequency modelling are:

— Ship characteristics:
  — Type of ship
  — Size of the ship
  — Age of the ship
  — Flag of the ship (Port State Control list, including white, grey and black sub lists)

- Environmental conditions:
  - Wind
  - Visibility
  - Current
  - Position of other traffic
- Layout:
  - Coastline
  - Fixed objects (offshore installations, wind turbines)

The general modelling of the accident frequencies is based on the approach in the Safety Assessment Model for Shipping and Offshore on the North Sea (SAMSON). SAMSON is a risk assessment model for shipping that has been developed at MARIN over the past 30 years [2].

The second part of the frequency model is the casualty rate, which is the probability that a predefined exposure type (e.g. a ship-ship encounter) will actually lead to an accident (e.g. a collision). This "static" casualty rate is determined using accident data from 1990-2012. By multiplying the calculated exposure and the static casualty rate, an average frequency is determined. To include the influence of different factors, such as wind, visibility and flag of the ship, the average level of the frequency is multiplied by different factors to incorporate the influence of the different factors.

The different multiplication factors are based on various statistical analyses and models. A more detailed description of the multiplication factors can be found in [3]. Within MarNIS, the multiplication model as described above, is validated by INRETS [6].

Determining the Consequences

The consequences of an accident at sea can be divided into three main categories:

- Consequences for life
- Consequences for the environment (pollution)
- Structural consequences

Details about the consequence models can be found in [3, 4, 5].

Risk control options

Apart from to the frequencies and the consequences, the third main part of the risk assessment model are the risk control options (RCOs). These are measures which can be taken to reduce the risk. Two types of measures may be listed:

- Preventive measures (influences the probability of an accident):
  - Escorting tugs
  - Pilots
  - Vessel Traffic Services
- Remedial measures (influences the consequence of an accident):
  - Search and Rescue units and activities
  - Oil pollution response units and equipment

Other risk control options are included in the modelling of the other frequency and consequence models as well [3]. In the current model for the risk index, the following RCOs are considered and implemented: use of an emergency towing vessel, search and rescue, oil pollution response units, and pilot and tugs.

Use of an Emergency Towing Vessel

By introducing an emergency towing vessel (ETV), a drifting contact with an object can be prevented. The reduction of the probability of a drifting contact depends on the position of the ETV, the speed for the prevailing weather conditions and the available power of the ETV.

Search and Rescue

The availability of Search and Rescue (SAR) units in an area will increase the survival probability of the persons on board after an accident. Hence, SAR decreases the expected costs for loss of life due to a nautical accident.

Oil pollution response units

The availability of oil pollution response units and equipment will decrease the amount of oil polluting a coast line. Thus, it will decrease the environmental damage costs and the clean-up costs.

Pilots, tugs, and Vessel Traffic Services

When a ship is in the vicinity of a port and has a pilot on board and/or uses tug boats, the probability of a navigational error decreases, and hence also the probability of a collision or other contact accidents decreases. Also the extra information provided by the vessel traffic services will decrease the probability of a collision.

3.2.6 Output

The output of the MarinRisk model is for each vessel in an area the calculated accident frequency, the expected consequences of the accident and finally a risk value that represents the risk costs. These frequencies and costs are calculated for each vessel and each time step.

The risk estimates can be shown in an Electronic Chart Display and Information System (ECDIS) environment when playing back AIS data (Figure 3.2.3). The results are also stored in a large log-file for further analyses, to construct risk-density plots which are useful to identify hotspot areas. Different risk density plots can be created, because all different accident frequencies and consequences are logged in the output file. For instance, it is possible to develop risk maps per month, or for specific consequences such as oil spills.

3.2.7 Strengths and limitations

Some strengths of the MarinRisk model include:

- Fully automated processing, i.e. no manual input required;
- Based on high resolution AIS data and accurate calculation methods;
- Actual vessel behaviour is used as a basis, so no assumptions on traffic flow are needed;
- Able to take into account changes in risk level.

Some limitations of the MarinRisk model include:

- Use of historic AIS data implies that changes in traffic intensities or traffic routes cannot be taken into account;
- Limitations of AIS data availability, and data errors can affect the accuracy of the results.

Notes and practicalities

The algorithm of MarinRisk is openly available for the PPR authorities, but in order to make it functional with AIS data input, coding is needed.

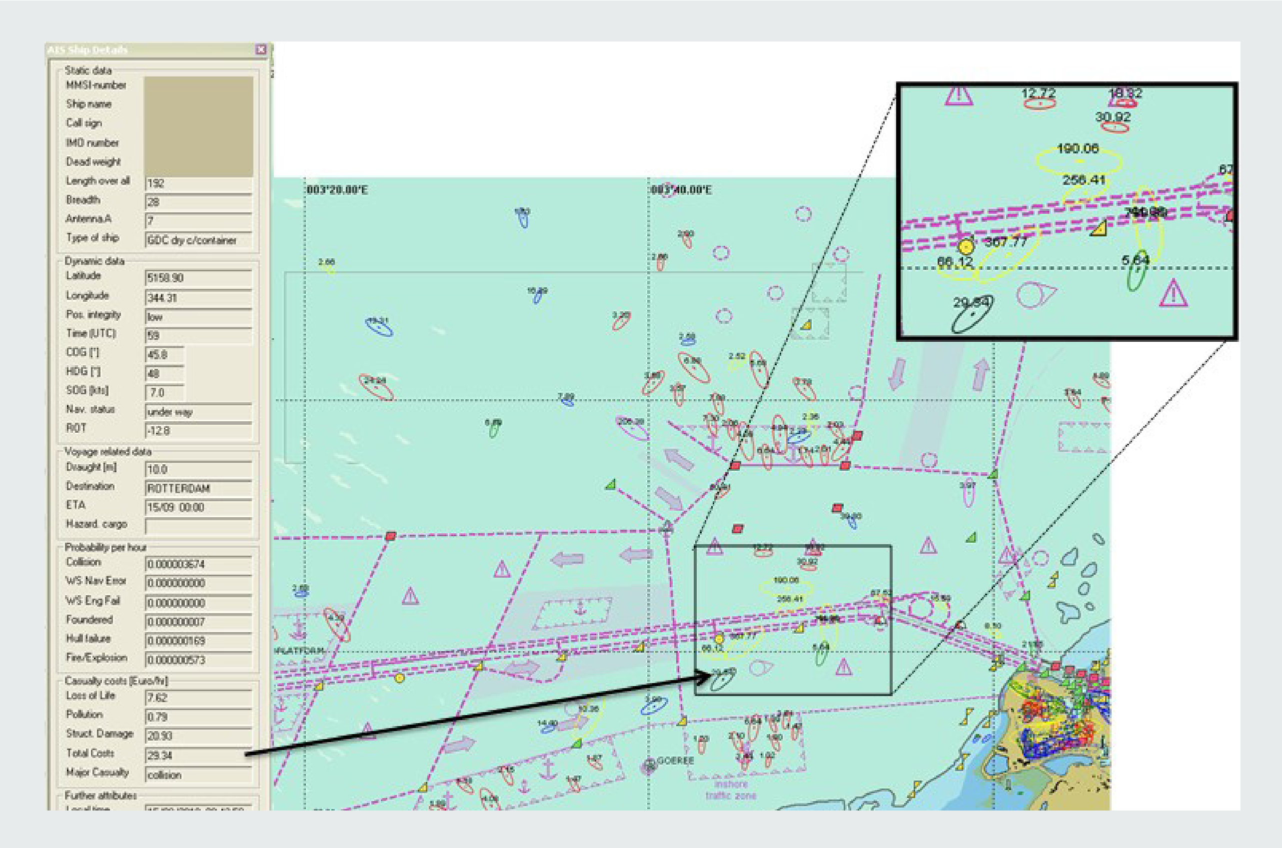


Figure 3.2.3.
Overview of the MarinRisk tool outputs in an ECDIS-environment

3.3. Delphi

3.3.1 Background

The Delphi method (also known as Delphoi) belongs to the subjective-intuitive methods of foresight [1]. It was initiated in the early 1950s by the California-based RAND Corporation [2]. The questions of RAND thinkers, at the time, primarily dealt with the military potential of future technology, as well as potential political issues and their resolution [3].

During the last ten years, the Delphi method has been used more often especially for national science and technology foresight [1]. Some modifications and methodological improvements have been made as well during this period. The Delphi method has also been applied in several studies in different transportation modes, also in the maritime domain [4, 5, 6, 7, 10].

3.3.2 Overview

The Delphi method is a procedure to obtain a reliable consensus opinion from a group of experts. It is based on the assumption that group judgments are more valid than individual judgments, which is known to usually be the case [8]. The method incorporates three important elements.

The first element is the anonymity among group members. The Delphi method was originally designed to encourage a true debate, independent of personalities [3]. The anonymity can reduce the effects of dominant individuals, which often is a concern when using group-based processes for collecting and synthesizing information [9]. Furthermore, the anonymity encourages group members to express their opinions and openly and constructively criticize each other.

The second element is the controlled feedback process. In the Delphi method, each group member is asked to consider his/her responses in relation to the responses of the rest of the group. Based on this, they are asked to respond to the next round of the survey [2]. Extreme opinions from the group members are made open and clear via the controlled feedback, and estimates are achieved by passing the problems of group dynamics [3].

The third element is the ability to use a variety of statistical analysis techniques to interpret the data. This further reduces the potential of group pressure for conformity [9]. In addition, the tools of statistical analysis enable an objective and impartial analysis and summary of the collected data.

3.3.3 Use

The Delphi method can be used to answer the following risk management questions:

— What kinds of future hazards should be considered?
— What are the associated risk levels?

The Delphi method is useful primarily in the risk identification stage of the extended screening risk and strategic management processes in the developed PPR risk management framework based on ISO 31000:2018, introduced in Section 2, and to a lesser extent in the intermittent process. It may also be useful for the risk analysis

Figure 3.3.1.
Overview of the Delphi tool: Risk management questions addressed, tool attributes, and applicability for different risk management processes and risk assessment stages

stage to determine the risk levels associated with the identified hazards, and in the risk evaluation phase to judge the effectiveness of risk control options for mitigating the risks. It provides qualitative outputs, and requires a medium commitment of resources and some experience with the method to execute an analysis.

The Delphi method is particularly suitable when quantitative data is limited or does not exist, or experiences on the subject are very limited. In addition, the method is useful in problems addressing strategic foresight. Hence, risks related to major accidental oil spills, unmanned ships, new fuel solutions or planned oil terminals (including intended navigational routes) are some examples of concerns in which the Delphi method can be applied in a PPR context.

Figure 3.3.2, taken from [10], presents an example of the use of Delphi method in the maritime domain. It illustrates the results from HELCOM MARITIME 16-2016 e-Delphi exercise - Perspectives to environmental issues and actions in the Baltic Sea.

3.3.4 Input

The input to the Delphi method is a set of expert opinions. Since the results of a Delphi depend on the knowledge of and co-operation between the experts, it is essential to include people who are likely to contribute valuable ideas to the issues addressed [3].

3.3.5 Process

Figure 3.3.3 presents the main components and flowchart of the Delphi method. These are [9]:

1. Forming a team to undertake and monitor a Delphi process on a given subject;
2. Selecting one or more panels to participate in the exercise;
3. Developing a questionnaire for the first round of the Delphi process;
4. Testing the questionnaire for proper wording (e.g. ambiguities);
5. Transmitting the first questionnaire to the panelists;
6. Analyzing the first round responses;
7. Preparing the second round questionnaire (and possible testing);
8. Transmitting the second round questionnaire to the panelists;
9. Analyzing the second round responses (Steps 8 to 9 are reiterated as long as desired or necessary to achieve stability in the results);
10. Preparing a report by the analysis team to present the conclusions of the exercise.

	ENVIRONMENTAL IMPACT		ACTIONS	
Emissions	Significance/ Severity for Baltic Environment	Probability of damage by 2030	Significance of actions	Probability of effective actions by 2030
Anti-fouling paints	Low	Low	Low	Low/ medium
Chronic oil pollution	Medium	Low	Medium	Medium
Residual discharges	Medium	Low	Medium	Medium
Underwater noise	Medium	Medium	Low	Low
Airborne emissions	High	High	High	High
Marine litter	Medium	Low	Low	High
Large oil/chemical spill	High	Medium	High	Medium
Sewage	Medium	Low	High	High
Ballast water management	Medium	Medium	High	High
Airborne emissions actions				
Alternative fuels			High	High
SECA			High	High
NECA			High	High
Other				
E-navigation			Medium	Medium

Figure 3.3.2.
An example of the use of the Delphi method in the maritime domain [10]

3.3.6 Output

The Delphi process usually provides statistical data, which can be used in many different ways. Often, comments are asked of the participants to help interpret the statistics [1]. As the Delphi process proceeds, including a series of subsequent controlled survey rounds, the expert opinions converge toward consensus. The final output of the Delphi process is a summarized conclusion on the matter in hand.

3.3.7 Strengths and limitations

Some strengths of the Delphi method include:

- Ability to explore issues that require judgement in a controlled and objective manner;
- As views are anonymous, unpopular opinions are more likely to be expressed;
- All views have equal weight, which avoids the problem of dominating personalities;
- Achieves ownership of outcomes;
- People do not need to be brought together in one place at one time.

Some limitations of the Delphi method include:

- It is rather labour-intensive and time-consuming;
- Participants need to be able to express themselves clearly in writing;
- The reliability of the process and the outcomes are sometimes criticized.

Notes and practicalities

Several commercial software applications have been developed based on the Delphi method, such as e-Delphi. Although these applications may be useful, the Delphi method can be deployed without a specific software.

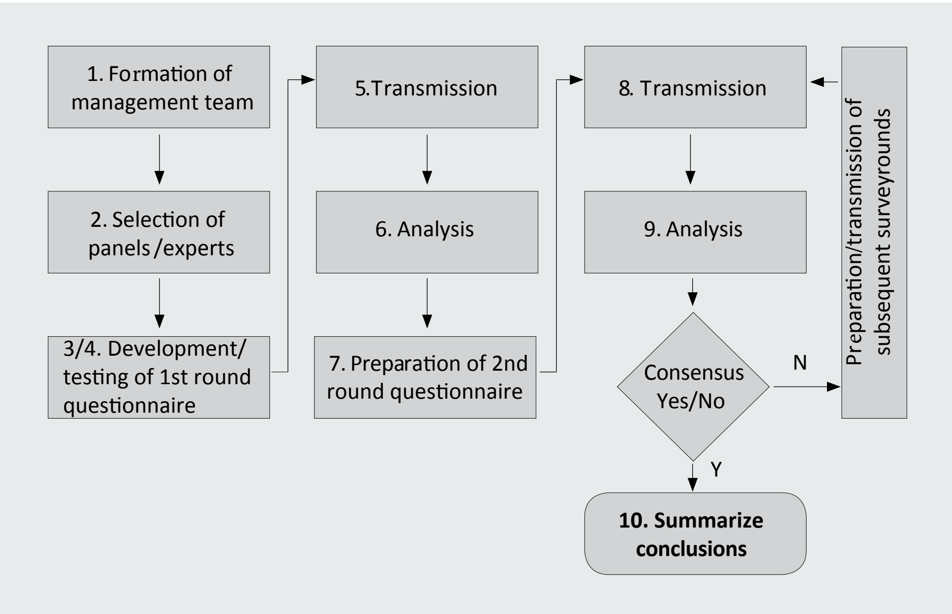


Figure 3.3.3.
Flowchart showing the main components of the Delphi process

3.4. RiskData Hub

3.4.1 Background

The effectiveness of Disaster Risk Management (DRM) depends greatly on the efficiency of managing relevant information. Over the past decades, technology has been developed for assisting decision-makers to use data and information related to disaster risk for policy formulation and implementation. Likewise, disaster risk dedicated web-platforms in general and geospatial data technologies such as WebGIS in particular, have acquired an important role in DRM. These bridge the gap between data and decision support systems (DSS).

The need to support the implementation of international actions for Disaster Risk Reduction [1], from global to regional and local level promoted the development of WebGIS platforms. The Sendai Framework for Disaster Reduction 2015-2030, recognized the critical role of geospatial technologies [2]. This recognition resulted in initiatives to use spatial information at all the stages of DRM covering all geographical scales (local, sub-national, national, regional).

EU Member States and associated countries are called, in the frame of the Decision No.1313/2013/EU of the European Parliament and of the Council on a Union Civil Protection Mechanism (UCPM), to prepare regular National Risk Assessments (NRA) and accordingly to assess their Risk Management Capabilities, while preparing their resultant Risk Management Plans. The preparation of evidence-based NRA requires the collection of data related to disaster damage and losses for a wide range of events of different nature.

In order to support these actions, the Disaster Risk Management Knowledge Centre (DRMKC) is currently advancing towards technological developments such as the GIS web-based platform, the RiskData Hub. It aims to support the implementation of international actions for DRM from global or regional level to local level. The scope is to pool results, technology and scientific knowledge for fostering DRM related actions. The approach is based on promoting the development of WebGIS platforms, improving the access to these, and sharing curated European-wide risk data to enhance disaster risk knowledge across all EU policies.

3.4.2 Overview

The RiskData Hub is a web-based platform for exchanging and sharing geospatial data, focusing on dissemination and visualisation of data, tools and methodologies. It is built considering Open Data Policy, which aims to reduce common limitations of DRM, increasing its efficiency [4]. This concept emerges from the idea that disaster risk science requires open data for replicable results, which is the fundament for scientific knowledge. It answers the need of DRM and demands not only a methodological framework, but also the actual tools and the data in order to assess risks.

The RiskData Hub is currently implemented applying the open source GeoNode software. GeoNode is a geographic Content Management System (CMS), mainly aimed at collaborative sharing and editing of geographic layers and maps. However, using spatial information requires the support of specific components listed below, as indicated in Figure 3.4.2.:

— A Database Management System and its spatial extension: PostgreSQL and PostGIS;
— A Database file system;

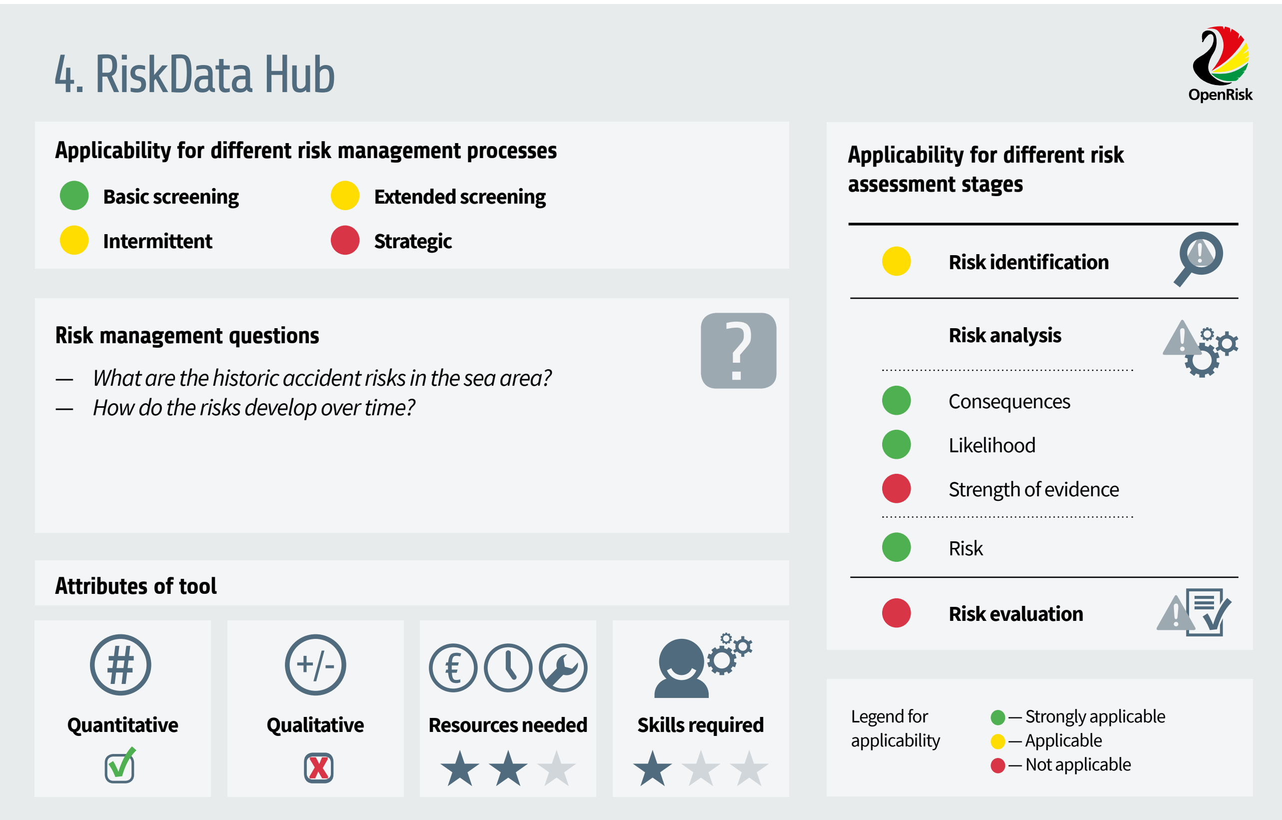


Figure 3.4.1.
Overview of the RiskData Hub tool: Risk management questions addressed, tool attributes, and applicability for different risk management processes and risk assessment stages

— A server-side software, which can provide standard Web Map Services: GeoServer;
— A CSM framework: Django;
— Client-side libraries for building WebGIS applications: OpenLayers, GeoExt and LeafletJs.

The RiskData Hub offers a simple interface to freely visualize access, download and link to geospatial data at a European wide scale. It presents the geospatial information in a homogeneous way across Europe considering continental Europe and its maritime area, in two distinct sections. The areal extent covers the member states of the European Union, EFTA (European Free Trade Association) and IPA (Instrument for Pre-Accession Assistance) countries from southeast Europe and Turkey.

The geospatial information hosted on the RiskData hub is built on the relation between exposure and hazard. This approach offers basic insights to practitioners and policy makers dealing with disaster risk management. Besides, it provides evidence-based information for decision-makers, contributes to the development of risk-reduction strategies and adaptation plans either to mitigate the disaster risk or to target adaptation measures.

The RiskData Hub proposes the identification of impact areas from spatial concurrence of hazards with exposure layers. The scope is to anticipate which areas are expected to suffer significant impact from hazards. By integrating hazard data and mapping areas of potential impact, means are provided serving as a starting point for prioritizing local case studies on impacts from maritime hazards, as the basis for the development of mitigation strategies.

A commonly used approach to estimate risk levels is based on vulnerability and the exposure as main drivers of risk [5]. Conceptual frameworks show the importance of reducing the risk by reducing vulnerability and mitigating hazard before a risk event can occur. From the various dimensions of vulnerability, described in [6], RiskData Hub proposes to measure the physical, environmental and socio-economical dimensions as proximity or predisposition to damage from a hazardous event, as illustrated in Figure 3.4.3.

The multi-scale approach for viewing disaster risk data considers administrative units as levels of aggregation. In the case of maritime risk management, the aggregation is done upon the exclusive economic zone (EEZ). This approach is rooted in the understanding that risk management reflects policy components which are linked with administrative directives, organizations and operational skills coordinated at level of administrative entities. It is a way of assessing accountability, capabilities and resources. Furthermore, the disaster risk information is linked to individual assets/exposed elements and can be easily integrated with preparedness, resilience and financing schemes [7].

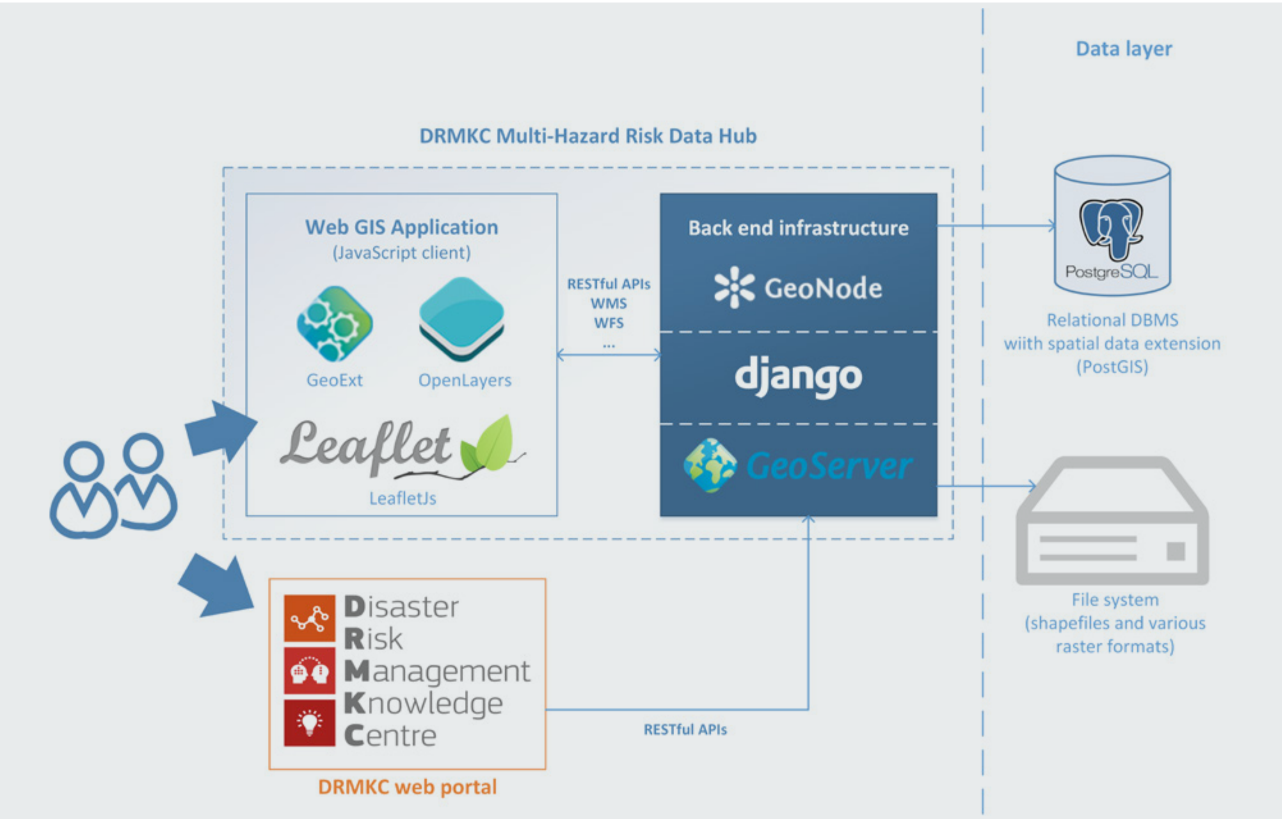


Figure 3.4.2.
Schema of the Multi-Hazard Risk Data Hub architecture, based on the Geonode technology stack. The hub will be also integrated with the DRMKC web portal (e.g. for displaying the latest published layers) through the RESTul web services made available by GeoNode.

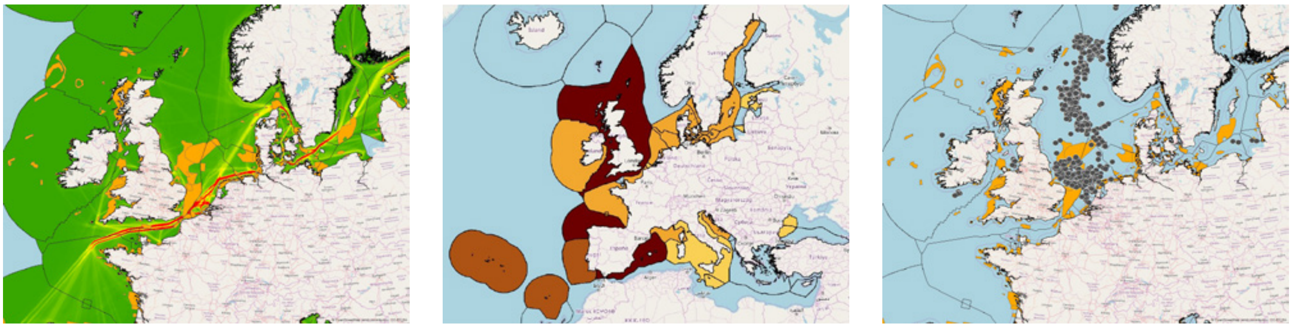


Figure 3.4.3.
RiskData Hub approach to mapping the exposure and vulnerability as proximity. Shipping proximity map (left), Natural reserve map (centre), Oil rigs proximity map (right).

The hazard mapping within the RiskData Hub considers return periods and scenarios (climate change, economic and socio-demographic scenarios). Consequently, the socio-economic and environmental exposure and potential impacts from extreme events are structured on return periods and climate change scenarios (RCP2.6, RCP4.5, and RCP8.5)[1] [8]. This approach suggests a probabilistic approach in disaster risk assessment. It also proposes a harmonized likelihood estimation of the extreme events. Moreover, this way of structuring the data supports management plans and strategies for DRM.

The cross-disciplinary approach includes a multi-hazard risk assessment in RiskData Hub. This suggests an alignment of methodological approaches and data used for disaster risk analysis across different hazards. It also helps to identify potential impact areas from multi-hazard occurrence, implementing three factors of the multi-hazard potential framework defined in [9]: identification, coincidence (spatial and temporal) and interaction among various hazards.

Records of losses and damages from historical events and lessons learnt are considered in RiskData Hub. Loss databases are established to track the expenditures from disasters and to plan disaster reduction strategies [10]. Availability and accessibility of loss and damage information offer the necessary link to evaluate whether the hazard metrics can predict impacts. Being designed to consolidate disaster risk knowledge, the loss datasets create the basis for studies relating physical characteristics of the natural hazard events to their various impacts.

Loss data accounting is now in demand at all levels from national, to European and international. This goal is best addressed at national and subnational level by the governmental departments or institutions addressing crisis management. However, there is no authoritative loss database that can provide a trend at European level. RiskData Hub proposes to contribute in loss data collection, developing an interface for centralised collection of data on losses and damages with national scope and local scale (which is still under development for the maritime area), as illustrated in Figure 3.4.4.

3.4.3 Use

The RiskData Hub can be used to answer the following risk management questions:

— What are the historic accident risks in the sea area?
— How do the risks develop over time?

The RiskData Hub is useful primarily in the risk analysis stage of the basic screening risk management process in the developed PPR risk management framework based on ISO 31000:2018, introduced in Section 2, and to a lesser extent in the extended screening and intermittent risk management processes. It also has a use in the risk identification stage, through the focus on exposures and hazards as information layers. It provides quantitative outputs, and requires a medium commitment of resources in terms of data provision to the RiskData Hub. Little experience is needed for using the method and for extracting results. The RiskData Hub can be used for:

— Linking policy and practice through geospatial technology and mapping, by combining top-down strategies (e.g. formulation and implementation of policy) with bottom-up methodological approaches (e.g. analysis of the causal factors of disasters);
— Supporting the use of local data in risk assessment applications for achieving local, national, and regional benefits;
— Supporting and guiding the development of databases of losses, damages, and exposures with national scope and local scale;
— Supporting disaster risk mapping as an essential component of risk management;
— Enabling research expertise for performing the national risk assessment;
— Providing a first estimation of damages and losses from extreme events, while anticipating the access to instruments able to finance risk-prevention measures;
— Capitalising on the existing knowledge, networks, tools, methods and data and supporting their broad dissemination and technology transfer to optimize resources and to move to a more homogeneous approach.

1 Three emissions scenarios, termed Representative Concentration Pathways (RCP) by the Intergovernmental Panel on Climate Change (IPCC). All scenarios specify radiative forcing relative to pre-industrial conditions. The RCP8.5 scenario is the most severe, with greenhouse gases continuing to increase through the next century, resulting in radiative forcings of 8.5 W/m2 , CO2 concentrations of 1370 ppm and a temperature anomaly of 4.9°C by 2100. The RCP4.5 scenario represents a medium future scenario, where greenhouse gases and therefore radiation stabilize by the end of the century with an overshoot at 4.5 W/m2, 650 ppm CO2, and a temperature anomaly of 2.4°C. The least severe future scenario is the RCP2.6, which includes a mid-century peak at 3 W/m2 before declining to 2.6 W/m2 , 490 ppm CO2, and a temperature anomaly of 1.5°C.

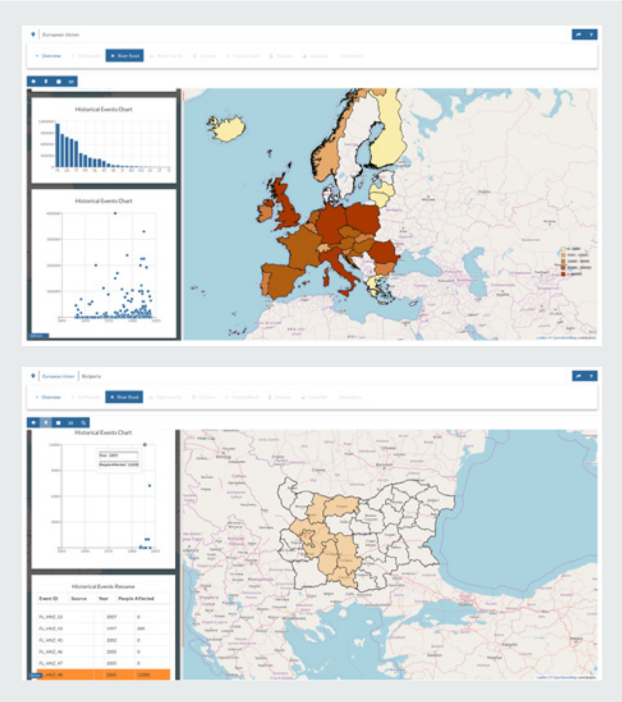


Figure 3.4.4.
Historical events and people affected by flood in Europe. Country level picture with area affected by the 13 June 2005 flood.

3.4.4 Input

The RiskData Hub hosts data shared on a voluntary basis and through scientific partnership by EU Member States and DRMKC partners. Producing an inventory of relevant disaster risk data will set the bases for providing science-based advice for DRM policies. The main input data are:

— Risk data: both raw and aggregated (at administrative units EEZ, NUTS 3, LAU level)[2] representing data of risk and determinants of risk such as exposure, vulnerability and hazard. We consider several types of exposure layers: physical (protected area, aquaculture, reefs etc.), infrastructure, population and demography, socio-economic activities. For vulnerability we consider proximity to risk "engines": traffic densities, oil rigs, major ports, marine currents etc. For the hazard assessment, we divide the data in endogenic (oil spill, river discharges, etc.) and exogenic (SST, salinity, etc.);
— General spatial data: represented by geospatial data (layers of administration boundaries, geophysical features, bathymetric maps) and stored in the Database Management System (PostgresSQL and PostGIS);
— Good practices in risk assessment: Outputs of past and actual projects;
— Metadata: following INSPIRE recommendations and stored in the Database Management System (PostgresSQL and PostGIS).

3.4.5 Process

The RiskData Hub identifies measureable and geographically defined impact areas from multiple hazards using geospatial analysis. In the context of disaster risk assessment, it is assumed that an element or system is at risk if they are located in the range of a hazard. Based on this assumption, the spatial extent of the hazardous event is determined, i.e. the area is identified which can be affected by a potential impact. The spatial location of the specific elements that are exposed, are mapped. In this way, hazard metrics are linked with exposure attributes, by suggesting and linking existing tools, methods, and data from diverse sources. Simultaneously, it is determined which hazard can lead to what potential impact.

3.4.6 Output

The RiskData Hub currently includes a Web Application, the RiskData Portal, and RiskData database. The Web Application has a map interface as core functionality. It enables geospatial data exploration and visualization both from local database and through links to other platforms and services.

The map interface, shown in Figure 3.4.5, is a JavaScript client application applied on top of Geonode, the geographic Content Management System (CMS). It allows users to easily select, visualize and download data, based on selected filters and geographical areas. Hierarchically classified administrative units represent the statistical units where data is geospatially represented. The map interface summarizes the information per hazard type. The information is then further divided in two modules: Risk Analysis and Historical Events. The user can select within these modules the domain of analysis represented by sector-structured exposure (e.g. population, economy, area protected, built-up space, infrastructure, etc.) and their attributes (the metrics of the domains, e.g. demographic metrics).

The Risk Analysis module is based on the identification of the impact areas by means of exposure analysis. Links to various exposure layers (population and built-up grids, Open Street Map layers, etc.) and the hazard layer from various sources are made available for the user to discover and compare.

The Historical Events module offers a collection of extreme events and related losses and damages. A spatial representation of area affected by hazardous events is presented by linking to Copernicus products (e.g. satellite images). Comparison between the magnitude of losses and regions' economic character aims to anticipate the access to EU financial instruments such as Solidarity Funds.

3.4.7 Strengths and limitations

Some strengths of the RiskData Hub include:

— Hosting and sharing multi-risk spatial and numerical data per hazard type;
— Providing an initial assessment of potential impacts from hazardous events;
— Providing means for centralised data collection with Europe-wide access;
— Using Open-Source Technologies and Guarantee Open Data Access, future development can easily be managed, and additional functionalities can be built into the service;

2 The Nomenclature of Territorial Units for Statistics (NUTS) and the LAU nomenclature are hierarchical classifications of statistical regions that together subdivide the EU economic territory into regions of five different levels (NUTS 1, 2 and 3 and LAU 1, 2, respectively, moving from larger to smaller territorial units). The NUTS classification has been officially established through Regulation (EC) No 1059/2003 of the European Parliament and of the Council and amendments. A non-official NUTS-like classification has been defined for the non-EU countries. The LAU classification is not covered by any legislative act. An introduction to the NUTS classification is available here: http://ec.europa.eu/eurostat/web/nuts/overview

— Assuring multiple user authorization levels, allowing member states to manage, create, update and publish data and information;
— Compliance to INSPIRE Directive, ensuring interoperability of geo-spatial open data.

Some limitations of the RiskData Hub include:

— No bindings other than the scientific partnership is liable for data collection;
— Possible discrepancies between member states in the alignment of methodological approaches and data used as input.

Notes and practicalities

The RiskData Hub provides three roles for users. The Admin role that is assigned to the Administrator that will manage users' profiles and data to the system. The second Admin role is foreseen to have national/local competency. This multi-user will have the character of national contact point and will have access to the map interface and the database. This group of users, under the advisory of the Administrator, will manage user credentials and it will allow tasks such as creating, updating and deleting data and information in their own created part of the web application. The member states will have a dedicated corner on the platform that will be managed by the country contact point - still to be defined. The third role, the wide public (scientists, decision makers, students etc.) will have access to the data, reports and analyses presented on the platform, freely available to download.

The DRMKC RiskData Hub is still at the level of a prototype, it requires further developments in terms of content and functionality. For the moment it can be accessed only within the Commissions' institutions at the address: http://139.191.10.182. It is foreseen to be publicly available within June 2018.

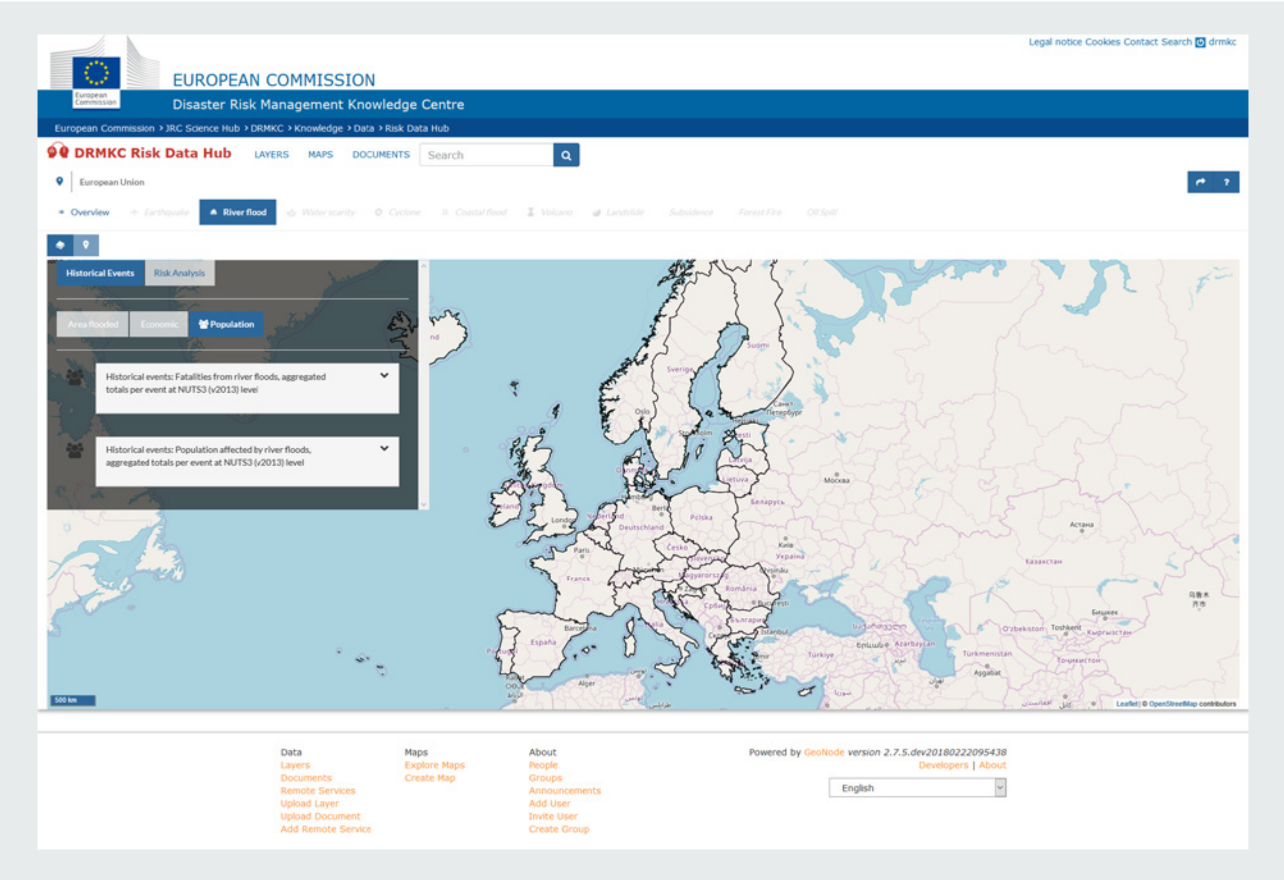


Figure 3.4.5.
RiskData Hub map interface

3.5. IALA Waterway Risk Assessment Programme

3.5.1 Background

In risk management for pollution preparedness and response, one important question concerns the sea areas where maritime accidents are likely to occur. This can be important information for decision making concerning the required response capacity in terms of response equipment in different sea areas [1]. Another use of this information is decisions related to the need for additional safety measures to prevent navigational accidents in specific sea areas, e.g. through enhancements in aids to navigation or through redesign of traffic separation schemes.

The IALA Waterway Risk Assessment Programme (IWRAP) is a modelling tool aimed to provide authorities a standardized quantitative method for estimating the probability 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, as well as for scenarios involving changes in traffic volume or composition, changes in route geometry, or changes in the applied Aids to Navigation in the area, or inclusion of other mitigation options [2].

IWRAP has evolved from a probabilistic methodology for estimating the probabilities of groundings and collisions [3, 4]. A description of the basic modelling approach is presented in [5], whereas [6] presents an early version of the software implementation of the model. In 2007, the IALA Risk Management Steering Group decided to initiate the development of a second generation of IWRAP, which resulted in the currently available IWRAP MK II tool. A detailed guide to the theory underlying IWRAP and an extensive user manual is made available by IALA [7].

3.5.2 Overview

The IWRAP MK II tool is based on a model for calculating the collision and grounding frequency on a specific route. This model involves a so-called causation probability, which is multiplied with a theoretically obtained number of grounding and collision candidates. This is written as:

$$\lambda_{acc} = P_C \times N_G \qquad \text{(Eq. 3.5.1)}$$

where λ_{acc} is the accident frequency, P_C the causation probability, and N_G the theoretical number of grounding or collision candidates.

The causation probability models the probability of the officer on watch not reacting in time when the vessel is on collision course with another vessel, or on a grounding course. Its numerical value is not uniform, but varies for different geographical locations and navigation conditions. The applied value in practical applications is typically adjusted by calibrating it with available data, whereas default values are available from IALA [2], see Table 3.5.1.

The theoretical number of grounding or collision candidates is deduced from an analysis of the vessel traffic in the given waterway or sea area. This involves a specification of the routes and the associated traffic on the routes, which needs to be grouped in a number of

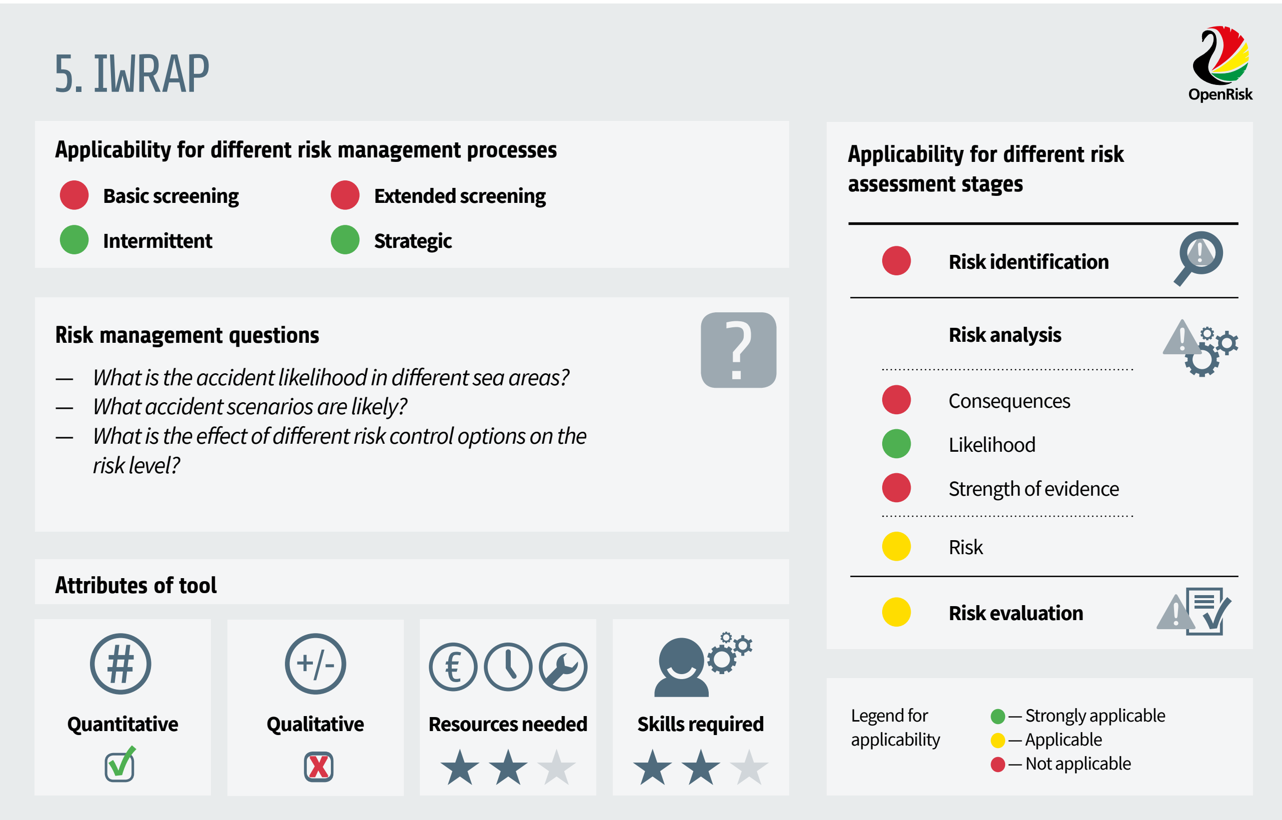


Figure 3.5.1.
Overview of the IWRAP tool: Risk management questions addressed, tool attributes, and applicability for different risk management processes and risk assessment stages

Table 3.5.1.
Default causation factors, IALA [2]

Condition	Causation factor [-]
Head on collisions	0.5 10^{-4}
Overtaking collisions	1.1 10^{-4}
Crossing collisions	1.3 10^{-4}
Collisions in bend	1.3 10^{-4}
Collisions in merging	1.3 10^{-4}
Groundings – forget to turn	1.6 10^{-4}

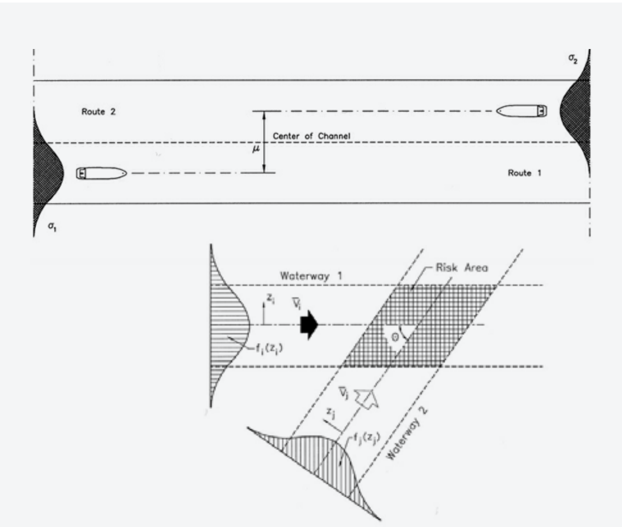


Figure 3.5.2.
Two collision types as defined in IWRAP, illustration from [8]

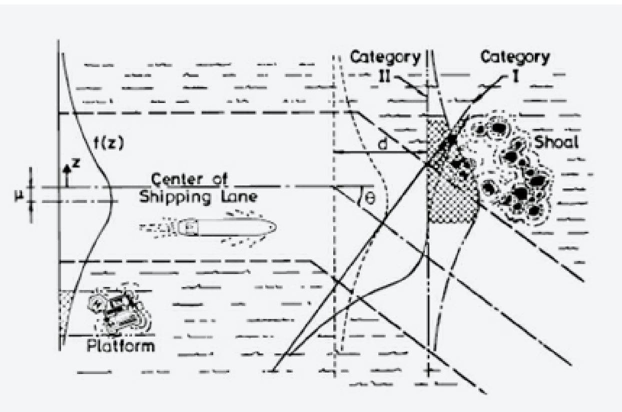


Figure 3.5.3.
Grounding types of category I and II, illustration from [8]

different ship classes according to vessel type, size, etc. The number of vessels per time unit per route segment also is needed in the analysis. IWRAP contains tools for extracting the traffic distribution and traffic densities from AIS (Automatic Identification System) data.

IWRAP divides collisions into two types [7]:

— Collisions along the route segment, i.e. overtaking or head-on collisions;
— Collisions when two routes cross each other, merge, or intersect each other in a turn.

The procedure for calculating the number of collision candidates NG for these two types is conceptually different, with the former depending on the lateral traffic distribution and the latter independent of this. This is illustrated in Figure 3.5.2. It is seen that for collisions along the route segment, the probability that the path of two meeting ships will overlap depends on the distribution of the lateral position where the vessels are sailing. For larger μ-values, the probability of collision decreases. Details about the mathematical formulas for calculating NG for these two collision types can be found in [8].

IWRAP recognizes four types of groundings [7]:

I. Ships following the ordinary direct route at normal speed. Accidents in this category are mainly due to human error, but may include ships subject to unexpected problems with the propulsion/steering system that occur in the vicinity of the fixed marine structure or the ground;
II. Ships that failed to change course at a given turning point near the obstacle;
III. Ships taking evasive actions near the obstacle and consequently running aground or colliding with the object;
IV. All other track patterns than category I, II, or III, for example ships completely out of course due to loss of propulsion.

Figure 3.5.3 illustrates the grounding types of category I and II of the above list. Groundings are further treated separately as powered groundings and drift groundings, where in the former the vessel kept propulsion up to the moment of impact, whereas in the latter the grounding is the result of a loss of propulsion power and subsequent drifting aground. The number of grounding candidates is based on a series of formulas which can be found in [7].

3.5.3 Use

The IWRAP tool can be used to answer the following risk management questions:

— What is the accident likelihood in different sea areas?
— What accident scenarios are likely?
— What is the effect of different risk control options on the risk level?

IWRAP is primarily useful in the risk analysis stage of the intermittent and strategic risk management processes in the developed PPR risk management framework based on ISO 31000:2018, introduced in Section 2. While the focus is exclusively on estimating the accident probabilities in the waterway areas, the tool also provides accident scenarios which can be used as input for estimating accidental consequences, e.g. using the Accidental Damage and Spill Assessment Model, see Section 3.8. Through modifying the causation factors, or by modifying the traffic patterns which affect the collision and grounding candidates, the effects of implementing risk control options can be evaluated. IWRAP provides quantitative outputs, and requires a medium commitment of resources in terms of developing suitable input data, and time to prepare a traffic flow model to execute the analysis. Moderate experience is needed for using the method and for extracting results.

3.5.4 Inputs and Outputs

The IWRAP tool can use various kinds of information. Here are some examples of useful sources:

— Traffic information, in particular 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

As outputs, IWRAP provides the annual average collision and grounding frequencies in the different route legs and waypoints. This can be further split up for different ship types. Insights in accident scenarios can also be obtained.

3.5.5 Process

The overall risk analysis process using the IWRAP Mk II tool involves the following steps:

1. Defining bathymetry, routes, waypoints and legs;
2. Entering traffic volume distributions on each leg;
3. Defining the lateral distribution of the traffic on the legs;
4. Setting up parameters for grounding due to drifting;
5. Defining other traffic in the area;
6. Selecting appropriate causation probabilities;
7. Calculating the results and final analysis.

Further details of the specific activities in each step can be found in [2] and [7].

It should be noted that while IWRAP Mk II is an advanced, flexible tool for creating models of waterways and for analyzing risk in terms of collision and grounding frequencies, the quality of the analysis is highly dependent on the analyst. The analyst must make a number of choices, such as selecting the route layout, estimating the traffic density and distribution, and determining causation factors. Therefore, it is essential that analysts using IWRAP Mk II are properly trained and fully capable of understanding the implications of their choices. Training sessions for the IWRAP Mk II software are organized regularly, see [7].

3.5.6 Strengths and limitations

Some strengths of IWRAP include:

— Stable and proven basic software;
— It has been used for different sea areas, e.g. the Gulf of Finland [9] and the sea area around Bornholm [10];
— Training sessions are organized regularly.

Some limitations of IWRAP include:

— Only calculates the frequencies of collision and grounding accidents, not the consequences. However, the results can be used as input information for determining accidental consequences (e.g. oil spills) when used alongside suitable tools;
— Commercial software is needed for ease of use, in case automatic import of AIS data is desired for calculating the traffic information. Adequate resources must be available to use the tool, also because manual creation of route legs can be very labour-intensive;
— The mathematical formulations of the accident frequency modelling are complex, and not very intuitive. Some work [11], moreover, shows that other methods to calculate accident frequencies, e.g. [12], can lead to very different results;
— Results are highly dependent on the expertise of the analyst;
— The utilization of the full potential of the IWRAP tool requires high resolution AIS data, which is not available in many countries.

Notes and practicalities

IWRAP Mk II is implemented as an MS-Windows™ based software. The basic IWRAP Mk II version is available free of charge to IALA members form the IALA-AISM website. A commercial version is also available, which automates the inputting of information on volume and composition of the vessel traffic in a given area, based on AIS data. Further information about this version can be found in IALA (2018).

3.6. Ports and Waterways Safety Assessment

3.6.1 Background

In risk management for oil spill preparedness and response, it is important to get a wide understanding of the importance of various aspects contributing to the risk levels in specific waterway areas, and to assess the effectiveness of mitigation measures. The Ports and Waterways Safety Assessment (PAWSA) method was developed to meet the requirements of the United States Coast Guard (USCG) in an acquisition program for Vessel Traffic Services (VTS).

The method was developed through a national dialogue group, in which maritime and waterway community stakeholders convened to identify the needs of waterway users with respect to Vessel Traffic Management (VTM) and VTS systems. This work led to the development of the PAWSA process, which is a disciplined approach to identify major waterway safety hazards, estimate risk levels, and evaluate potential mitigation measures through expert inputs. The overall goal is to find solutions that are both cost effective and meet the needs of waterway users and stakeholders.

An initial modelling approach [1], focusing on supporting decisions to assess traffic management requirements, was later refined in a formal multi-attribute decision analysis model [2]. Based on experiences with the PAWSA workshops, the process was thoroughly revised and the methodologies refined.

Over the years, the PAWSA method has been applied intensively between 1999 and 2001 by Coast Guard Office of Navigation Systems (CG-NAV) to assess the waterway risks in 28 ports around the United States, resulting in the PAWSA Final Report [3]. CG-NAV continues to conduct assessments, with the most recent PAWSA workshop focusing on the navigational safety and environmental protection of the Buzzards Bay waterway system in Massachusetts, USA [4]. The PAWSA method has been recommended by the International Association of Marine Aids to Navigation and Lighthouse Authorities as part of the IALA Risk Management Tool for Ports and Restricted Waterways [5], and IMO has circulated the applicability of the method to the member governments [6]. The method has also been applied in a Chinese channel [7] and a European port [8].

3.6.2 Overview

PAWSA is a formal process, in which specific methods and tools are used in a workshop where waterway users and stakeholders discuss safety issues related to the waterway. These discussions lead to numerical ratings, which provide 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 organized into five logical segments, referred to as "books". The responses are recorded in an aggregate form, and used in the appropriate subsequent phases of the PAWSA process as a basis for discussions among the participants.

The PAWSA process makes use of a waterway risk model, numerical ratings, and freely available software, and is organized as a workshop with a predefined process, and specifically chosen participants. These are briefly described below, with further details given in [9].

Figure 3.6.1.
Overview of the PAWSA tool: Risk management questions addressed, tool attributes, and applicability for different risk management processes and risk assessment stages

Waterway risk model

The PAWSA waterway risk model is a simple diagram in which a set of risk factors, dealing both with contributing factors to the occurrence of waterway casualties, as well as with their effects. These are categorized in the following six risk categories:

1. **Vessel conditions:** the quality of vessels and their crews that operate on a waterway.
2. **Traffic conditions:** the number of vessels that use a waterway, and their interactions.
3. **Navigational conditions:** the environmental conditions that vessels must deal with in a waterway relating to wind, water movement (currents, waves), and weather.
4. **Waterway conditions:** the physical properties of the waterway which affect how easy it is to maneuver a vessel.
5. **Immediate consequences:** the immediate impacts of a waterway casualty: injured or killed persons, spilled oil or hazardous materials, disruptions to the marine transportation system.
6. **Subsequent consequences:** the subsequent effects of waterway casualties incurred hours, days, months, and even years afterwards, e.g. shore-side facility shut-downs, loss of employment, destruction of fishing areas, decrease or extinction of species, contamination of drinking water or cooling water supplies.

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 3.6.2.
PAWSA waterway risk model, from [9]

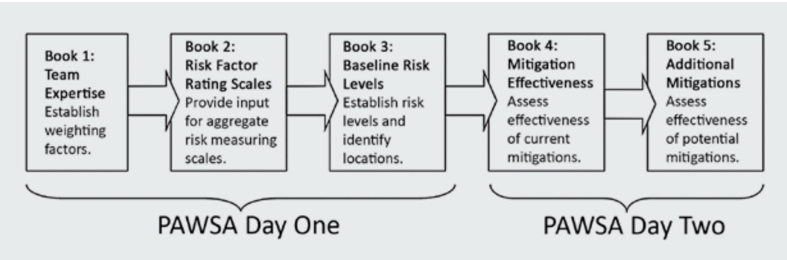


Figure 3.6.3.
PAWSA process: five "books"

The diagram in Figure 3.6.2 shows these six risk categories, along with the risk factors included in each of these.

Numerical ratings in the five "books" of the PAWSA process

A simple overview of the PAWSA process is given in Figure 3.6.3, showing the focus of the different segments ("books") along with recommendations on the workshop timing. The five "books" are briefly outlined here; for further details see [9].

Book 1. Team expertise. In this segment, the expertise of each team is captured relative to the other teams in the workshop. The results of these ratings are used to weigh each team's inputs for all other books.

Book 2. Risk factor rating scales. In this segment, measurement scales are constructed for each risk factor of Figure 3.6.2. Participants are asked to compare specified qualitative descriptions to each other in a pair-wise manner. These qualitative descriptions characterize the range of possible conditions affecting risk in a waterway for that factor.

Book 3. Baseline risk levels. In this segment, participants determine where the waterway falls on the risk scales developed in Book 2. The result of these ratings is the risk level for each factor, where actions already implemented to reduce risk in the waterway are not taken into account.

Book 4. Mitigation effectiveness. In this segment, two activities are performed. First, the participants describe the risk mitigation strategies which already are implemented to reduce the risk level for the waterway. The effectiveness of these strategies is assessed for reducing the risk level for each factor of the model. This results in a rating of the present risk level, accounting for existing mitigations.

Second, the participants make judgments whether the risk mitigation strategies which already are in place adequately balance the resulting risk level. If for any risk factor, there is a strong consensus that the existing mitigations adequately deal with those risks, then that factor is excluded from further consideration.

Book 5. Additional mitigations. In this segment, participants can provide ideas about specific mitigation actions which should be taken, and are asked to estimate how effective those actions would be in further reducing the risk levels. Focus is on those risk factors where the results of Book 4 indicate that the risks are not adequately balanced. Following a discussion, participants decide which ideas have most promise for each discussed risk factor, provide a short description of the action needed, and justify the rating of how much risk reduction the implementation of the idea would entail.

Participants and workshop organization

PAWSA is an expert- and stakeholder-centered process, in which a workshop where discussions and assessments are made, is an essential element. These are briefly considered next.

Workshops are typically executed with a maximum number of participants of 30. Two major groups of participants are targeted: (i) experts in navigation and traffic management in the waterway, and (ii) significant stakeholder groups within the affected local community. The PAWSA guidelines [9] contain further considerations related to selecting participants, including a number of criteria for ensuring a comprehensive PAWSA process. It also contains guidance on practical issues such as inviting participants and read-ahead materials.

As many PAWSA workshops have been organized especially for port and waterway areas in the USA, there is a lot of experience regarding the workshop organization. The PAWSA guidelines contain specific information on the following issues, which can be used as guidance [9]:

1. Preliminary logistics. This addresses roles and responsibilities for organizing a PAWSA workshop, and the selection of a suitable workshop facility.
2. Workshop preparation. This concerns workshop equipment and material requirements, including waterway charts, an information folder for participants, waterway profile materials, the software for use by the participants, and practical materials such as attendance lists and name tags.
3. Workshop conduction. This addresses a pre-workshop meeting of the workshop organizing team, the workshop design with detailed information on what to do when and how, the facility setup, and activities on day one and two of the workshop.
4. Post-workshop action items. This concerns a quality assurance check on the information in the PAWSA books, an analysis of the ratings obtained during the workshop, the completion of the final attendee contact list, performing the workshop critique analysis, and the preparation of the PAWSA workshop report.

3.6.3 Use

The PAWSA tool can be used to answer the following risk management questions:

- How important are different waterway factors as contributors to risk?
- What is the effect of different risk control options on the risk level?

PAWSA is primarily useful in the risk analysis stage of the intermittent and strategic risk management processes in the developed PPR risk management framework based on ISO 31000:2018, introduced in Section 2. PAWSA also has a role in the risk identification and risk evaluation stages. The tool provides qualitative outputs. The process requires a high commitment of resources in terms of finances and time of analysts and substance experts. Moderate experience is needed for leading the necessary workshops, using the method, and for extracting results.

3.6.4 Inputs and Outputs

The PAWSA process can use various kinds of information as inputs for the expert ratings for the risk factors in the waterway risk model, the assessments of the adequacy of the risk mitigation strategies and the ratings of the effectiveness of additional measures. Some examples of information sources which can be useful are listed below, with further details provided in [9]:

- Expert knowledge
- Maritime accident and incident reports and analyses
- Waterway charts
- Traffic information, e.g. from AIS data, port or administration statistics, etc.
- Reports concerning flow of goods in the waterway

As outputs, the PAWSA process is intended to lead to a report, in which the results of the five “books” are described. In particular, the ratings of the team expertise, the baseline risk factors, the mitigation effectiveness, and the effectiveness of additional mitigation strategies, are included in the report. Details about the report format can be found in [9], and example reports in [4].

3.6.5 Strengths and limitations

Some strengths of PAWSA include:

- The waterway risk model and the process are based on extensive consultations within the maritime cluster, with involvement from academia. The process has been refined over many years of use;
- The process is based on wide expertise from diverse waterway experts and stakeholder groups, leading to a maximally relevant knowledge base, while facilitating acceptance of the results;
- The process includes mechanisms to weigh the teams’ expertise for specific issues, increasing the validity of the ratings;
- Focus is not only on the ratings per se, but also on the justification provided in support of these;
- PAWSA considers both factors concerned with accident prevention, preparedness and response;
- The process has a track record of intense use, is supported by an elaborate manual containing practical information, and easy-to-use software is available for use.

Some limitations of PAWSA include:

- The process is resource-intensive, both in terms of financial, personnel and time commitments.
- The process is best suited for local waterway or port areas, and 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. The ratings cannot be easily used along with cost-effectiveness criteria, and are more appropriately used as starting points for quantification of risk reduction and cost effectiveness using other (quantitative) methods.

Notes and practicalities

All material required for the use of the PAWSA method is openly available on the US Coast Guard's website.

3.7. Maritime Event Risk Classification Method

3.7.1 Background

The Event Risk Classification (ERC) is a part of the ARMS Methodology for Operational Risk Assessment. It was originally developed for aviation by the ARMS Working Group from 2007 to 2010. Nowadays it is widely used by different airlines and has a strong track record in providing useful results [1]. The development of the maritime application of ERC started in the Finnish Transport Safety Agency from 2013 to 2015 [2]. This work continued in the OpenRisk project and resulted in the ERC-M tool, consisting of the definition of event classification matrices for environmental damages, loss of life or injuries and economic losses, and in a process for risk identification and analysis. The main expected end-users of this method are Pollution Preparedness and Response authorities, but it can be used also by other authorities, such as Vessel Traffic Services and pilotage authorities.

3.7.2 Overview

Risk identification is the process of finding, recognizing and recording risks. The term risk has been defined in many ways. In other words, the definition of the ISO 31000:2018 is not the only one. The ARMS working group refers to the following definition “Risk is a state of uncertainty where some of the possibilities involve a loss, catastrophe, or other undesirable outcome” [1]. In addition, the working group has used the traditional definition of risk - severity and likelihood - in the method.

The two main components in the ARMS methodology are Event Risk and Safety Issue. The Event Risk is a risk that was present in an individual experienced event in a specific context. In other words, it is not the risk associated with all similar events in the future. For example, an engine blackout occurring in a low traffic open sea area in good weather conditions, is a different situation from a blackout in a high traffic port approach in poor weather conditions. The Safety Issue is defined as a manifestation of a hazard or combination of several hazards in a specific context [1]. It can be understood as events which emerge from the same source(s) of risk in a specific context. For examples, those sources can be blackouts of the general cargo ships on the Baltic Sea.

The ERC-M method is used for analyzing the Event Risk. According to the definition, it is the initial risk classification of operational events using the ERC matrix. The ERC-M matrix is a qualitative matrix for combining consequence and likelihood in order to assess the risk index of a particular event. The matrix takes into account the adequacy and effectiveness of remaining (un-failed) controls. The ERC risk index values can be read directly from the matrix. They are ordinal numerical weightings given to each square of the risk matrix to enable differentiation of risk events for the purpose of subsequent analysis.

The ERC-M takes into account different types of consequences of events. This is because an event can have multiple consequences and can affect multiple objectives. The application includes separate matrices for the risk of loss of human life, environmental damages and economical losses, as shown in Figure 3.7.2. The criteria of these matrices have been derived from the ARMS methodology and adapted to the maritime needs during the OpenRisk project through interviews and workshops.

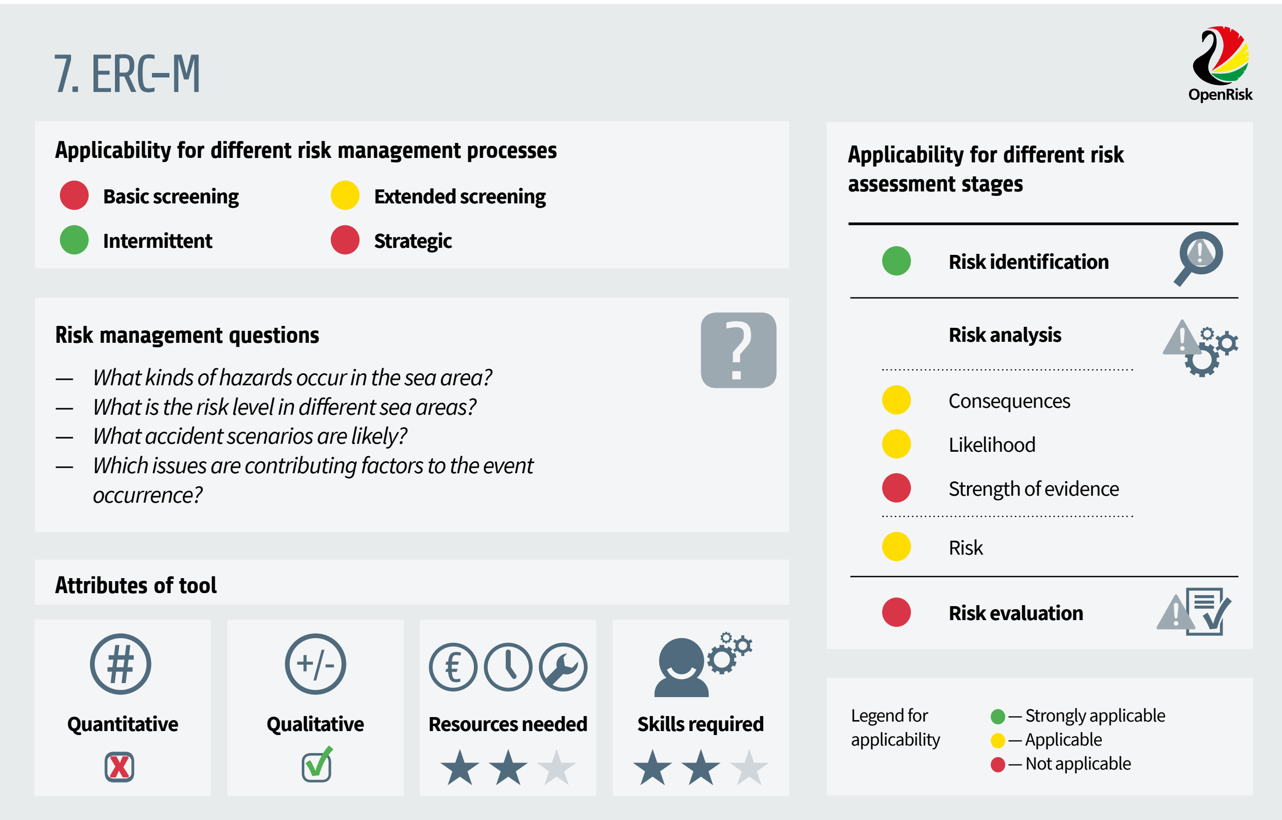


Figure 3.7.1.
Overview of the ERC-M tool: Risk management questions addressed, tool attributes, and applicability for different risk management processes and risk assessment stages

ERC-M Event Risk Classification Matrices

Question 2: What was the effectiveness of the remaining barriers between this event and the most credible accident scenario?

Question 1: If this event had escalated into an accident outcome, what would have been the most credible outcome?

Loss of life or serious injury

Effective	Limited	Minimal	Not effective	Nr of casualties or injuries	Typical accident scenarios
250	503	2 503	12 500	100-	Major passenger ship accidents such as Estonian, Sewol and Scandinavian Star.
50	102	502	2 500	5 - 99	Accidents that have occured to passenger or cargo ships with several casualties or serious injuries.
10	21	101	500	1 - 4	Accidents that have occured to small cargo ships, fishing vessels, tugs and the like, where the potential for loss of life or serious injuries is limited.
2	4	20	100	Less serious injuries	Less serious injuries for crew members or passangers e.g. fractures or minor wounds that have occured during a grounding, contact and like.
1				Zero or insignificant	Any event which could escalate into loss of life or injuries (e.g. diversion, delay, small violation)

Environmental Damages

Effective	Limited	Minimal	Not effective	EU POLSCALE Cathegory	Estimated quantity on-shore (m3)	Lenght of polluted coastline (km)	Scale of the incident	Duration of the response	Environmental Severity (Wildlife)	Environmental Severity (Sensitive Areas)	Economic Severity Scale
250	503	2 503	12 500	Catastrophic	> 10.000	> 100	International	> 6 months	Intensely affected over a wide area	Extensive loss of valuable habitats	Economic activities halted temporary
50	102	502	2 500	Severe	1.001 to 10.000	11 to 100	National	up to 6 months	Affected over many locations wide	Severe but not totally affected	Principal economic activities disrupted
10	21	101	500	Moderate	11 to 1.000	2 to 10	Regional	up to 1 month	Locally affected	Locally affected	Some activities disrupted to a small extent
2	4	20	100	Slight	0.1 to 10	up to 1	Local	up to 1 week	Affected but not significantly	Affected but not significantly	Limited and temporary disturbance
1				Zero or insignificant	< 0.1	0	-	> 1 day	NA	NA	NA

Economical Losses

Effective	Limited	Minimal	Not effective	Cathegory of consequences	Typical insurance claims and examples
250	503	2 503	12 500	Catastrophic	Hull & Machinery up to 750 000 000 € or P&I up to 100 000 000 € Examples: Costa Concordia, Prestige and Erika
50	102	502	2 500	Very serious casuality to ships, cargo or severe damages to third party	Hull & Machinery up to 120 000 000 € or P&I up to 20 000 000 € Examples: total losses, wreck removals, rescue operations and collisions
10	21	101	500	Serious casualty to ships, cargo or moderate damages to third party	Hull & Machinery up to 1 000 000 € or P&I up to 300 000 € Examples: basic dry docking due to grounding or slight environmental damages
2	4	20	100	Less serious casualty to ships or cargo	Cargo & Liability 10 000-50 000 € or Hull & Machinery 30 000-100 000 € Examples: Minor damages to ship, ship's equipment or cargo.
1				Zero or insignificant	Any event which could not escalate into economical losses.

Effectiveness rating	Definition
Effective	An abnormal situation, more demanding to manage, but with still a considerable remaining safety margin. This could be a violation of the COLREG rules in a sea area with no other traffic nor range of rocks around for example.
Limited	An abnormal situation, more demanding to manage, but with still a considerable remaining safety margin. This could be a violation of the COLREG rules in a sea area, with some other traffic or range of rocks around for example.
Minimal	Some barrier(s) were still in place but their total effectiveness was 'minimal'. This could be a close near miss situation for example.
Not effective	An accident was not avoided, or the only thing separating the event from an accident was pure luck or exceptional skill, which is not trained nor required.

Figure 3.7.2.
ERC-M Event Risk Classification Matrices for loss of life, environmental damages, and economic losses

Safety Issues can be explored with methods applicable for risk analysis. Typical tools and techniques used for the Safety Issue in airlines are Safety Issue Risk Assessment (SIRA) and BowTie analysis. The SIRA tool is a part of the ARMS methodology. It includes the risk controls (barriers) in the assessment. The conceptual framework for this risk assessment is one where the occurrence probability is calculated as the product of four factors: prevention, avoidance, recovery, and minimization of losses. The severity is assessed separately, and the probability-severity combination is compared with predefined acceptability limits. The BowTie method is widely used in different industries and is suitable for maritime needs as well.

3.7.3 Use

The ERC-M tool can be used to answer the following risk management questions:

- What kinds of hazards occur in the sea area?
- What is the risk level in different sea areas?
- What accident scenarios are likely?
- Which issues are contributing factors to the event occurrence?

ERC-M is primarily useful in the risk identification and risk analysis stages of the intermittent risk management process in the developed PPR risk management framework based on ISO 31000:2018, introduced in Section 2. ERC-M may also have a role in the extended screening process. The tool provides qualitative outputs. The process requires a medium commitment of resources in terms of finances, and analysts' time. Moderate experience is needed for applying the method, and for extracting results.

In the maritime context, an important use of the ERC-M is to identify Safety Issues. In principle, both concepts of risk, Event Risk and Safety Issue, can be used for risk identification. However, Safety Issues need to be analyzed based on aggregate statistics of many risk events rather than using casuistic stories of the most significant events.

Furthermore, the maritime ERC-M can be used for enriching safety data. The risk index values makes it possible to provide risk-based statistics, which gives a much better basis for decision-making than classical statistics based only on the number of events [3].

3.7.4 Input

The maritime ERC deals with various types of safety data. The main rule is that it is used for events, even when there is no actual consequence [1]. In order to make reliable assessments, it is important to get all the data available of each event assessed.Here are some examples of potential data sources:

- VTS Incident Reports
- Marine Casualty Reports
- Accident Investigation Reports
- Shipping Companies Accident and Incident Reports
- Pilotage Incident Reports

The safety data should be entered into a structured database, which can be used for recording risks and data analyses, and where individual events can easily be found. The database facilitates different kinds of statistical analyses for the risk identification. When creating the database, it is necessary to classify the data in different categories and sub-categories. Here are some examples:

- Date and time
- Location (latitude/longitude)
- Weather and sea conditions including visibility (good/moderate/poor)
- IMO number
- Ship type and size (e.g. HELCOM detailed classification)
- Ship speed during the event (knots)
- Information of cargo (if available)
- Pilot onboard (yes/no)
- Event description or type
- Accident or scenario (grounding/collision/contact/fire or explosion/foundering/capsizing/other)
- Aspect of risk (environmental damages/loss of life/economic losses)

In addition to these factual elements, it is recommended to collect data about the adequacy and effectiveness of the controls. This is valuable for further risk analyses.

3.7.5 Process

Figure 3.7.3 illustrates the main steps of the ERC-M risk identification process. The first step consists of data collection, and the construction of a structured database to record risks and serve as a basis for further analyses.

The second step in the process is the initial risk classification of events by using the ERC-M matrices. This step attaches risk index values to each event in terms of loss of human life, environmental damages and economical losses. This is necessary for creating safety statistics reflecting the risks of historic maritime events.

The method contains two questions, which help a person who is carrying out assessment to place the events in the correct position on each matrix. These are:

- Question 1. Had this event escalated into an accident, what would have been the most credible accident outcome?
- Question 2. What was the effectiveness of the remaining controls between this event and the most credible accident outcome?

The first question is used to identify the most credible accident outcome, when a considered event in a particular situation occurs. It determines the potential consequences of the event, and is used to determine the classification of the event on the vertical axis of the matrix. The second question focuses on the remaining controls between the event as it occurred and the most credible accident outcome. This relates to the likelihood of the accidental event, and is used to determine the classification of the event on the horizontal axis of the matrix.

The ERC-M classification should be carried out by an analyst (or ideally a team) with operational experience, and training in using the method. Care should be taken not to neglect low risks which occur frequently and have a significant cumulative effect. There is likely to be some subjectivity between users in the answer to the first question depending upon how they consider the factors causing the event. However, that variation is dealt with in question 2 through consideration of the remaining controls, and hence the probability of that accident outcome. The risk colors and values in the ERC-M are intended to ensure that possible variations in the exact positioning of the event in the matrix produce similar outputs in terms of risk [1]. Rather than aiming to very accurately estimate the risk level, the ERC-M method aims to indicate rather roughly what risk levels are associated with events which actually occurred in particular situations.

The third step in the process is data analysis for the risk identification and analysis. Even though single events are important, the Safety Issues are more important in this maritime context. These provide specific issues which are commonly involved in the occurrence of maritime incidents, and hence assist in the risk identification stage. The overall classification of the risk levels also provide insights for the risk analysis stage. By looking for patterns in the database, it is also possible to gain an understanding of the likely accident scenarios in the sea area, which can provide useful information for spill consequence and drift models such as ADSAM and SeaTrack Web, see Section 3.8 and Section 3.9. Most of the data analyses can be done with Microsoft Excel software, or similar packages. However, for the hotspot identification and the like more sophisticated GIS software is needed, such as ArcMap.

3.7.6 Output

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 that describe different aspects of risk on ship types, time periods and accidents for example. The output can include also information about adequacy and effectiveness of the controls.

3.7.7 Strengths and limitations

Some strengths of the ERC-M include:

- It focuses on events which actually occurred, assisting in identifying risks and the safety issues involved in the event occurrence;
- It provides a rapid ranking of risks into different levels;
- It can provide insights in the spatial distribution of hazardous event occurrence, and in differences between for instance ship types;
- It is relatively easy to understand and use.

Some limitations of the ERC-M include:

- It provides relatively coarse information, limited to historic events;
- It is highly dependent on the availability and quality of data and information about events;
- It is somewhat time-consuming, requires some commitment of resources, and some training.

Notes and practicalities

The full scale ERC-M risk assessment matrices, for environmental damages, loss of life or injuries and economical losses are openly available on HELCOM Response website.

The ARMS Methodology for operational risk assessment is free of charge and may be customized to suit particular needs.

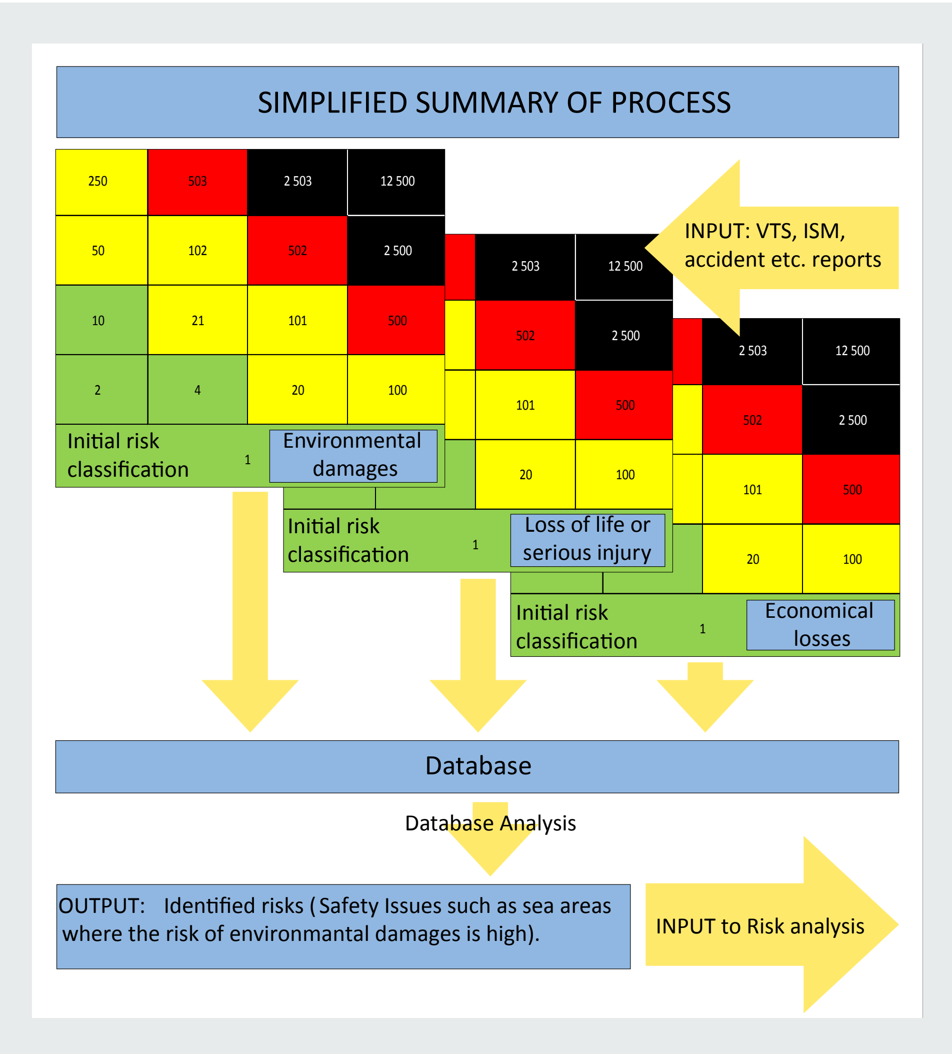


Figure 3.7.3.
Summary of ERC risk identification process

3.8. Accidental Damage and Spill Assessment Model for Collision and Grounding

3.8.1 Background

In risk management for pollution preparedness and response, an important question is how large the possible spills in a waterway area are likely to be [1]. This depends, amongst others, on the vessel types operating in different areas, the cargoes transported, and the types of incidents and accidents which can lead to an oil spill. Several approaches have been proposed for determining the required response capacity, including estimates of the possible or likely oil spills in different sea areas [2, 3].

Decisions regarding the target spill have major implications for the risk management processes, as this involves decisions regarding the required response equipment, which directly relates to investment and operational costs [1]. Hence, tools which can assist in determining the likely oil spill sizes can be of great value in pollution preparedness and response risk management, e.g. for setting target spill sizes as a basis for the design of the response system.

A number of approaches have been developed and applied for estimating target spills. Acknowledging the importance of preparedness to both oil spills from illegal discharges and accidents, the target spills are usually defined with reference to the latter spill type. This is because accidental spills can be much larger than typical spills from illegal discharges, and because response planning needs to ensure effective oil combating also in the case of major spills [1]. Existing simple approaches for accidental spill estimation include, e.g. estimates based on the carrying capacity of tankers [3], or direct expert judgment [4]. Some more advanced models for estimating oil outflow have been developed as well, e.g. [5, 6]. These models, however, have limitations, e.g. in relying on important simplifying assumptions concerning the accidental damage extent, by providing very conservative estimates regarding the spill in case of an accidental hull breach (typically assuming all oil is spilled), or having a limited scope of applicability to specific tanker sizes. Moreover, these models are not implemented in accessible and practically useful tools, further limiting their applicability.

In order to address the above issues, new tools have been developed in the OpenRisk project for assessing the consequences in collision and grounding accidents, focusing on the oil spill sizes from tankers in collision and grounding accidents. These limitations in scope are made because tankers present the main concern in oil spill response planning, as clear from existing approaches for estimating spills, and because collisions and groundings are widely understood as the main accident types with a potential to lead to major oil spills [7].

The tools integrate a number of existing models for estimating typical tanker layouts, assessing the damage in collision and grounding accidents, and assessing the oil outflow for a given damage extent. The tool directly links accident scenarios with corresponding oil outflows, so no intermediate information processing is required by the user.

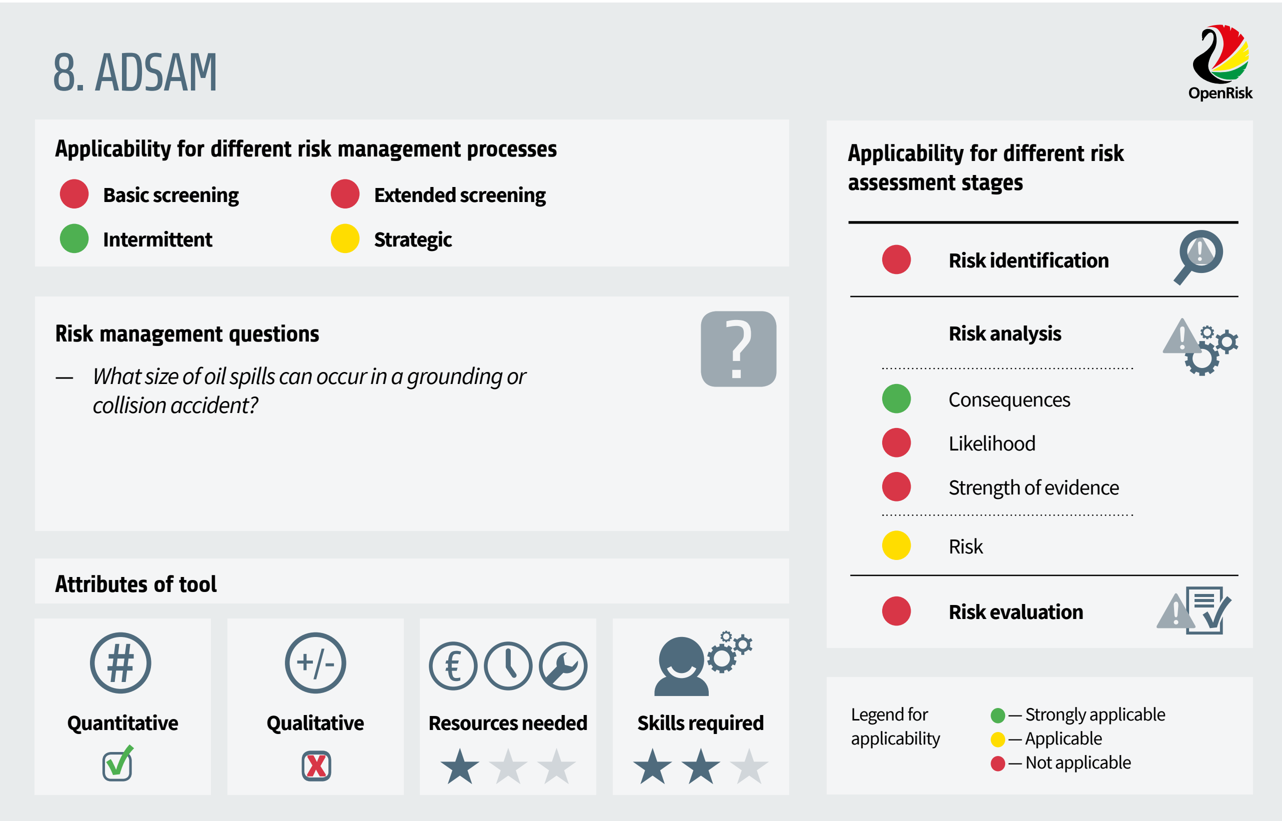


Figure 3.8.1.
Overview of the ADSAM-C/G tools: Risk management questions addressed, tool attributes, and applicability for different risk management processes and risk assessment stages

3.8.2 Overview

The spill consequence tools are known as ADSAM-G and ADSAM-C, which are abbreviations of respectively "Accidental Damage and Spill Assessment Model for Grounding", and "Accidental Damage and Spill Assessment Model for Collision". The tools take several parameters into account which jointly describe a number of key aspects of the accident scenario, providing estimates of the oil outflow in the scenario. The ADSAM-G tool is implemented in an online web application, while the ADSAM-C tool is implemented as a stand-alone Bayesian Network. ADSAM-G has also been developed into a Bayesian Network, known as ADSAM-GP. Whereas ADSAM-G provides point estimates of oil spills for accurately described single scenarios, ADSAM-GP and ADSAM-C provide a probabilistic description of oil consequences.[1] This means that it is possible to evaluate the probability of different consequences considering the uncertainty about the input scenarios. Bayesian Networks are graphical tools with a certain intuitive appeal, and are widely used in quantitative risk analysis [8], also in maritime applications [9]. Bayesian Networks are also a major element in the Spatial Bayesian Oil Spill Risk Tool, introduced in Section 3.15.

The ADSAM-G and ADSAM-C tools are developed based on several types and sources of background evidence. These elements include:

1. Data and a model for the general layout for tankers, including the main dimensions, and the size and position of the cargo and bunker tanks. Details are described in [10];
2. Models for assessing the collision and grounding damage for a specific accident scenario. For details, see [11, 12];
3. A model for assessing the oil outflow in the time domain. For details, see [13].

1 ADSAM-C is not yet implemented in the online application, as the current version of the underlying model only is a beta-version. Due to some technical issues with the underlying model, it moreover only covers a limited set of scenarios.

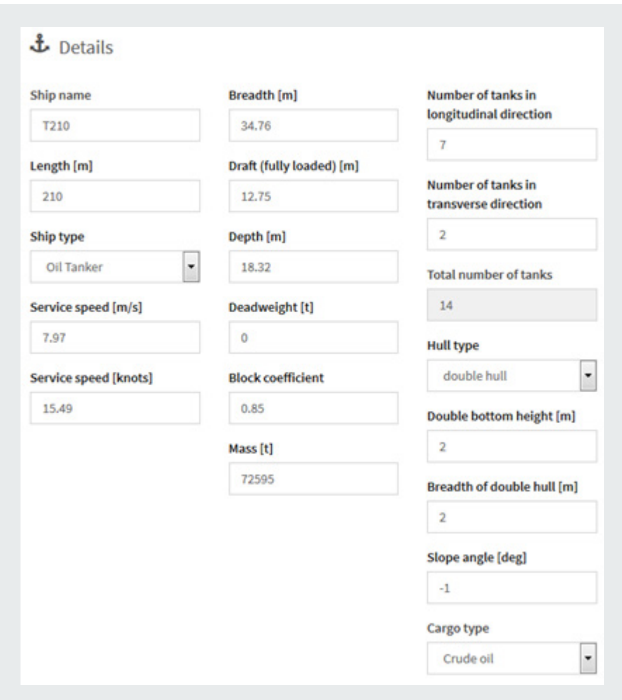


Figure 3.8.2.
Accidental Damage and Spill Assessment Model for Grounding (ADSAM-G): Vessel definition

In the following sub-sections, the ADSAM-G, ADSAM-GP, and ADSAM-C tools are introduced.

Accidental Damage and Spill Assessment Model for Grounding (Deterministic): ADSAM-G

ADSAM-G is implemented in an online application, which can be used to determine the oil spill in a specific single grounding accident scenario. The tool first allows to define a ship type, for which the oil spill calculations can be performed. The definition of a ship type requires the specification of a number of vessel details, including the main dimensions, number of cargo tanks, hull type, and others. This is shown in Figure 3.8.2. Then, the tool allows the specification of an accident scenario. This requires a set of contextual parameters, including the position and characteristics of the rock, characteristics of the transported oil type, and impact speed and location of the vessel impacting the rock. This is shown in Figure 3.8.3. Details about the input parameters and outputs are given in Section 3.8.4.

Accidental Damage and Spill Assessment Model for Grounding (Probabilistic): ADSAM-GP

ADSAM-GP is implemented as a stand-alone model, which can be used to determine the oil spill in range of grounding accident scenarios. The tool implements a set of predefined tanker vessels of different sizes, and a set of transported oil types with predefined characteristics. The tool also permits the definition of the accident scenario, in particular the rock size, ship speed at impact, the water depth, and impact position. ADSAM-GP is a probabilistic model, which means that the accident scenario is defined through a set of input variables, which have a number of defined states. These different states can be assigned probabilities, where two (or more) states are given non-zero probabilities. This corresponds to situations where the analyst is uncertain about the values of the parameter under consideration. The ADSAM-GP tool is shown in Figure 3.8.4. The nodes at the top of the figure describe the inputs characterizing the accident scenarios (e.g. tanker size, impact location), whereas the nodes at the bottom represent the outputs in terms of oil outflow size (e.g. size of oil outflow 1 hour after impact). The nodes are connected with arrows to encode information about the probabilistic dependencies between inputs and outputs. Each node consists of a set of so-called states, which represent a class (e.g. a certain oil type) or range (e.g. a range of impact speeds) for the respective variable. Details about the input parameters and outputs are given in Section 3.8.4.

Accidental Damage and Spill Assessment Model for Collision: ADSAM-C

ADSAM-C is implemented as a stand-alone model, which can be used to determine the oil spill in range of ship-ship collision accident scenarios. The tool implements a set of predefined tanker vessels of different sizes, a set of predefined impacting vessels of different sizes, and a set of transported oil types with predefined characteristics. The tool also permits other characteristics of the accident scenario, in particular the speeds of the vessels at the time of impact, the impact angle, and the relative position along the tanker hull where the striking vessel impacts the tanker. ADSAM-GP is a probabilistic model, which means that the accident scenario is defined through a set of input variables, which have a number of defined states. These different states can be assigned probabilities, where two (or more) states are given non-zero probabilities. This corresponds to situations where the analyst is uncertain about the values of the parameter under consideration. The ADSAM-C tool is shown in Figure 3.8.5. The nodes at the top of the figure describe the inputs characterizing the accident scenarios (e.g. tanker size, impact location), whereas the nodes at the

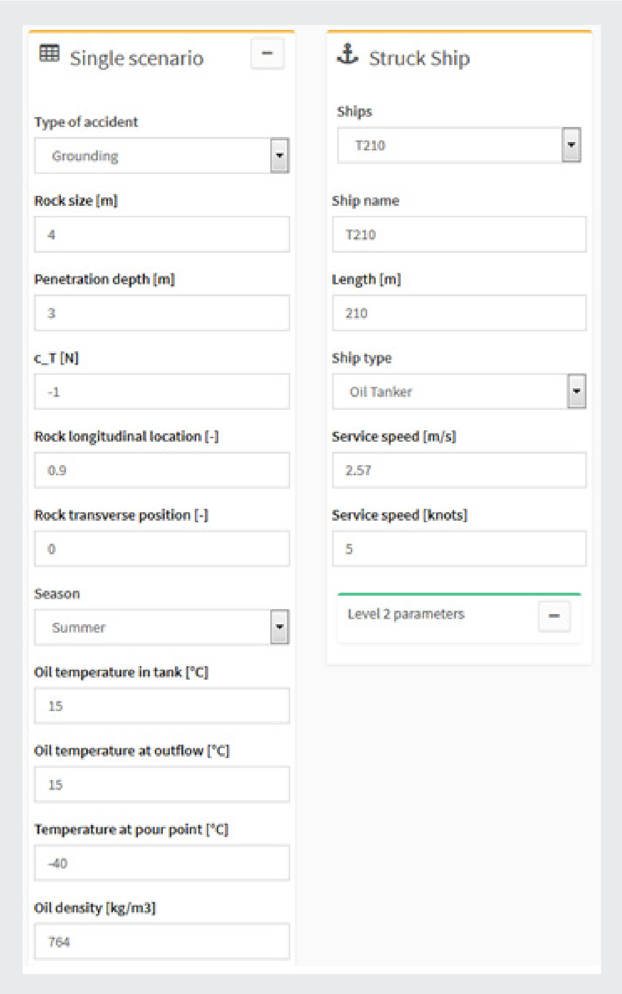


Figure 3.8.3.
Accidental Damage and Spill Assessment Model for Grounding (ADSAM-G): Scenario definition

bottom represent the outputs in terms of oil outflow size (e.g. size of oil outflow 1 hour after impact). The nodes are connected with arrows to encode information about the probabilistic dependencies between inputs and outputs. Each node consists of a set of so-called states, which represent a class (e.g. a certain oil type) or a specific value (e.g. a particular impact speed) for the respective variable. Details about the input parameters and outputs are given in Section 3.8.4.

3.8.3 Use

The ADSAM-G/C tool can be used to answer the following risk management question:

— What size of oil spills can occur in a grounding or collision accident?

ADSAM-G and ADSAM-C are primarily useful in the risk analysis stage of the intermittent risk management process in the developed PPR risk management framework based on ISO 31000:2018, introduced in Section 2. The tools also have a role in the strategic risk management process. Focus is on the consequences. The tool provides quantitative outputs about the spill sizes. The process requires a low commitment of resources in terms of finances, and analysts' time, once the tool is fully implemented. Little experience is needed for applying the method, and for extracting results.

3.8.4 Input and output

The ADSAM-G and ADSAM-C tools can use various kinds of information as inputs for the nodes describing the accident scenarios. These information sources can be useful:

— Expert knowledge
— Maritime accident and incident reports and analyses
— Traffic information, e.g. from AIS data, port or administration statistics, etc.
— Reports concerning flow of goods to and from different ports
— Hydrographic information

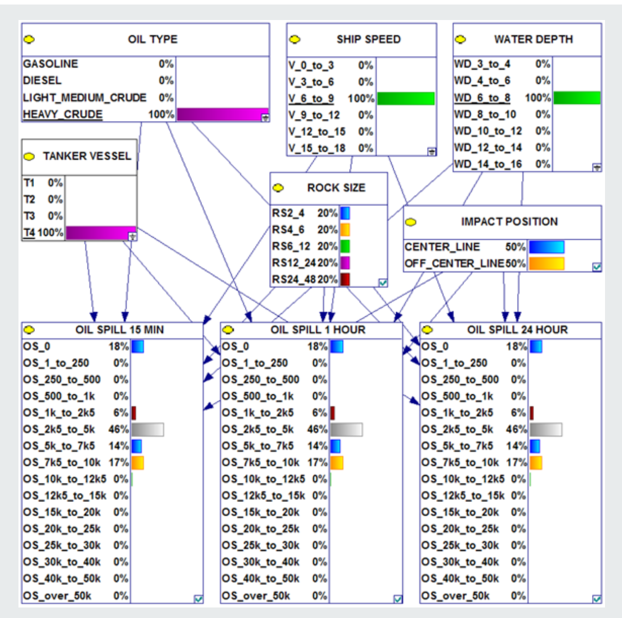


Figure 3.8.4.
Accidental Damage and Spill Assessment Model for Grounding (ADSAM-GP): Layout of the tool

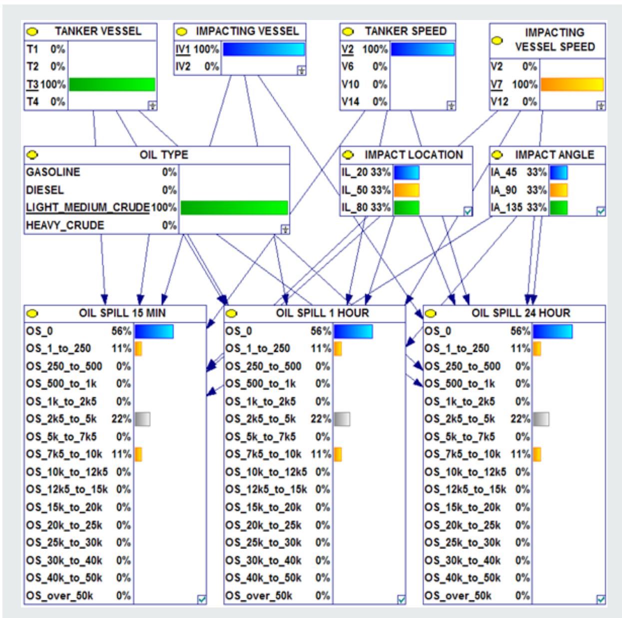


Figure 3.8.5.
Accidental Damage and Spill Assessment Model for Collision (ADSAM-C): Layout of the tool

For ADSAM-G, ADSAM-GP, and ADSAM-C, the input and output parameters are shown in Table 3.8.1, Table 3.8.2, and Table 3.8.3, respectively. The tables also include a description of the meaning of the inputs and outputs, and indicate the units of measurement. For the probabilistic models (ADSAM-GP and ADSAM-C), also the states of the input and output parameter nodes are listed. For ADSAM-G, the value "-1" can be used as a default value, in which case the parameter is automatically calculated.

3.8.5 Process

In the below description, the use of the ADSAM-G, ADSAM-GP, and ADSAM-C tools is explained in context of the intermittent risk management process. Two main use cases are distinguished: the plausible, and the worst-case scenario.

Table 3.8.1.
Input scenario and output parameters of ADSAM-G tool: description and units

Parameter	Description	Unit
Tanker vessel parameters		
Length	Vessel length between perpendiculars	[m]
Breadth	Moulded breadth of the vessel	[m]
Draft (fully loaded)	Moulded draft of the vessel, fully loaded summer draft	[m]
Depth	Moulded depth of the vessel, distance from keel to freeboard	[m]
Block coefficient	Ratio of underwater volume of ship to volume of a rectangular block having the same overall length, breadth, and draft	[-]
Double bottom height	Height of the double bottom tank	[m]
Breadth of double hull	Breadth of the double hull side tank	[m]
Deadweight	The vessel's carrying capacity	[tonnes]
Mass	The total ship mass	[tonnes]
Number of tanks, longitudinal	Number of cargo tanks in the longitudinal direction	[-]
Number of tanks, transverse	Number of cargo tanks in the transverse direction	[-]
Scenario parameters		
Rock size	The shape of the rock, which here refers to the width of the parabole-shaped rock, 1 metre below the rock tip	[m]
Penetration depth	The depth to which the rock tip extends into the grounded vessel, i.e. distance of the rock tip above the keel plate	[m]
Service speed	The speed with which the vessel impacts the rock	[kn],[m/s]
c_T	Structural resistance coefficient	[N]
Rock longitudinal location	Longitudinal position along the grounded vessel where the rock impacts the hull, with 0 = aft, 1 = fore	[-]
Rock transverse position	Transverse position along the grounded vessel where the rock impacts the hull, with -0.5 port side, 0.5 starboard side	[-]
Oil temperature in tank	Temperature at which oil is transported in the cargo tank	[°]
Oil temperature at outflow	Temperature at which oil flows out from grounded vessel	[°]
Oil pour point temperature	Temperature below which a liquid loses its flow characteristics	[°]
Oil density	Density of the oil	[kg/m3]
Seawater density	Density of seawater	[kg/m3]
Ice cover thickness	The thickness of the equivalent level ice sheet	[m]

Use case 1: Plausible scenario

In this use case, the ADSAM-GP and ADSAM-C tools are applied in such a way that all states of the input nodes are assigned probabilities, i.e. each state is assigned a probability between 0 and 1, such that the sum of all probabilities for the states of a given variable is equal to 1. The probabilities are assigned to the states so that they express the analysis uncertainty about the true state of the variables, so that in combination a set of plausible scenarios is constructed. The tool then determines the joint probability over all possible scenarios, so that a combined probability estimate is given of the probabilities of different oil outflow scenarios.

From this information, the relative importance of different spill scenarios can be obtained, which can be used to determine target spills with an explicit consideration of the probability of their occurrence. The process can be summarized as follows:

1. Obtain data for the input nodes;
2. Determine, either through statistical analysis or expert judgment, the probabilities of the different states of the input nodes;
3. Enter these probabilities in the states of the nodes, by double-clicking on the node, selecting the "definition" tab and entering the probabilities in the tables;
4. Select in the menu bar "Network" -> "Update Immediately" (or press Ctrl+F5). The tool now calculates the probabilities of the output nodes describing the oil outflow;
5. If desirable, specific scenarios can be investigated by selecting states of interest of the input parameters, by double-clicking on the respective state of the node;
6. In the steps 4 and 5, the resulting oil outflows should be interpreted in light of the model limitations as described in Section 3.8.6.

In the application of the ADSAM-G tool, the input parameters are directly defined based on the available information (data, expert judgment) for defining the plausible scenario.

Use case 2: Worst-case scenario

In this use case, the ADSAM-GP and ADSAM-C tools are applied so that only the states of the input nodes are selected, which correspond to the worst-case impact conditions. In different sea areas, it is possible to select the maximum tanker size as struck vessel, whereas for the other input parameters, the worst-case state is chosen. The tool then determines the joint probability over the corresponding scenarios, so that a description is given of the probabilities of the oil outflow scenarios corresponding to the worst-case accident scenarios. The process can be summarized as follows:

1. Obtain data for the input nodes (e.g. tanker sizes in different sea areas), and/or select the

worst-case state of the inputs;
2. Double-click on the state of the nodes corresponding to the worst-case accident condition;
3. Select in the menu bar “Network” -> “Update Immediately” (or press Ctrl+F5). The tool now calculates the probabilities of the output nodes describing the oil outflow.

In the application of the ADSAM-G tool, the input parameters are directly defined based on the available information (data, expert judgment) for defining the worst-case scenario.

3.8.6 Strengths and limitations

Some strengths of the ADSAM-G/ADSAM-GP and ADSAM-C tools include:

- The tools implement state-of-the-art models for assessing the accidental damage in grounding and collision accidents involving a double hull tanker, and for assessing the subsequent oil outflow in cases where the inner hull is breached;
- The tools are easy to use, and have an intuitive graphical display;
- The inputs can rely on different kinds of data, information and expert judgments;
- The tools require relatively little time to set up the information for the input parameters, and the outcomes are determined very quickly when the tool is executed.

Some limitations of the ADSAM-G/ADSAM-GP and ADSAM-C include:

- Only cargo oil outflows of tankers are considered;
- The tanker sizes are in the current version limited to those operating in the Baltic Sea area;
- Only four representative types of cargo oil are considered in ADSAM-GP and ADSAM-C;
- Further consequences of the collision and grounding damage, e.g. further hull collapse or explosion, are not considered;
- The oil outflow models assume small ship motions, i.e. effects of oil outflow due to wave action, are not considered.

Notes and practicalities

The ADSAM-G web application tool can be accessed online at http://www.sea.ee/adsam.

The ADSAM-GP and ADSAM-C tools are available on HELCOM website, in .xdsl-format. This is a Bayesian Network model format, which can be opened using the GeNIe software, downloadable from https://www.bayesfusion.com.

Table 3.8.2.
Input and output parameters of ADSAM-GP tool: description and units

Parameter	Description	Unit
Inputs		
Tanker vessel	Grounded tanker, i.e. the representative tankers defined in Table 3.8.4, with states {T1, T2, T3, T4}	[-]
Oil type	Cargo oil type, i.e. the representative oil types defined in Table 3.8.5, with states {T1, T2, T3, T4}	[-]
Ship speed	The speed at which the ship impacts the rock in the accident scenario, with states {0-3, 3-6, 6-9, 9-12, 12-15, 15-18}	[kn]
Rock size	The shape of the rock in the accident scenario, with states {2-4, 4-6, 6-12, 12-24, 24-48} *	[1/m]
Water depth	The water depth in the accident scenario, measured from the waterline to the top of the rock, with states {3-4, 4-6, 6-8, 8-10, 10-12, 12-14, 14-16}	[m]
Impact position	The rock position relative to the ship center line, with states {center_line, off_center_line} **	[-]
Outputs		
Oil spill 15 min	Volume of oil spilled after 15 minutes following the accident, with states {0, 1-250, 250-500, 500-1k, 1k-2k5, 2k5-5k, 5k-7k5, 7k5-10k, 10k-12k5, 12k5-15k0, 15k-20k, 20k-25k, 25k-30k, 30k-40k, 40k-50k, over 50k}	[m3]
Oil spill 1 hour	Volume of oil spilled after 15 minutes following the accident, with states {0, 1-250, 250-500, 500-1k, 1k-2k5, 2k5-5k, 5k-7k5, 7k5-10k, 10k-12k5, 12k5-15k0, 15k-20k, 20k-25k, 25k-30k, 30k-40k, 40k-50k, over 50k}	[m3]
Oil spill 24 hours	Volume of oil spilled after 15 minutes following the accident, with states {0, 1-250, 250-500, 500-1k, 1k-2k5, 2k5-5k, 5k-7k5, 7k5-10k, 10k-12k5, 12k5-15k0, 15k-20k, 20k-25k, 25k-30k, 30k-40k, 40k-50k, over 50k}	[m3]

*) The values correspond to the width of the base of the parabole-shaped rock at 1 metre below the rock tip.
**) State “center_line”: the rock center aligns with the midship section. State “off_center_line”: the rock center aligns with a transverse position B/4 away from the midship cross-section, where B is the vessel width.

Table 3.8.3.
Input and output parameters of ADSAM-C tool: description and units

Parameter	Description	Unit
Inputs		
Tanker vessel	Tanker involved in collision, i.e. the representative tankers defined in Table 3.8.4, with states {T1, T2, T3, T4}	[-]
Impacting vessel	Impacting vessel in collision, i.e. the representative vessels defined in, with states {IV1, IV2}	[-]
Oil type	Cargo oil type, i.e. the representative oil types defined in Table 3.8.5, with states {T1, T2, T3, T4}	[-]
Tanker speed	The speed at which the tanker vessel proceeds at the time of impact, with states {2, 6, 10, 14}	[kn]
Impacting vessel speed	The speed at which the impacting vessel proceeds at the time of impact, with states {2, 7, 12}	[kn]
Impact location	The location along the hull of the struck vessel (i.e. the tanker) where the striking vessel impacts, with states {20, 50, 80} *	[%]
Impact angle	The angle between the striking vessel and the struck vessel, with states {25, 90, 135}	[°]
Oil spill 15 min	Volume of oil spilled after 15 minutes following the accident, with states {0, 1-250, 250-500, 500-1k, 1k-2k5, 2k5-5k, 5k-7k5, 7k5-10k, 10k-12k5, 12k5-15k0, 15k-20k, 20k-25k, 25k-30k, 30k-40k, 40k-50k, over 50k}	[m3]
Oil spill 1 hour	Volume of oil spilled after 15 minutes following the accident, with states {0, 1-250, 250-500, 500-1k, 1k-2k5, 2k5-5k, 5k-7k5, 7k5-10k, 10k-12k5, 12k5-15k0, 15k-20k, 20k-25k, 25k-30k, 30k-40k, 40k-50k, over 50k}	[m3]
Oil spill 24 hours	Volume of oil spilled after 15 minutes following the accident, with states {0, 1-250, 250-500, 500-1k, 1k-2k5, 2k5-5k, 5k-7k5, 7k5-10k, 10k-12k5, 12k5-15k0, 15k-20k, 20k-25k, 25k-30k, 30k-40k, 40k-50k, over 50k}	[m3]

*) The value "0" corresponds to the aft perpendicular, "100" with the fore perpendicular.

Table 3.8.4.
Characteristics of the representative tankers in ADSAM-GP and ADSAM-C

ID	L [m]	B [m]	T [m]	D [m]	DWT [tonnes]	BCap [m3]	Mlad [tonnes]
T1	109.1	16.0	5.2	7.5	5565	695	10653
T2	159.0	27.0	10.7	15.7	37000	2211	35086
T3	249.0	44.0	8.2	21.8	115527	4186	144997
T4	254.2	45.6	16.2	22.6	151000	4074	154838

Notes:
L = length, B = breadth, T = draft, D = depth, DWT = deadweight, BCap = Bunker capacity, Mlad = mass in laden condition

Table 3.8.5.
Characteristics of the representative oil types in ADSAM-GP and ADSAM-C

Oil type	ρ_{oil} [kg/m3]	T_{1oil} [°C]	T_{2oil} [°C]	T_{ppoil} [°C]
Gasoline	764.0	15	15	-40
Diesel	823.7	15	15	-29
Light-medium crude	908.9	15	15	-7.1
Heavy crude	953.0	15	15	-8.6

Notes:
ρ_{oil} = oil density, T_{1oil} = temperature at which oil is transported, T_{2oil} = temperature at which oil flows out from the vessel, T_{ppoil} = pour point temperature of the oil

3.9. SeaTrack Web

3.9.1 Background

SeaTrack Web started as a simple trajectory model developed in the 1970s by the Swedish Meteorological and Hydrological Institute (SMHI). By the 1990s, it had evolved to an operational oil drift forecasting system. HELCOM Recommendation 12/6 [1], superseded by Recommendation 24/7 [2], stating that every country around the Baltic Sea should have an operational oil drift forecasting system by 1993, enhanced the development further.

Today, SeaTrack Web is hosted by SMHI, with developments jointly executed by SMHI and a group of partner institutions around the Baltic Sea. These include the Defence Centre for Operational Oceanography (FCOO) in Denmark, the Federal Maritime and Hydrographic Agency (BSH) in Germany, and the Finnish Meteorological Institute (FMI) in Finland. The system has been developed in close cooperation with end users, and the number of functions has increased over the years. A completely overhauled version, with new web interface and enhanced model algorithms, was released in 2014 and a comprehensive upgrade was released in 2017. Recent advances have also been made to improve the parameterization of the oil drift model in sea ice conditions [3].

3.9.2 Overview

The SeaTrack Web system consists of three main parts: forcing in the form of forecasted flow and wind fields, an oil drift model, and a graphical user interface [4]. The oil drift model is called PADM (Particle Advection and Dispersion Model). It is executed whenever a SeaTrack Web user requests a simulation.

The geographical coverage of SeaTrack Web system is illustrated in Figure 3.9.2.

The Circulation and Weather Models

In SeaTrack Web, one needs to access forecasted current fields of the NEMO-Nordic model (Nucleus of European Modelling of the Ocean), which is a 3-dimensional circulation model covering the Gulf of Bothnia, the Gulf of Finland, the Baltic Sea, the Sounds, the Kattegat, the Skagerrak, the North Sea, and the English Channel [5].

The meteorological forecast models used in SeaTrack Web are operated by the European Centre for Medium-Range Weather Forecasts (ECMWF), and are implemented using forecasts of 4 days and hind casts of 6 days. The forecasts are made twice a day. The NEMO/ECMWF-model provides SeaTrack Web with current fields every 15 minutes, with the horizontal grid resolution 2 nautical miles (nm). In SeaTrack Web, the forecasted surface currents (with a depth between 0 and 4 m) can be plotted for 2 nm. NEMO-Nordic provides currents at a maximum of 50 different depth levels (depending on the location's depth), which influence the drift and spreading of the substance.

Oil Drift Model

The oil drift model used in SeaTrack Web is built around a Lagrangian particle model known as PADM (Particle Advection and Dispersion Model) [4]. The PADM is a Lagrangian particle spreading model, which means that the substance or object being simulated is represented as a cloud of particles. The trajectory of each particle is calculated based on the spatial-temporal evolution of flow fields.

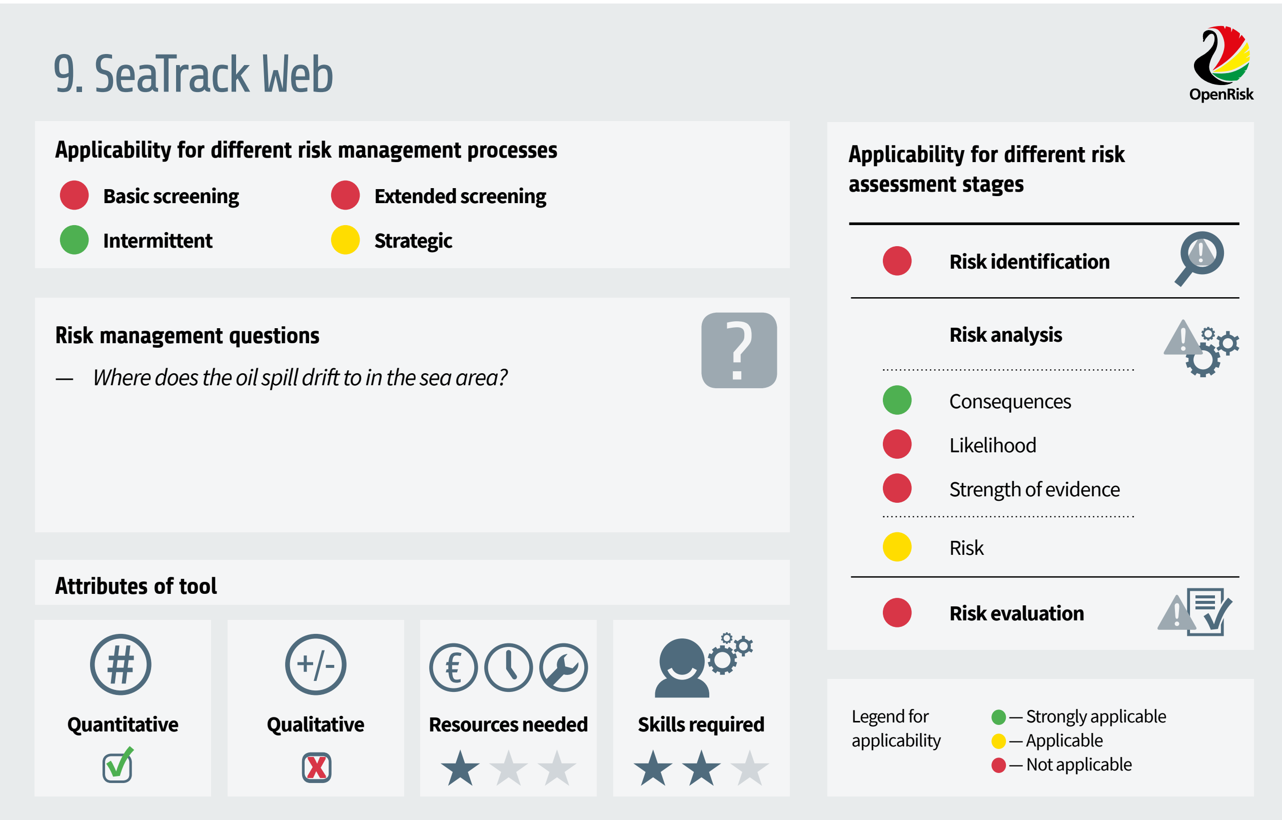


Figure 3.9.1.
Overview of the SeaTrack Web tool: Risk management questions addressed, tool attributes, and applicability for different risk management processes and risk assessment stages

In the current version of the PADM, it is assumed that the particles do not influence the flow field, i.e. a particle does not have any effect on the flow in which it is located. Particles are affected by boundaries such as the coastline, the sea bottom, or the surface. Particles cannot pass through a solid boundary but may either stick to a boundary or slip along it.

Each particle has a set of properties. The most important of these is its position. However, a particle can have a variety of additional properties depending on what substance or object it represents, e.g. mass, volume, size, chemical properties, density, etc. These can be constants or vary with time, location, temperature, etc.

In the current version of SeaTrack Web, algorithms have been implemented for the following substances: oils, floating objects, and algae. Two oil-related processes have been included in PADM: spreading, which includes all processes related to the movement of the particles, and weathering. A graphical user interface (GUI) is developed, for easy application by its users, see Figure 3.9.3.

3.9.3 Use

The SeaTrack Web tool can be used to answer the following risk management question:

— Where does the oil spill drift to in the sea area?

SeaTrack Web is useful in the risk analysis stage of the intermittent risk management process in the developed PPR risk management framework based on ISO 31000:2018, introduced in Section 2. SeaTrack Web can also have a role in a strategic risk management process. The tool provides quantitative outputs. The process requires little commitment of resources in terms of finances, and analysts' time. Moderate experience is needed for applying the method, and for extracting results.

The aim of SeaTrack Web is to provide knowledge concerning oil spill prediction, which is useful for response planning. SeaTrack Web uses the latest technology, 3-dimensional modeling, updated atmospheric and ocean forecasts and observations, and satellite information to provide fast and effective predictions of oil drift (Figure 3.9.4).

SeaTrack Web consists of a few simulation tools, such as Oil Observation, Continuous Oil Spill, Floating Object and Algae simulation tool. An exercise tool is under construction and the development of a passive point tool is planned, which will enable simulation of chemicals or radioactive substances.

Oil Observation

The Oil Observation tool is used to simulate the movement of observed oil in the water. It is possible to run the simulation both forwards and backwards in time.

Figure 3.9.2.
The coverage area of SeaTrack Web

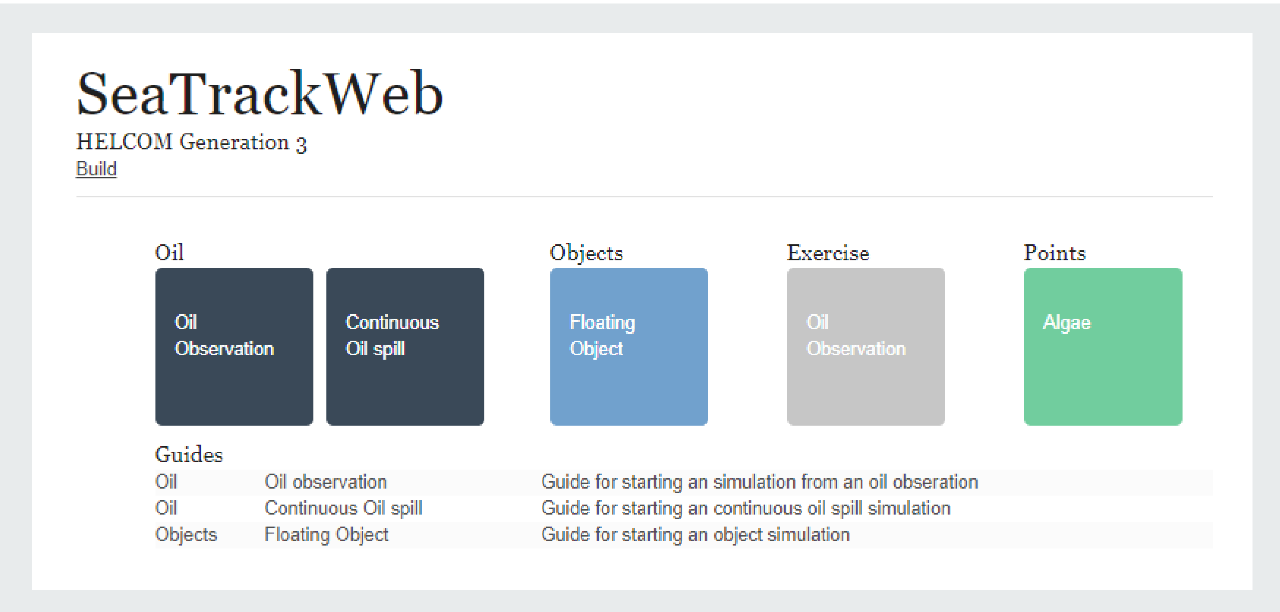


Figure 3.9.3.
The front page of SeaTrack Web

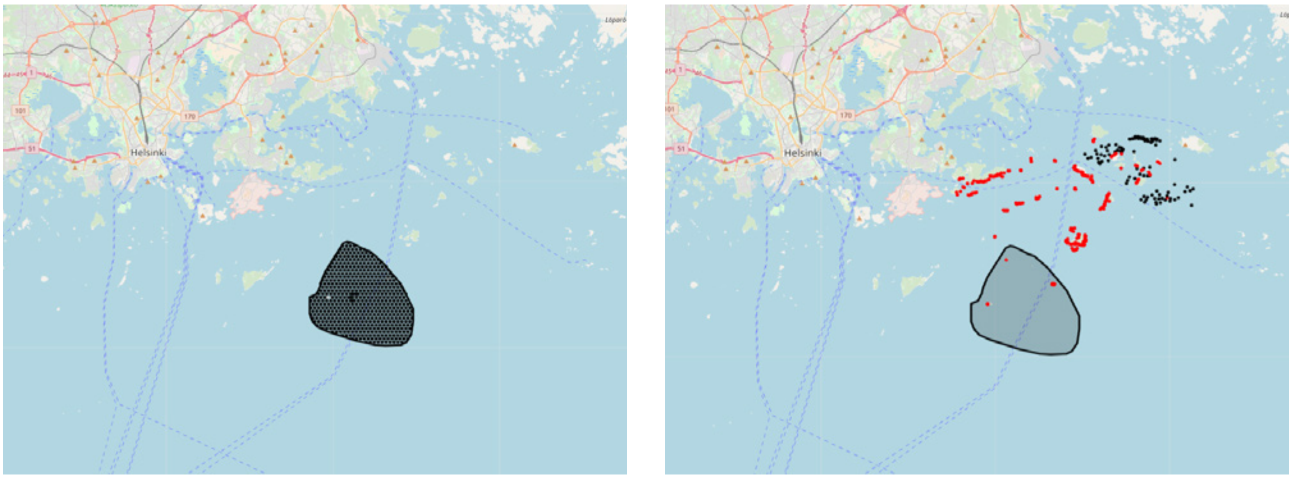


Figure 3.9.4.
Example of an Oil Observation (left) and its forecasted movement (right)

Continuous Oil Spill

The Continuous Oil Spill tool is used to simulate the movement of oil from, for example, a vessel leaking oil due to accidental impact. In this case, more and more oil is leaking into the water. In such simulations, the outlet depth and location should be specified.

Floating Object

The floating object tool is used to track lost buoys and other kinds of objects, initial location and wind factor of the lost object is needed. The simulation can be run both forwards and backwards in time.

Algae

The Algae simulation tool is used to track algae observations. The initial location of the algae observations is needed. The simulation can be run both forwards and backwards in time.

3.9.4 Input

SeaTrack Web is mainly designed for simulating Oil Observations, and the data often comes from visual observations but it could also come from satellite oil detections. For Floating Object the data most likely comes from visual observations and for Algae the data comes from satellite observations. For Oil Spill the input data comes from an oil spill which is found likely to occur based on prior risk analysis results. Information is needed about its location, oil characteristics, and sea and atmospheric forcing. These input data can be developed based on other risk analysis tools, e.g. accident scenarios obtained from IWRAP (Section 3.5) or ERC-M (Section 3.7), and oil spill consequences obtained from ADSAM (Section 3.8).

3.9.5 Process

The main steps for the SeaTrack Web analysis are as follows:

1. Collect the required data; such as time, position, oil type, amount, etc.;
2. Start a simulation in SeaTrack Web;
3. Check if the oil will reach near any maritime protection area or any other sensitive areas.

3.9.6 Output

The output in SeaTrack Web concerning oil spills consists of the location of the oil drift over time, along with the characteristics of the oil. The results can be:

— Saved: in order to be displayed later;
— Shared: the simulation url can then be pasted into an email and sent to others so that they can see it in their browser;
— Exported: for every time step the data for the simulation can be exported into e.g. Excel. The data includes Position, Current speed, Current direction, Wind speed, Wind direction, Oil volume, Oil viscosity, Density, Evaporated oil, Oil at surface, Dispersed oil, Oil at sea bed, Oil at shore and Water content;
— Showed in a graph: the parameters that can be plotted are the oil volume, the percentage of oil in a unit of water, viscosity, density, wind and current direction, current speed, and wind speed.

3.9.7 Strengths and limitations

Some strengths of SeaTrack Web include:

— It is relatively simple to use and gives a clear pictorial representation of the problem;
— It is web-based, so no program needs to be installed;
— It can easily be used for different kind of cases.

Some limitations of SeaTrack Web include:

— The accuracy of the weather and circulation models are difficult to validate, due to the scarcity of observations in/over the sea;
— It is difficult to validate the drift results obtained from SeaTrack Web since oil accidents are (fortunately) rare occurrences;
— It may over-simplify complex situations.

Notes and practicalities

The tool can be accessed at https://stw.smhi.se. Access can be provided upon sending an email to seatrackweb@smhi.se. Provide information about your institution and inform us why you want access to SeaTrack Web. HELCOM members already have access to SeaTrack Web.

3.10. Next Generation SmartResponse Web

3.10.1 Background

The Next Generation SmartResponse Web (NG-SRW) is an online information management software platform, which enables obtaining a broad understanding of the development of oil spill scenarios in a marine environment. The tool is primarily developed for operational response planning to enhance situational awareness [1] through creating a common operational picture [2, 3]. The tool can also make important contributions to pollution preparedness and response planning, by creating realistic accident scenarios including the (accidental) oil spills, the oil drift in the sea, and the consequences to the ecosystem values and human uses of the marine space. The detailed understanding of oil spill consequences in many areas of concern to response planners, can assist in risk management and developing adequate procedures.

The first version of SmartResponse Web was developed in the INTERREG CB MIMIC project "Minimizing risks of maritime oil transport by holistic safety strategies" during 2011-2013 [4]. The development of the Next Generation SmartResponse Web was implemented in the project BONUS STORMWINDS "Strategic and Operational Risk Management for Wintertime Maritime Transportation System" during 2015-2018 [5].

3.10.2 Overview

The Next Generation SmartResponse Web (NG-SRW) is an online information management and exchange software platform. As shown in Figure 3.10.2, the main elements consist of the Accidental Damage and Spill Assessment Model (ADSAM) (see Section 3.8), the Particle Dispersion Model implemented in SeaTrack Web (see Section 3.9), and web map services with several geospatial information layers concerning marine ecosystem values and human use of marine spaces. NG-SRW also enables a link to historic or real-time data from the Automatic Identification System (AIS), which is mainly useful in operational planning to obtain insights in the maritime traffic conditions in the area of the spill [6].

NG-SRW is based on ASP.NET (Active Server Pages) technology enabling use of any device (phone, pad, and computer) with Windows, iOS or Android operating systems. GIS data is stored on a GIS server in the MS SQL Server geo-database and shared as Web Map Services (WMS).

3.10.3 Inputs and outputs

NG-SRW provides access to web services related to:

1. Accident Damage and Spill Assessment Model (ADSAM) [7]. This is a tool which simulates shipping accident consequences

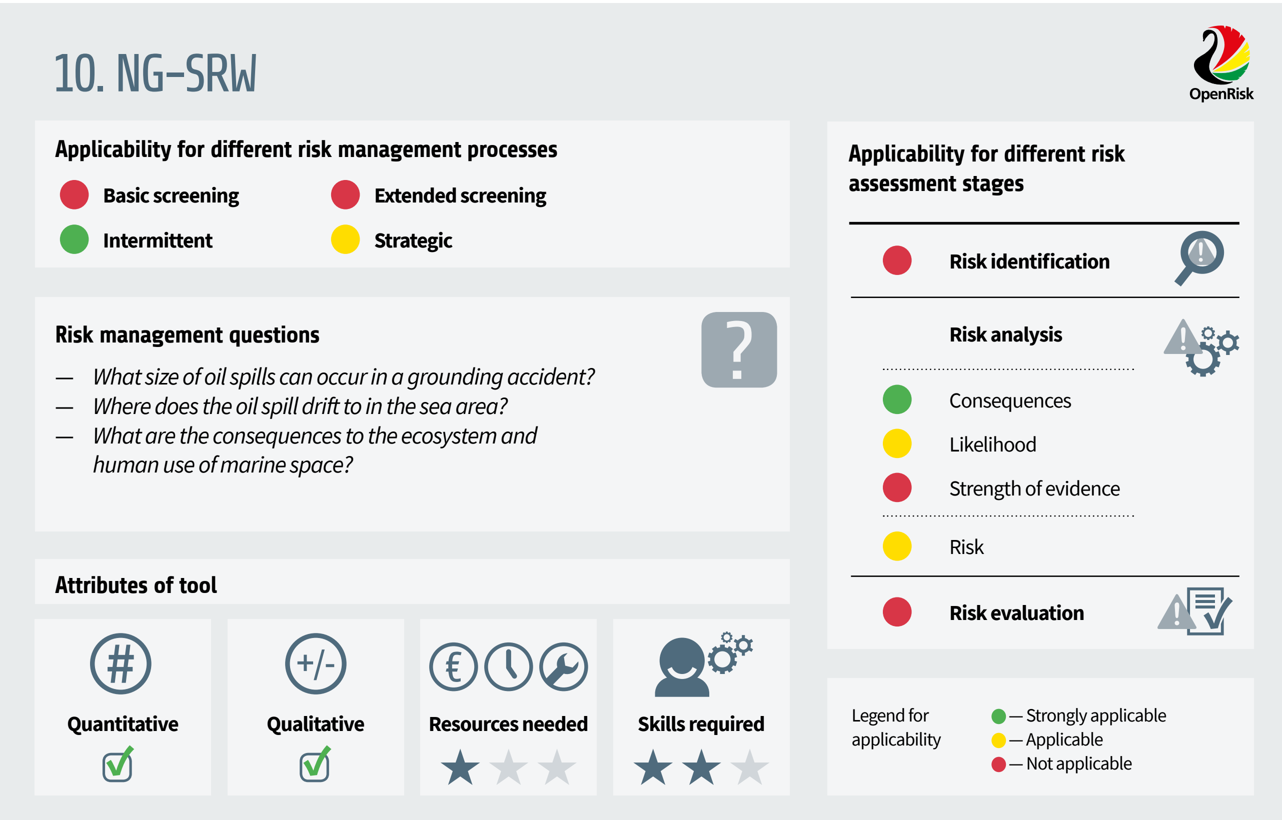


Figure 3.10.1.
Overview of the NG-SRW tool: Risk management questions addressed, tool attributes, and applicability for different risk management processes and risk assessment stages

in relation to real-time environmental conditions in open water and in ice conditions, see Section 3.8.
2. SeaTrack Web [8, 9] for oil spill propagation in open water and in sea ice conditions, see Section 3.9.
3. Environmental Sensitivity Index (ESI) maps. Such maps have been an integral component of oil-spill contingency planning and response in the United States since 1979, serving as a quick reference for oil spill responders regarding the marine ecosystem values [10].

The inputs required for running NG-SRW are very similar to the ones required for application of ADSAM and SeaTrack Web. Also the outputs of those elements of the NG-SRW tool are very similar to the outputs of ADSAM and SeaTrack Web. For more information on these, the reader is referred to Section 3.8 and Section 3.9, respectively.

As an additional element within NG-SRW, the tool focuses on environmental protection and response efficiency based on the Environmental Sensitivity Index (ESI), which ranks shorelines into 10 classes with respect to sensitivity, natural persistence of oil, and ease of clean-up. Some countries outside the US have adopted the ESI approach to classify their own shorelines for similar oil spill contingency planning. The outcome is being referred to as Regional Environmental Sensitivity Index (RESI) maps [11]. The Web Map Services are grouped in the RESI framework, and include the following map layers:

1. Shoreline classification, ranked according to a scale in relation to sensitivity, natural persistence of oil, and ease of clean-up;
2. Biological resources sensitive to oil spills include oil-sensitive plants, animals or habitats, or are used by oil-sensitive species;
3. Human-use resources, i.e. areas with increased sensitivity and values because of their use (e.g. beaches, parks, marine protected areas of different level, historic/cultural sites).

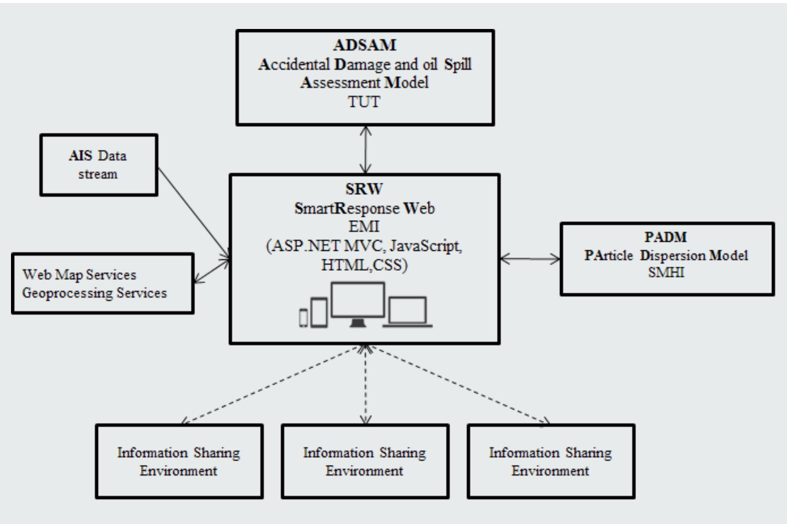


Figure 3.10.2.
Basic configuration of the NG-SRW application [6]

NG-SRW requires the map layers to be implemented as inputs before running the tool for specific scenarios. In applications, the tool provides outputs which can be tracked through dynamic monitors. These relate to situational characteristics related to environmental conditions (wind and current speed and direction), the state of the oil slick (evaporated percentage, water content, oil at surface, etc.), and ecological indicators (shoreline classes, environmental sensitivity index).

In the current implementation of NG-SRW, the GIS map layers of the RESI Classification of the Estonian shoreline are integrated and are ready for use by the national oil spill response authorities for contingency planning, training and in emergency situations. The software can rather easily be extended to other sea areas as well, provided GIS map layers for those areas are available.

3.10.4 Process

NG-SRW aims to create, visualize, and share analyses of maritime accident consequences with information about marine environment and human use relevant to pollution preparedness and response planners and decision makers. A user identifies the specific content to be included in the scenario and can focus on selected aspects of the consequences to assist decision making. Figure 3.10.3 illustrates the oil spill drift monitoring in a background of ecosystem and human use values.

3.10.5 Use

The NG-SRW tool can be used to answer the following risk management questions:

- What size of oil spills can occur in a grounding accident?
- Where does the oil spill drift to in the sea area?
- What are the consequences to the ecosystem and human use of marine space?

NG-SRW is primarily useful in the risk analysis stage of the intermittent risk management process in the developed PPR risk management framework based on ISO 31000:2018, introduced in Section 2. It may also have a role in the strategic risk management process. Focus is on the consequences, but the tool may also be useful in analyzing the probability of certain scenarios to occur, if the model is applied in batch runs as in [12]. The tool provides quantitative outputs (e.g. about the spill sizes) as well as qualitative outputs (e.g. about selected map layers). The process requires a low commitment of resources in terms of finances, and analysts' time, once the tool is fully implemented. Moderate experience is needed for applying the method, and for extracting results.

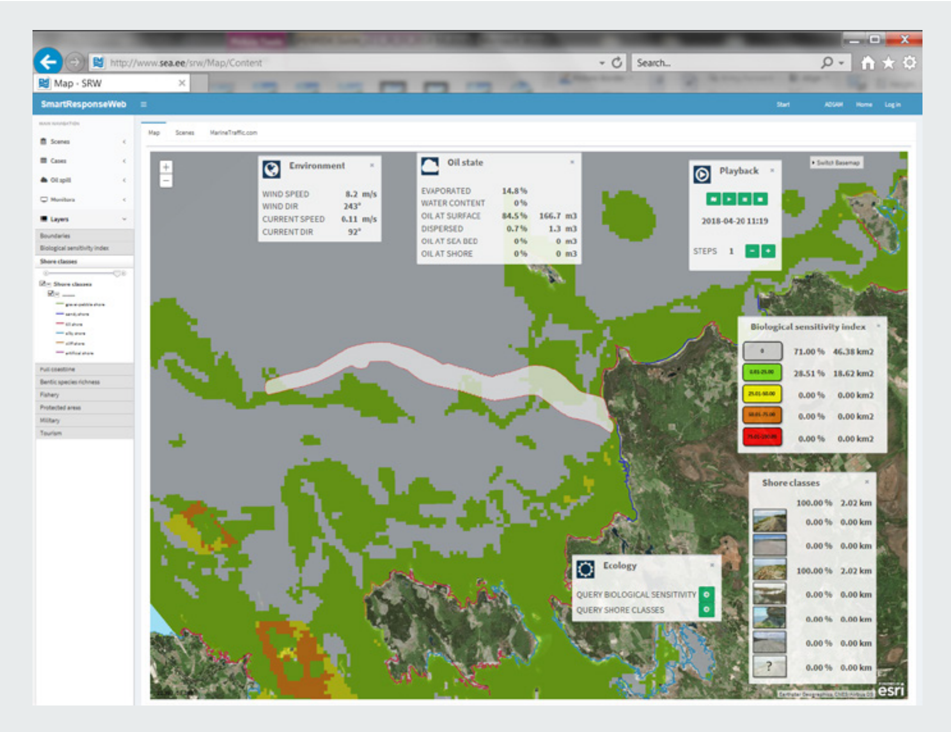


Figure 3.10.3.
NG-SRW application enables the integration of spill monitoring and evaluation functions directly into oil spill preparedness and response management processes

3.10.6 Strengths and limitations

Some strengths of the NG-SRW include:

— It integrates several tools to obtain a holistic image of specific accident consequences;
— It is available online, so no software needs to be installed and is easily accessible;
— The tool is intuitive and easy to use, and its results require relatively little training to be useful to decision makers.

Some limitations of the NG-SRW include:

— It currently only implements ADSAM-G, i.e. only accidental spills from groundings are considered;
— It requires detailed information to set up a case;
— The geospatial information layers are currently only implemented for Estonian waters.

Notes and practicalities

The NG-SRW tool can be accessed via web page www.sea.ee/srw. Login is required to enable the SeaTrack Web based calculation of oil spill propagation in open water and ice.

Currently, the model and web application are applicable only for Estonian waters, but they can be modified for other sea areas as well.

3.11. Response System Planning Calculators

3.11.1 Background

A set of response planning calculators, produced by BSEE (Bureau of Safety and Environment Enforcement) in collaboration with Genwest Inc., are publicly available and can be downloaded from the BSEE website [1]. These calculators enable the planning of response systems for mechanical recovery (ERSP), in situ burning (EBSP) and surface applied dispersants (EDSP). BSEE suggests that these calculators represent the current best practice, and that they offer significant improvements in estimating the capabilities of oil spill response systems. Thus, BSEE encourages authorities to consider using these tools in preparing oil spill preparedness and response plans.

The ERSP, EBPS and EDSP Calculators are intended as planning tools for estimating the potential of different oil spill response systems to mitigate (recover, burn, or disperse) discharged oil relative to one another. These planning tools are not intended to be used as models for calculating system performance during an actual oil spill, which is affected by many factors such as the distribution of oil on the water surface, oil weathering and other ambient on-scene conditions which are not included in the calculators.

3.11.2 Overview

For mechanical recovery, the ERSP Calculator gives Estimated Recovery System Potential (ERSP) value in barrels of oil recovered for each of the first three days following the instantaneous discharge of a batch oil spill, or daily for an ongoing continuous discharge of oil [2].

The ERSP Calculator is primarily a planning tool for estimating the potential for mechanical recovery of spilled oil by an advancing skimming system. The calculator helps to evaluate the ERSP of a skimming system for two kinds of spill scenarios:

— Continuous spills, such as a well blowout, in which oil is discharged at a steady rate for a relatively long period of time;
— Batch spills, such as a spill from a tank vessel, storage tank, or pipeline, in which oil is discharged nearly instantaneously or over a relatively short time period.

The ERSP Calculator can also be used to explore how to configure a skimming system to best encounter, recover, store, and offload oil more efficiently.

For *in situ* burning, the EBSP Calculator generates an Estimated Burn System Potential (EBSP) value in barrels of oil burned for each of the first three days following the instantaneous discharge of a batch oil spill or daily for an ongoing continuous discharge of oil [3]. It accounts for the performance of an advancing controlled burn system as it encounters, concentrates and burns oil inside of the system's burn boom. The EBSP Calculator is primarily a planning tool for estimating the potential for collection and burning of spilled oil by an advancing burn system. The calculator helps to evaluate the EBSP of a burning system for two kinds of spill scenarios:

— Continuous spills, such as a well blowout, in which oil is discharged at a steady rate for a relatively long period of time;
— Batch spills, such as a spill from a tank vessel, storage tank, or pipeline, in which oil is discharged nearly instantaneously or over a relatively short time period.

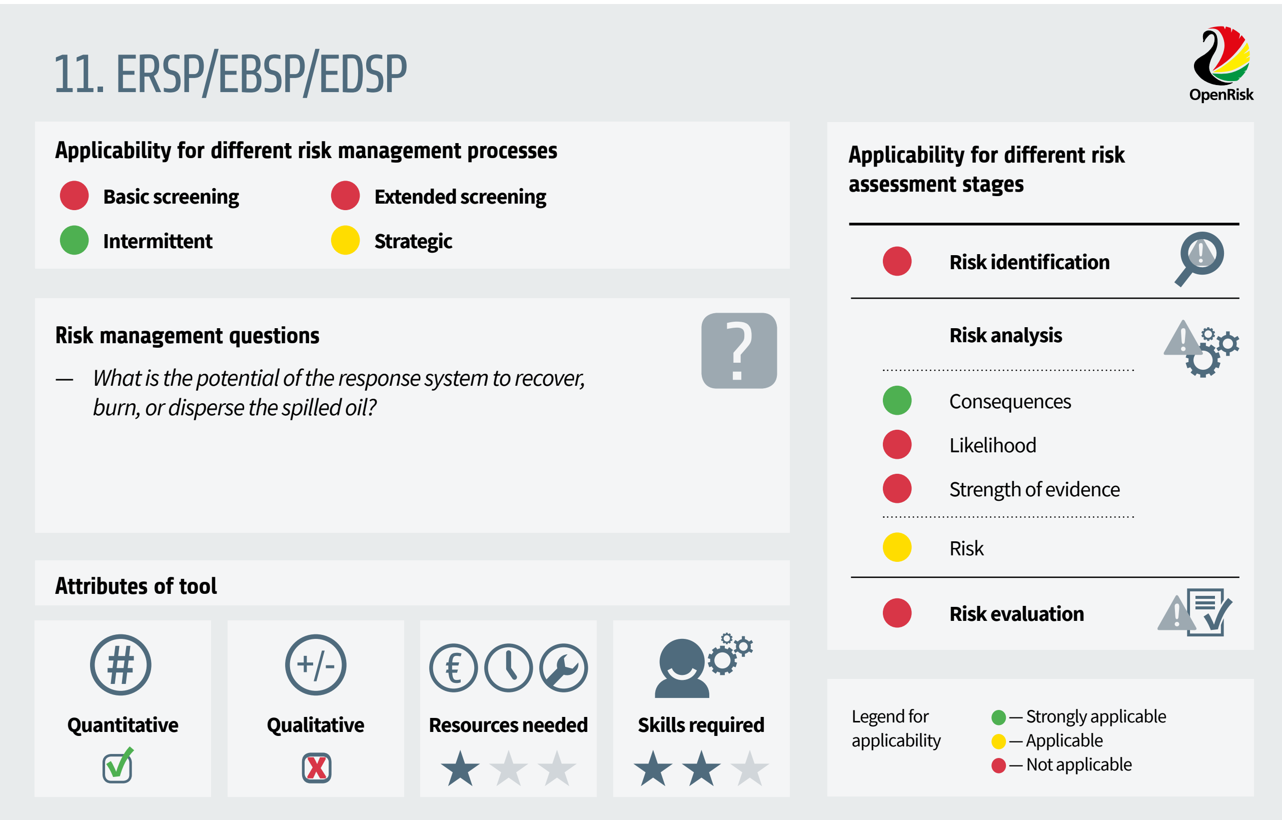


Figure 3.11.1.
Overview of the ERSP/EBSP/EDSP tools: Risk management questions addressed, tool attributes, and applicability for different risk management processes and risk assessment stages

Besides evaluating the potential of advancing oil spill burning systems to meet various regulatory planning requirements, the EBSP can also be used to explore how to configure a burning system to best encounter and burn oil more efficiently.

For surface applied dispersants, the EDSP Calculator generates an Estimated Dispersant System Potential (EDSP) value for two Operating Periods following the discharge of an oil spill [4]. Dispersants are fluid chemicals that bond to oil molecules and separate them from water molecules, thus breaking up the oil. The result is tiny oil droplets that can biodegrade and disperse more quickly than a mass of oil. The calculator accounts for the performance of an aircraft or vessel dispersant application system as it sprays dispersant on an oil slick. It also takes into account the time necessary to mobilize the system and the time needed to cascade the system from its home base to the incident staging site, if necessary. The EDSP Calculator is primarily a planning tool for estimating the potential for dispersant application on spilled oil by defined dispersant application systems. It estimates the potential of a single system and does not address the total potential or number of systems that would be necessary for a plan. The Calculator can be used to evaluate the potential of a dispersant application system for different spill planning situations:

- Estimated Dispersant System Potential (EDSP), a regulatory measure of a dispersant system's potential ability to treat oil;
- Effective Daily Application Capacity (EDAC), a regulatory measure of how much dispersant can be applied by a dispersant application platform that is used in conjunction with U.S. Coast Guard regulated oil spill response plans;
- Operational spill planning, where users are not constrained to EDAC values and assumptions.

The EDSP Calculator was developed with the intent of reinforcing incentives for creating and acquiring more effective dispersant application systems, and in addition, evaluating the potential of a dispersant application system to meet various regulatory planning requirements. Experimentation with the calculator is helpful in understanding the effects of different configurations on a system's treatment potential, and may provide incentives for developing more effective dispersant application systems.

3.11.3 Use

The ERSP/EBSP/EDSP tools can be used to answer the following risk management question:

- What is the potential of the response system to recover, burn, or disperse the spilled oil?

The ERSP/EBSP/EDSP calculators are primarily useful in the risk analysis stage of the intermittent risk management process in the developed PPR risk management framework based on ISO 31000:2018, introduced in Section 2. The calculators may also have a role in the strategic risk management process. The tool provides quantitative outputs. The process requires low commitment of resources in terms of finances, and analysts' time. Moderate experience is needed for applying the method, and for extracting results.

The three calculators present tools for planning purposes. They can help planners to evaluate different scenarios by comparing different inputs in preparing, revising, and updating oil response plans. The ERSP Calculator, for example, allows a user to explore how to configure a skimming system to best encounter, recover, store, and offload oil. The EBSP Calculator can provide planners knowledge about how to configure a burning system to best encounter and burn oil. The EDSP calculator on the other hand, can be very helpful in understanding the effects of different configurations on a system's treatment potential, and may provide necessary information and possibilities to develop more effective dispersant application systems.

3.11.4 Input

3.11.4.1 Inputs for the ERSP Calculator (for mechanical recovery)

In the following, the main inputs to the calculator are outlined, according to Figure 3.11.2. For detailed information, see [2].

- Discharge Type (Continuous Spill and Batch Spill): The user must identify the type of spill for which the system is being evaluated. This selection will determine the format of the output which the ERSP Calculator will display.
- Skimming System Identifiers: These screens are useful for both planners and regulators to identify and track the ERSP Calculator input and output data associated with major equipment configurations.
- Name of Simulation: Entry field for the name or other form of identifier for the skimming system (up to 48 characters).
- Simulation Details: Configuration details including the type of platform, skimmer, pump, and boom being used and other key information to identify this simulation.

Encounter Rate Inputs:
- Operating Period [hrs]
- Speed [kts]
- Swath [ft]

Recovery Inputs:
- Maximum Total Fluid Recovery Rate [gpm]
- Throughput Efficiency [%]
- Recovery Efficiency [%]

Storage Inputs:
- On-board Storage [bbl]
- Percent Decant [%]
- Decant Pump Rate [gpm]
- Rig + Derig Time [min]
- One Way Transit Time To Offload [min]
- Discharge Pump Rate [gpm]

3.11.4.2 Inputs for the EBSP Calculator (for in situ *burning)*

In the following, the main inputs to the calculator are outlined, according to Figure 3.11.3. For detailed information, see [3].

- Discharge Type (Continuous Spill and Batch Spill): The user must identify the type of spill for which the system is being evaluated. This selection will determine the format of the output which the EBSP Calculator will display.
- Burning System Identifiers: These screens are useful for both planners and regulators to identify and track the EBSP Calculator input and output data associated with major equipment configurations.
- Name of Simulation: Entry field for the name or other form of identifier for the burn system (up to 48 characters).
- Simulation Details: Configuration details including the type of

burn boom being used and other key information to identify this simulation.

Encounter Rate Inputs
- Operating Period [hrs]
- Oil Collection Speed [kts]
- Burning Offset Distance [ft]
- Enhanced Collection Swath Width [ft]

Fire Boom Inputs
- Fire Boom Length [ft]
- Fire Boom Draft [in]

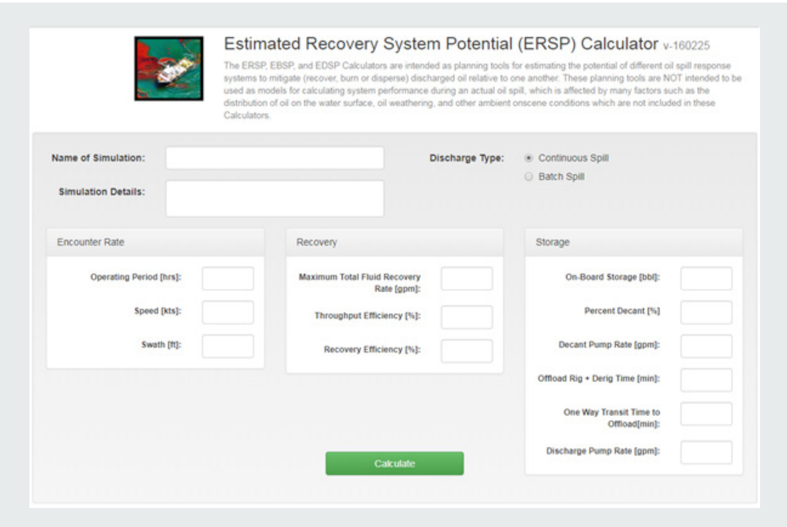


Figure 3.11.2.
Estimated Recovery System Potential (ERSP) Calculator [2]

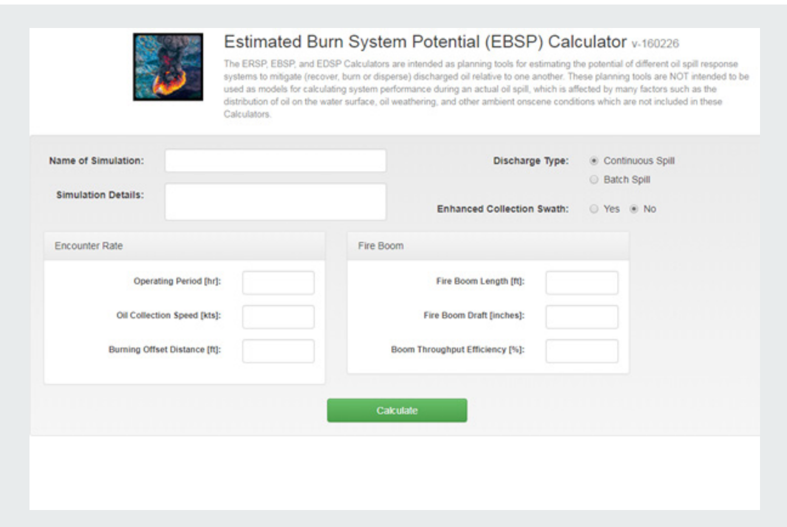


Figure 3.11.3.
Estimated Burn System Potential (EBSP) Calculator [3]

3.11.4.3. Inputs for the EDSP Calculator (for surface applied dispersants)

In the following, the main inputs to the calculator are outlined, according to Figure 3.11.4. For detailed information, see [4].

- Dispersant System Identifiers: These screens are useful for both planners and regulators to identify and track the EDSP Calculator input and output data associated with major equipment configurations.
- Name of Simulation: Entry field for the name or other form of identifier for the dispersant application system (up to 48 characters).
- Simulation Details: Enter configuration details including the type of platform, skimmer, pump, and boom being used and other key information to identify this simulation.

Mobilization/Cascading Inputs
- Mobilization Time
- Distance to Staging Site
- Transit with Payload

Scenario Inputs
- Operating Period [hrs]
- One-way Transit Distance (Staging area to/from spill)
- Dispersant/Fuel Load

Dispersant Spraying Operations Inputs
- Dispersant to Oil Ratio
- Dosage
- Average Spray Pass Length
- Pass Type

Effective Daily Application Capacity (EDAC) Input
- Aircraft Selection
- Aircraft PDF References
- Vessel Platform Inputs
- Mobilization/Staging:
- Cascade Transit Speed
- Max Range
- Dispersant Payload
- Dispersant Load Time
- Fuel Load Time
- Sortie Operations:
- Transit Speed
- Application Speed
- Pump Rate
- Swath Width
- U Turn Time
- Max Sortie Time
- Resupply On Scene

3.11.5 Process

Each calculator has its own system of processing the input data. For running a scenario using a specific calculator, the first step is always to define the spill type as continuous or batch spill. After the spill type is set, each calculator requires input data describing the scenario in focus. At the end of the process, all three calculators provide output according to their respective usage areas. The user may then make alterations or change the input data to gain further insights in the next run. For details concerning the definitions of input/output items, as well as the methods for interpreting the results, the reader is referred to the user manual of each calculator [2, 3, 4].

3.11.6 Output

3.11.6.1. Outputs of the ERSP Calculator (for mechanical recovery)

The ERSP Calculator outputs are displayed both in graphical and tabular form. Notes are generated by the calculator to alert the user that adjustments to input data may be necessary. The graphical data is presented in the form of summary data, followed by bar charts which depict the breakdown of fluids recovered, and a recovery cycle timeline during each operating period. Batch spills have a set of bar charts for three consecutive days, while a continuous spill only has one bar chart which would assume to be repeated for each day of the ongoing discharge of oil.

In the following, the main results obtained from the calculator are outlined. For more detailed information, see [2].

Encounter Rate Results

— Maximum Effective Swath (ft)
— Swath Used For Calculation (ft)
— Oil/Emulsion Encounter Rate (gpm)
— Areal Coverage Rate (acre/min)
— Area Covered in Operating Period (acres)
— Area Covered in Operating Period (Sq Miles)

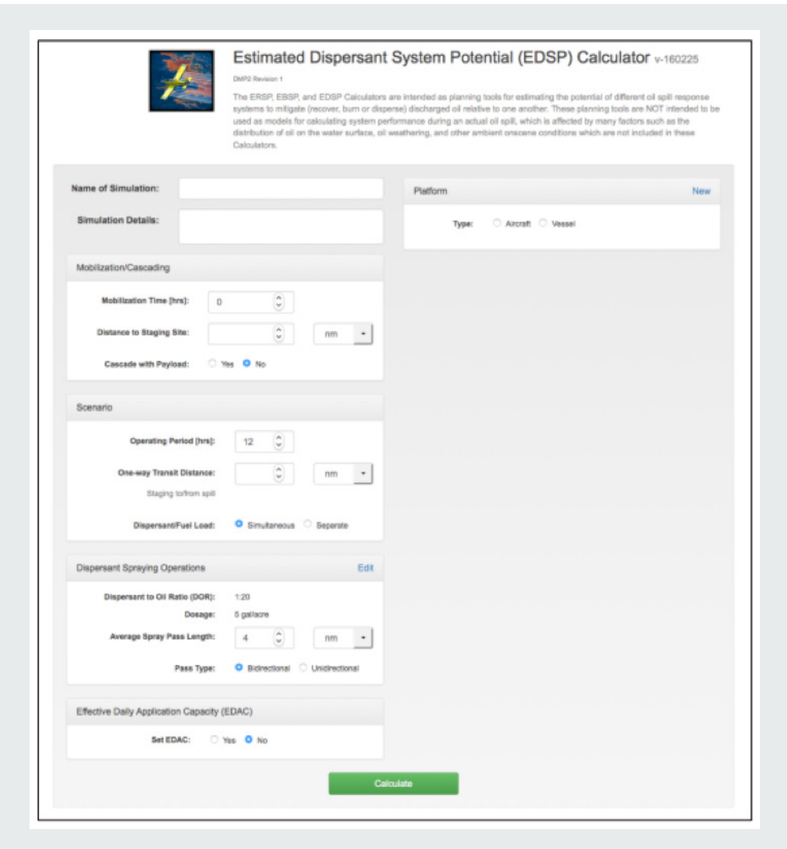


Figure 3.11.4.
Estimated Dispersant System Potential (EDSP) Calculator [4]

Recovery Results

— Total Fluid Recovery Rate (gpm)
— Free Water Recovery Rate (gpm)
— Oil/Emulsion Recovery Rate (gpm)
— Water in Emulsion Recovery Rate (gpm)
— Oil Recovery Rate (gpm)

Storage Results

— Water Retained Rate (gpm)
— Decant Rate (gpm)
— Time to Fill Onboard Storage (hr)
— Total Offload Cycle Time for Full Tank(s) (hr)
— Time for One Full Cycle (hr)
— Skimming Time in Operating Period (hr)
— Skimming Time in Operating Period (%)
— Total Number of Fills in Operating Period

Volume Results

— Total Volume Oil/Emulsion + Free Water Retained in Operating Period (bbl)
— Total Volume of Free Water Recovered & Retained in Operating Period (bbl)
— Total Volume Oil/Emulsion Recovered in Operating Period (bbl)
— Total Volume of Water in Emulsion Recovered in Operating Period (bbl)
— ERSP (Total Volume Oil Recovered in Operating Period) (bbl)

3.11.6.2. Outputs of the EBSP Calculator (for in situ burning)

The EBSP Calculator outputs are displayed both in graphical and tabular form. Notes are generated by the calculator to alert the user that adjustments to input data may be necessary. Below only tabular data output is presented. For more detailed information, see [3].

Figure 3.11.5 shows the tabular data outputs, which present additional planning details relating to encounter, collection and aerial coverage rates, and burning-related aspects of the system. The column labels also show the oil slick thickness and the emulsification values that were used by the EBSP calculator for each operating period. The following results are obtained, as shown in Figure 3.11.5:

— Swath Calculated from Fire Boom Length: The swath is 0.3 times the fire boom length.
— Oil/Emulsion Encounter Rate: This is a function of the swath, the thickness of the oil/emulsion and the speed of the collection/burn system.
— Oil/Emulsion Collection Rate: The encounter rate times the throughput efficiency.
— Fire Boom Capacity: The boom is defined to be "full" or at its holding capacity when the oil/emulsion in the boom is 1/3 the distance from the apex to the leading ends of the boom and the average oil/emulsion thickness is 1/3 of the boom draft.
— Areal Coverage Rate: This is the rate at which the burning system "sweeps the oil slick" in units of acres per minute. It is a function of Speed and Swath.
— Time to Fill: This is the fire boom capacity divided by the collection rate.
— Offset Time: This is the time necessary to move

the full fire boom from the collection to the area where the oil can be ignited and burned safely, and return to the collection area. It is calculated as the offset distance divided by the oil collection speed.
— Burn Rate: The Burn Rate is a function of the percent emulsion of the oil.
— Burn Time: The total amount of time burning in each Operating Period.
— Number of Burn Cycles in OP: The number of burn cycles decreases over successive Operating Periods due to the reduced availability of thicker oil and the additional time that is needed to fill the fire boom to its holding capacity
— Collection Time in OP: The total amount of time collecting in each Operating Period.

3.11.6.3. Outputs of the EDSP Calculator (for surface applied dispersants)

The EDSP Calculator outputs are displayed both in graphical and tabular form [4]. The graphical data is presented using summary data and with a dispersant spraying cycle timeline during each operating period.

Results for Each Operating Period:
— Cascade Time
— Time On Scene to Commence Spray Operations for OP1 (Cascade Time + One Way Transit Time)
— Adjusted OP Time
— Payload Deliveries
— Dispersant Applied
— Total Area Coverage
— Oil Treated (EDSP)

Results per Sortie for a Complete Payload Application:
— One-way Transit Time (including Taxi + Takeoff/Landing for Aircraft)
— Calculated Pump Rate
— Spray Time/Pass
— Number of Passes/Sortie
— Spray Time/Sortie
— Total Time/Sortie
— Areal Coverage Rate
— Area Covered/Sortie

3.11.7 Strengths and limitations

Some strengths of the ERSP, EBSP, and EDSP Calculators include:

— They are easily and freely accessible;
— They do not require significant investment to run;
— They all can be used for producing and updating oil response plans;
— They allow the users to make comparisons of different scenarios;
— They present a full-scenario-test of different oil spills for training purposes.

Some limitations of the ERSP, EBSP, and EDSP Calculators include:

— They are designed for preparedness planning, not for use during an actual operation;
— They make simplifications, and do not take some factors into consideration which may be important in actual response operations, such as the distribution of oil on the water surface, oil weathering and other ambient on-scene conditions.

Notes and practicalities

The Response System Planning Calculators and material needed for using the calculators are openly available on the website of Bureau of Safety and Environmental Enforcement of U.S. Department of the Interior.

Operating period: **Encounted product (oil/emulsion) thickness:** **Per cent of water in oil/water emulsion**	**Operating period 1.** **0,1** **35**	**Operating period 2.** **0,05** **55**	**Operating period 3.** **0,025** **75**
Swath calculator from fire boom lenght	210 ft	210 ft	210 ft
Oil/emulsion encounter rate	11363 gpm	5682 gpm	2841 gpm
Oil/emulsion collection rate	8523 gpm	4261 gpm	2131 gpm
Fire boom capacity	800 bbl	800 bbl	800 bbl
Areal coverage rate	4,19 acre/min	4,19 acre/min	4,19 acre/min
Time to fill	0,07 hrs	0,13 hrs	0,26 hrs
Offset time	1,97 min	1,97 min	1,97 min
Burn rate	0,09 in/min	0,06 in/min	0,04 in/min
Burn time	43,5 min	62,9 min	113,1 min
Number of burn cycles in operation	6,46	5,35	3,73
Collection time in operation	1,3 hrs	1,4 hrs	3,1 hrs
EBSP = Total volume of oil burned in oparating period	**5 600 bbl**	**4 800 bbl**	**3 200 bbl**

Figure 3.11.5.
Outputs obtained from the EBSP Calculator [3]

3.12. BowTie Method

3.12.1 Background

The BowTie method can be considered to be a combination of earlier developed fault tree analysis (FTA) and event tree analysis (ETA) methods. The first BowTie diagrams seem to have appeared in the Imperial Chemistry Industry course in Australia 1979, but how and when the method found its exact origin is not completely clear [1]. A significant milestone in the history of BowTie was the catastrophic incident on the Piper Alpha platform in 1988, which shook the oil and gas industry.

In the early 1990s, the Royal Dutch Shell adopted the BowTie method as part of its methodological toolbox for managing risks [2]. The method rapidly gained support throughout the industry because the BowTie diagrams appeared to be a suitable visual tool [1]. Nowadays, the BowTie method is also used for risk management related to different transport modes such as maritime and aviation [3, 4].

3.12.2 Overview

The BowTie method is a linear diagrammatic way of describing, analyzing, and communicating the pathways of the identified risks from causes to consequences. It is designed to develop a better understanding of the risk [5]. The method provides an input to risk assessment and to decisions, with a particular focus on failure pathways and the most appropriate treatment strategies. The main strength of the BowTie method is its simplicity.

Figure 3.12.2 presents the main components of the BowTie method. The fault tree on the left side of the BowTie diagram examines the possible hazards that cause the top event, which is shown at the center of the diagram. The event tree on the right side presents the possible consequences should the top event occur [6].

Using the diagram representation, the focus of the BowTie method is on the controls between the causes and the event, and the event and consequences. The aim of the controls on the left side of the BowTie diagram is to prevent the occurrence of the undesired event. The controls on the right size minimize the effect of the consequences of the undesired event, and thus relate to response and recovery [7].

The BowTie method also makes it possible to explore the robustness of preventive and recovery controls, including escalation factors, which can have potential negative effects on the success of control measures implemented. For example, severe sea conditions can be an escalation factor, having negative effect for control measures such as oil booms, and hence can limit or prevent their use. Furthermore, this method is designed to identify the owners of different controls, which is important for communication and the implementation of the risk management solution in practice.

The BowTie method is useful where there are clear independent pathways leading to failure. Because of this linear approach, the method has been also criticized in the safety sciences [8, 9].

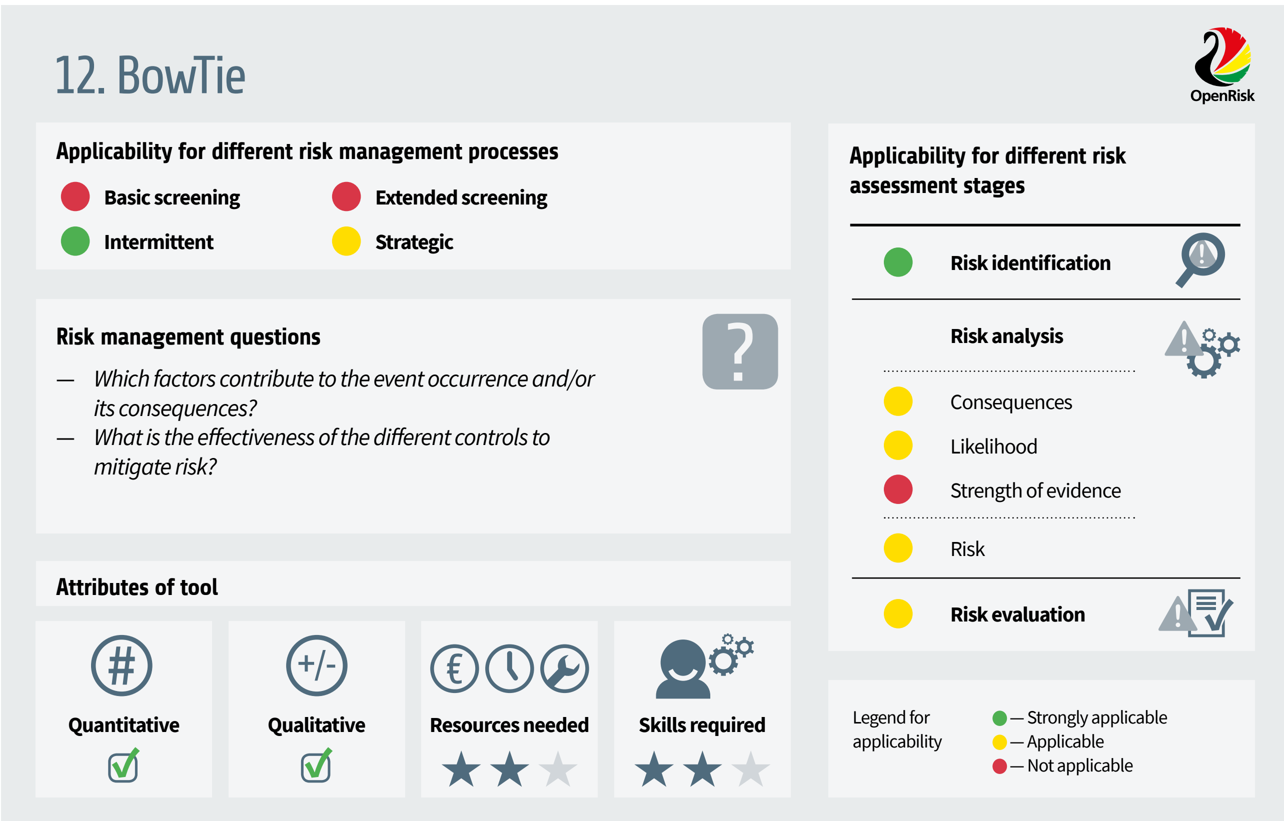


Figure 3.12.1.
Overview of the BowTie tool: Risk management questions addressed, tool attributes, and applicability for different risk management processes and risk assessment stages

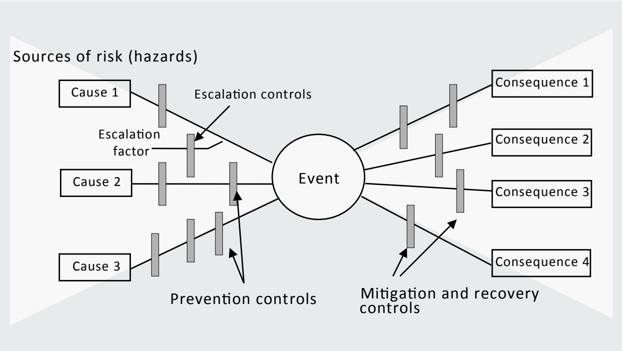


Figure 3.12.2.
The main components of the BowTie method according to the ISO 31000:2018

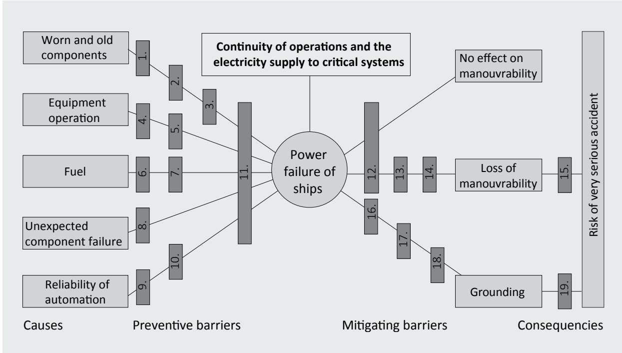


Figure 3.12.3.
BowTie diagram on power failure of ships [10]

The context of e.g. Pollution Preparedness and Response can be considered complex (pathways and barriers are not necessarily independent and controls may be procedural and hence the effectiveness unclear), which sets certain limitations on use of the BowTie. Despite of its limitations, the method is still useful for obtaining a high-level overview and is capable to provide valuable information for prioritizing the treatment of certain pathways over others.

3.12.3 Use

The BowTie method can be used to answer the following risk management questions:

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

The BowTie method is primarily useful in the risk identification and risk analysis stages of the intermittent risk management process in the developed PPR risk management framework based on ISO 31000:2018, introduced in Section 2. BowTie may also have a role in the strategic risk management process. The tool can provide qualitative and quantitative outputs. The process requires a medium commitment of resources in terms of finances, and analyst´s and expert´s time. Moderate experience is needed for applying the method, and for extracting results.

The scope of the Pollution Preparedness and Response system can be considered wide and complex. It includes various controls for dealing with pollution incidents, either nationally or in co-operation with other countries. In addition, there are also a multitude of different authorities and stakeholders involved in implementing the controls and assuring their functioning. Because of this, the level of abstraction of the investigated system and the corresponding level of detail to which the BowTie method is implemented in a model is an important decision to make.

In practice, the BowTie diagram should not be too specific because the diagram will become too large if all information about the entire system is included. On the other hand, it should not

Table 3.12.1.
Description of controls related to Figure 3.12.3

ID	Control	ID	Control
1	Maintenance system	10	Testing, maintenance of automation system
2	Duplication of critical systems	11	Functioning of backup and emergency systems
3	Deviations and responding to them	12	Quick startup of backup and emergency systems
4	Knowledge of systems	13	Safe procedures
5	User interface clarity and instructions	14	Good local knowledge and situational awareness
6	Full duplication of the fuel system	15	Narrow part of fairway, shoal and rocks
7	Fuel quality monitoring and maintenance	16	Narrow part of fairway, shoal and rocks
8	Component choice during construction/renewal	17	Inadequate power in backup- and emergency systems
9	Design	18/19	Favourable traffic situation

be too generic either, since relevant information that is necessary to put the analysis into practice might be lost. Depending on the abstraction level, there will be either more diagrams that are more detailed, or fewer diagrams that are more abstract. A good practice is to start the analysis at a rather high level of abstraction to prioritize the areas in need of strengthened risk control, which may be followed by a more detailed modeling of the system in the areas closer to this control.

In the linear way of thinking, accidents are usually seen as a result of a longer chain of events. For example, a blackout can lead to a loss of control over a ship, which can lead to a grounding of a ship, which can lead to an oil spill and damages to the environment. Which one is made into a top event is an important decision to make, because this choice affects how the diagram will unfold. To clarify this point, for the maritime safety authorities the top event could be the blackout, whereas for PPR authorities it could be the arrival at the accident site. It is also important to realize that the top event is not an absolute event. It is very much a subjective choice that depends on the perspective one takes, and the specific purpose of the analysis [1].

Figure 3.12.3 shows an example of using the BowTie method. It is from a safety study of power failures on ships, which was conducted by the Finnish Safety Investigation Authority [10].

3.12.4 Input

The BowTie method is mainly designed to be used in a brainstorming session with domain experts, but the input data can also include other data and information sources. Here are some examples of potential data sources:

— Expert knowledge
— Maritime accident and incident reports
— Reports and data of response capacity, quality and location
— Reports and data of coastal endangered species and recreation areas
— Reports and data of coastal nuclear power stations and other industry

3.12.5 Process

According to the ISO 31000:2018 standard, the main steps for the BowTie analysis are as follows:

1. A particular risk is identified for analysis and represented as the central element of a BowTie diagram;
2. Causes of the event are listed considering sources of risk;
3. The mechanisms by which the sources of the risk can lead to the critical event are identified;
4. Lines are drawn between each cause and the event forming the left-hand side of the BowTie diagram, and factors which can lead to escalation can be included in the diagram;
5. Controls that should prevent each cause leading to the unwanted event and further consequences, can be shown as vertical bars across these lines. Where there were factors which might cause escalation, controls to escalation can also be represented;
6. On the right-hand side of the BowTie diagram, different potential consequences of the unwanted event are identified and lines drawn to radiate out from the event to each potential consequence;
7. Controls to the consequence are depicted as bars across the radial lines;
8. Management functions which support controls (such as training and inspection) can be shown under the bow tie and linked to the respective control.

3.12.6 Output

The output of the BowTie method is a diagram, which shows the causes of the identified risk and the potential consequences if the risk materializes. In addition, it shows the preventive controls and controls for mitigating the consequences, including escalation factors that could have negative effect on them. Furthermore, it is possible to add additional information on BowTie diagrams such as information about the robustness and owners of different controls, which can be useful for risk management purposes.

3.12.7 Strengths and limitations

Some strengths of BowTie include:

— It is simple to understand and gives a clear pictorial representation of the problem;
— It focuses attention on controls which are supposed to be in place for both prevention and mitigation, including their effectiveness;
— It can be used for desirable consequences;
— It does not need a high level of expertise to use.

Some limitations of BowTie include:

— It cannot depict where multiple causes occur simultaneously to cause the consequences;
— It may over-simplify complex situations, particularly where quantification is attempted.

Notes and practicalities

Several commercial software applications have been developed based on BowTie method, such as BowTie XP. Although these applications may be useful, the BowTie method can be deployed without a specific software.

3.13. Functional Resonance Analysis Method

3.13.1 Background

Understanding why accidents occur is a complex endeavor, and accident causation theories have evolved significantly over the decades. The Functional Resonance Analysis Method (FRAM) is a qualitative tool that was developed by Erik Hollnagel in the early-to-mid 2000s as part of the 'Safety-II' ideology. Strictly speaking, FRAM is not a risk assessment method, nor is it an accident investigation method – but it can be used to augment these processes [1].

The 'Safety-II' way-of-thinking considers successful and unsuccessful events to stem from the same source, and treats them as consequences of system performances and variability. This is in stark contrast with 'Safety-I' thinking traditional risk assessment and accident investigation methods, which attempt to determine the root causes of problems and identify sources or factors, which lead to failures and hazards in systems and processes. In this sense, the scope of 'Safety-II' and tools such as FRAM is broader than that of 'Safety-I' and traditional risk-assessment tools: whilst the latter only focus on things that go wrong, the former also attempt to understand why things go right (which is the case most of the time in systems).

FRAM, being a fairly contemporary tool, has yet to see widespread use in different industries. However, high-risk industries such as aviation, maritime, medical and the nuclear sectors have explored the use of the tool in different contexts over the last decade [2]. Within the maritime domain, FRAM has been used primarily to model the operations of Vessel Traffic Services and pilots [3]; the same work also compared VTS to Air-Traffic Control (ATC), and provided recommendations for stakeholders on how to develop safe and 'resilient' VTS systems. More recently, it has also been used to augment the Formal Safety Assessment process and the fault-tree method [4].

Pollution Preparedness and Response authorities are also end-users that could potentially benefit from the use of FRAM. This chapter thus describes the key points of FRAM in accordance with the ISO 31000:2018 risk management framework.

3.13.2 Overview

The essence of FRAM is to compare 'work-as-imagined' against 'work-as-done'. For such a comparison, it is necessary to break-down a system or a process. While typical risk assessment tools break-down systems by components, FRAM describes systems through functions – i.e. an activity or a task that is conducted in order to fulfill a specific aim. Each function can be described using six aspects:

In FRAM, the functions are depicted pictorially as hexagons, with the six aspects on the different vertices, see Table 3.13.1 and Figure 3.13.2. Functions can be distinguished in two classes: foreground and background. A background function is assumed not to have specified potential variability and detailed components in the FRAM analysis and so it has only outputs [5]. A foreground function plays a key role in the analysis and, therefore, it needs a more detailed description and consequences for the outcome of the event being analysed, possibly with regard to all the six aspects. Upstream functions are executed prior to downstream functions in the instantiation of the model and can thus impact on their variability of downstream functions depending on their characteristics.

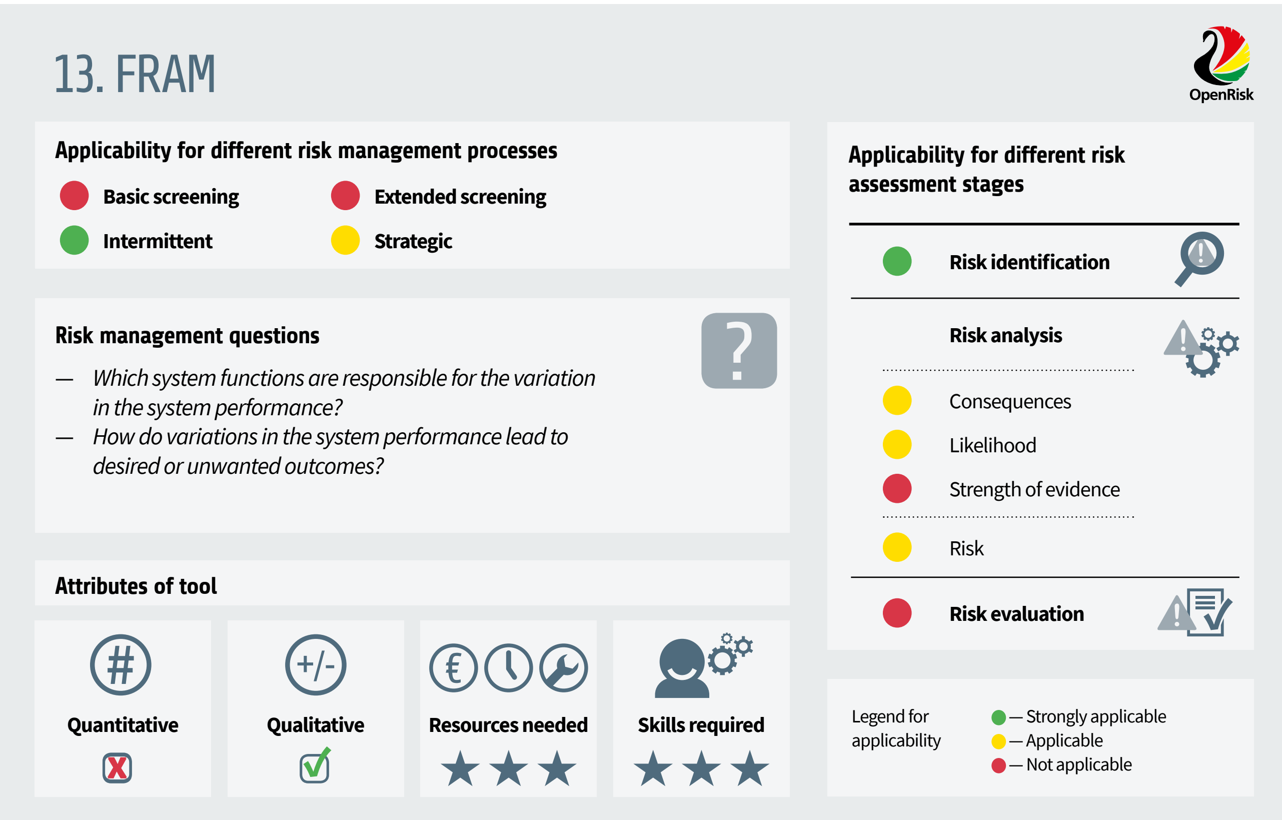


Figure 3.13.1.
Overview of the FRAM tool: Risk management questions addressed, tool attributes, and applicability for different risk management processes and risk assessment stages

By creating and describing links between the different functions, it is possible to qualitatively assess the coupling and complexity within a system. This, in turn, provides an insight about the criticality of the various functions and the overall system. Different versions of a FRAM model can be created for the same system or process to depict the variations in functions and their aspects; each different version is referred to as an instantiation of the model. The instantiations of a system can be qualitatively compared to identify potential interactions and variations that lead to successful or unsuccessful events.

Table 3.13.1.
The six aspects which describe functions in FRAM, [4]

Aspect	Description
Input (I)	Conventional input and/or a signal that activates the function, is used or transformed by the function (requires change of state for the function to start)
Output (O)	Result of what the function does, represents a change of the system's state or output parameters
Precondition (P)	Conditions that need to be fulfilled before the function can be carried out
Control (C)	What supervises or regulates the function so that it derives the desired output
Time (T)	Aspects of time that affect the way the function is carried out
Resource (R)	Material or matter that are consumed, or executive conditions, that need to be present, while the function is active

Figure 3.13.2.
An example of the use of FRAM in maritime domain. Each hexagon represents a different function. Foreground functions are white with a grey border and background functions are grey, [6]

3.13.3 Use

FRAM can be used to answer the following risk management question:

— Which system functions are responsible for the variation in the system performance?
— How do variations in the system performance lead to desired or unwanted outcomes?

FRAM is primarily useful in the risk identification stage of the intermittent risk management process in the developed PPR risk management framework based on ISO 31000:2018, introduced in Section 2. FRAM may also have a role in the risk analysis stage, and in the strategic risk management process. The tool provides qualitative outputs. The process requires a high commitment of resources in terms of finances, and analysts' and experts' time. Significant experience is needed for applying the method, and for extracting results.

Given the holistic, proactive nature of FRAM, it is possible to use the method for specific systems in context of oil/chemical risk assessment, for instances for identifying/analyzing risks of new technologies, for instance autonomous vessels, and novel fuel/propulsion systems. The tool can also be used to identify/analyze risks of Pollution Preparedness and Response processes and systems.

By allowing users to determine which variations of functions lead to successful or unsuccessful outcomes, FRAM can also be used to identify targeted risk-control measures. Figure 3.13.2 depicts an example of FRAM that was conducted to model a VTS system.

3.13.4 Input

Typically, the input for a FRAM model is based on information obtained from incident/accident reports, work manuals, interviews, and observational studies. The input aims at describing how people do their work in the context of different functions that are required as part of a system or process [7]. More specifically, interview questions and the direction of inquiry can focus on the time, control, and resource constraints that people face during different tasks, as well as an insight about the necessary pre-conditions for performing the work to achieve successful outcomes.

3.13.5 Process

The application of FRAM can be described as a 4-step process [7, 8, 9]:

1. The user identifies the different functions and the links between them in a system or process, and characterizes them using the six aspects shown in Table 3.13.1. This is done using the input data (analysis of accident reports and manuals, interviews, and observations);
2. The model is checked for completeness and validity based on stakeholder feedback;
3. Variations of each function and links between functions in a model, and each instantiation, are identified and compared using qualitative descriptors and statements;
4. The user identifies solutions to mitigate variations that lead to unsuccessful events, and amplify variations that lead to successful events.

3.13.6 Output

The output of a FRAM model can be visualized using the FRAM Visualizer. It pictorially depicts the functions within a system or process, as well as the links between the different functions. The output is purely qualitative, and end-users can make statements about the safety or resilience of a system or process using the visual output.

3.13.7 Strengths and limitations

Some strengths of FRAM include:

- It promotes holistic systemic thinking;
- It helps users to overcome the issues such as blame culture, which are often associated with deep root-cause analyses [10];
- It is a generic tool which can be used to model any conceivable activity, system or process.

Some limitations of FRAM include:

- It is resource-intensive and requires significant expertise;
- It does not directly provide probability and consequence values, or any quantitative values for that matter, so it should be supplemented with other methods if risk levels are required;
- It is highly sensitive to the views and judgments of analysts and domain experts, which can raise concerns about model validity.

Notes and practicalities

The FRAM Visualizer and material needed for using the method are openly available on the website of Functional Resonance Analysis Method.

3.14. Key Performance Indicators

3.14.1 Background

Key Performance Indicators (KPIs) are metrics which can be used to evaluate the success and/or the performance of various systems and processes. KPIs are tailored to match the aims and objectives of a system, and different stakeholders may use different KPIs for the same system, depending on their own needs and requirements.

The notion of KPIs was traditionally linked to financial and economic contexts, where metrics for market and industry performance are highly sought-after. In recent years, high-risk industries such as the transport sectors have also adopted a widespread use of KPIs to monitor the performance of their systems in terms of safety and efficiency. Examples of use of KPIs in the aviation industry, for instance, include the Performance Based Navigation process.

In the maritime industry, KPIs were initially promoted by InterManager in the form of their 'Ship Performance Indicator Standard' [1]. The standard developed by InterManager is now a part of BIMCO's Shipping KPI System. Since then, the maritime and shipping industry as a whole has moved towards a common set of KPIs which has allowed the industry as a whole to work towards improved performance.

While KPIs have been widely used by shipping companies, coastal state authorities are yet to make use of them on a wider basis. Given that Pollution Preparedness and Response (PPR) authorities often need to monitor risks on a continuous basis, and take actions based on any noticeable or significant deviations, KPIs can be an ideal tool for their use in PPR risk management.

3.14.2 Overview

The aim of KPIs is to measure the performance of a system or process with respect to its aims and objectives. To do so, end-users are first required to determine the nature of the aims – e.g. safety-related, efficiency-related, financial-related, etc. Following this, users should identify various overarching measures that are used to monitor the fulfillment of these aims. These measures are referred to as performance indicators. Various performance indicators for each aim/objective can be grouped and aggregated using empirical formulae to calculate various KPIs for a system (see Example of KPIs for PPR). This is an approach commonly used in the maritime industry by organizations such as BIMCO and InterManager [2].

KPIs provide quantified values of system performance, thus require quantified values of various data. This data must be recorded continuously over time to monitor system deviations and changes. The unit of data can vary, depending on what is being measured. For instance, finance-related KPIs may require data in terms of monetary values, whereas safety-related KPIs may focus on data in terms of probabilities and consequences. For maritime systems, specific methods have been proposed to develop KPIs for safety management systems [3, 4]. These stress the need to base the KPIs on the actual context of the organizational processes and functions, while also considering the regulatory requirements.

Figure 3.14.1.
Overview of the KPIs tool: Risk management questions addressed, tool attributes, and applicability for different risk management processes and risk assessment stages

3.14.3 Use

Key Performance Indicators (KPIs) can be used to answer the following risk management question:

- How important are different system indicators in regards event occurrence and/or consequence?
- What is the performance of different system elements compared to target levels?

KPIs are primarily useful in the basic and extended screening processes in the developed PPR risk management framework based on ISO 31000:2018, introduced in Section 2. KPIs may also have a role in the intermittent risk management process. The KPIs are useful in the risk analysis and evaluation stages, providing insight in the risk levels based on a set of indicators, and how well the system performs compared to defined target levels. Depending on how KPIs are defined, they provide quantitative or qualitative outcomes. The process requires a moderate commitment of resources in terms of finances, and analysts' and experts' time. Moderate experience is needed for applying the method, and for extracting results.

3.14.4 Input

As KPIs can be considered to be an aggregation and quantification of various performance indicators, the input often comes from individual performance numbers of a system. The performance data of systems should be recorded on a continuous basis, so that end-users can make comparisons over time. Stakeholder consultation can play a key role in defining the KPIs, as well as in identifying the constituent performance indicators and determining the empirical calculation formulae.

3.14.5 Process

The process of using KPIs can be described as [1]:

- Identify and calculate a set of KPIs. Three questions need to be answered at this stage:
  - What is the KPI to measure in terms of systems aims and objectives?
  - How can (a) be measured? In other words, what data can be considered which will quantify and measure (a)?
  - When is this data to be measured and monitored?
- Evaluate. At this stage, user must set boundaries of acceptability and monitor the KPI value(s) over time against the acceptability criteria;
- Take action. Appropriate corrective action must be undertaken if the KPI value(s) start to increase or decrease.

3.14.6 Output

KPIs are metrics, which can be used by stakeholders to identify deficiencies and high-risk components in a system or process. These values can then be used to initiate or justify risk management processes, which in turn can be used to optimize the allocation of resources and risk control options.

3.14.7 Strengths and limitations

Some strengths of KPIs include:

- They allow end-users to monitor system deviations over time, and thus identify any changes in risk values;
- They can allow end-users to optimize limited resources in an optimum manner, both financially and in terms of risk.

Some limitations of KPIs include:

- They may be resource intensive and require significant expertise, as well as reliable data;
- They may not necessarily provide the context for deviations in system performance.

Example of Key Performance Indicators for Pollution Preparedness and Response

The following tables contain a non-exhaustive list of KPIs which can be relevant for PPR purposes.

Table 3.14.1 contains KPIs that are currently widely used in the maritime industry [2]. These KPIs are primarily ship-related, and collected by shipping companies in the first instance. They can be used in a PPR context to identify high-risk ships over different time periods, and thus allow decision-makers to optimize resource allocation through preliminary and intermittent risk management processes. It is important to note that KPIs must be combined with ship- and environmental metadata (e.g. ship type, average speed, wind conditions, etc.) in order to provide a comprehensive risk profile for preliminary and intermittent risk management processes.

Table 3.14.1.
KPIs used in the maritime industry [2]

KPI	Formula	Performance Indicators
Port State Control Performance	$\frac{A}{B}$	A: Number of PSC inspections resulting in zero deficiencies B: Number of PSC inspections
Crew Disciplinary Frequency	$\frac{A+B+C+D+E}{F}$	A: Number of absconded crew B: Number of charges of criminal offences C: Number of cases where drugs or alcohol is abused D: Number of dismissed crew E: Number of logged warnings F: Total exposure hours
Crew Planning	A+B	A: Number of seafarers not relieved on time B: Number of violation of rest hours
HR Deficiencies	$\frac{A}{B}$	A: Number of HR related deficiencies B: Number of recorded external inspections
Cadets per Ship	$\frac{A}{B}$	A: Number of cadets under training with the ship manager B: Number of ships operated under DOC holder
Officer Retention Rate	$1 - \left(\frac{A-B-C}{D}\right)$	A: Number of officer terminations from whatever cause B: Number of unavoidable officer terminations C: Number of beneficial officer terminations D: Average number of officers employed
Officers Experience Rate	$\frac{A}{4B}$	A: Number of officer experience points B: Number of officers onboard
Training days per Officer	$\frac{A}{B}$	A: Number of officer trainee man days B: Number of officer days onboard all ships under technical management (DOC)
Release of Substances	A+B	A: Number of releases of solid substances to the environment B: Number of oil spills
BWM Violations	A	A: Number of ballast water management violations
Contained Spills	A	A: Number of contained spills of liquid
Environmental Deficiencies	$\frac{A}{B}$	A: Number of environmental related deficiencies B: Number of recorded external inspections
Navigational Deficiencies	$\frac{A}{B}$	A: Number of navigational related deficiencies B: Number of recorded external inspections
Navigational Incidents	2A+B+2C	A: Number of collisions B: Number of allisions C: Number of groundings
Cargo Related Incidents	A	A: Number of cargo related incidents
Operational Deficiencies	$\frac{A}{B}$	A: Number of operational related deficiencies B: Number of recorded external inspections
Vetting Deficiencies	$\frac{A}{B}$	A: Number of observations during commercial inspections B: Number of commercial inspections
Condition of Class	A	A: Number of conditions of class
Failure of critical equipment and systems	A	A: Number of failure of critical equipment and systems

Table 3.14.2.
Proposed KPIs for Pollution Preparedness and Response

Proposed KPI	Formula	Proposed Performance Indicators
Coastal State Preparedness	N/A	A: Number of PPR vessels available B: Number of PPR aircraft available C: Number of stand-by personnel available D: Types of vessels available E: Total coastline (km) F: Total EEZ/responsibility area in (sqkm)
Coastal State Response	N/A	A: Number of spill incidents responded to B: Average area of response covered C: Average time to respond to incident D: Total number of spill incidents in responsibility area
Political Factors	N/A	A: Responsibility area covered by MoUs with neighbouring states B: Preparedness capabilities of neighbouring states C: Response capabilities of neighbouring states
Societal Factors	N/A	A: Perception of coastal communities towards PPR B: Awareness of coastal communities towards PPR
Environmental Factors	N/A	A: Environmental damage due to spills B: Environmental damage avoided due to PPR C: Financial cost of PPR
Regional Factors	N/A	A: Expected developments related to maritime traffic B: Expected developments at the global and regional levels related to PPR C: Heightened concern of the general public at the impact of global shipping activities on the marine environment D: Level of interaction at the global, regional, sub-regional and national levels
Organizational Factors	N/A	A: Number of spill deficiency observed onboard ships B: Number of completed training on board ships towards PPR C: Number of major spill non-conformity observed onboard ships D: Number of detention due to the spill E: Number of spill near-miss reported by ships F: DPA internal audit judgement towards PPR G: HSEQ Manager audit judgement towards PPR
Human Factors	N/A	A: Human mental factors impacting spill incidents B: Human physiological factors impacting spill incidents
Vessel Condition	N/A	A: Vessel age B: Vessel type C: Vessel tonnage D: Vessel automation
Coast Environment	N/A	A: Hydrological condition B: Meteorological condition C: Channel condition D: Wharf condition
Emergency device	N/A	A: Number of emergency devices B: Qualification and capability of device
Crisis management procedures	N/A	A: Existence of in place regulations for oil pollution crisis management B: Involvement of all concerned governmental/civilian agencies C: Clearly defined decision making process D: Involvement of stakeholders in crisis management procedures E: Regular scenario based crisis management exercises
Oil Pollution Risk Assessment Procedure	N/A	A: Predicting and quantifying risks involved B: Risk analysis C: Risk minimization D: Transferring output of risk assessment analyses into OSR Manuals

Table 3.14.2.
(continued)

Proposed KPI	Formula	Proposed Performance Indicators
OSR Manuals/Plans	N/A	A: Coverage of OSR Manuals B: Efficiency of inter-agency cooperation C: Familiarity of crew with OSR Manuals D: Official assessment of existing OSR Manuals
Oil Response Facilities	N/A	A: Ratio of coverage B: Shore-based locations and capabilities C: Variety of response assets D: Number of assets ready to use E: Sustainability of shore-based and seagoing assets
Facilities' frequency of updating	N/A	A: Present response strategies B: Present response tactics and techniques C: Up-to-date level of knowledge in hands D: Sufficiency of updating procedure E: Frequency of technology update
The frequency of emergency drills	N/A	A: Variety of oil pollution scenarios B: Number of emergency response teams C: Competency of emergency response personnel
On site communication	N/A	A: Establishment of full scale communication network B: Efficiency of communication lines C: Frequency of emergency communication drills
Quality of Emergency response training	N/A	A: Minimum requirements for response team training B: Certification process C: Refreshment training and re-certification process D: Frequency of large scale emergency response exercises
Governmental Support	N/A	A:In place regulatory rules B: Government approved contingency plans C: Government approved sustainable logistic plan D: Government inspections and corrective measures E: Management of public relations during an emergency F: Regular financial support for enhancing response facilities/procedures

3.15. Spatial Bayesian Oil Spill Risk Tool

3.15.1 Background

Oil spills can have severe impacts on marine and coastal ecosystems. However, each oil spill is a unique combination of varying factors, which together determine the final impact. The amount of spilled oil as well as oil type are important factors in the potential contamination of coastal areas, and, for instance, the efficiency of oil recovery. In addition, weather conditions have a major role, as high wind speeds and wave heights typically intensify and speed up weathering processes such as emulsification and dispersion of oil. Further, wind and currents define where the spilled oil will drift after an accident.

The final impact of oil on the environment depends on various geological and ecological attributes of the contaminated areas. Prevailing water levels and waves, together with the profile of the shoreline, affect the contamination of coastal areas and the organisms inhabiting them. The type of shoreline (rocky shores, sand or gravel beaches, etc.), in turn, defines the sensitivity of the coastal environment and affects possibilities to clean the contaminated areas.

The harmful effects of oil vary among different types of organisms and their developmental stages [1]. Oil can cause harm to individual organisms via the toxicity of oil compounds, physical contamination, or habitat modifications induced by oil. Irrespective of the exposure route, species differ in their susceptibility to the negative impacts of oil. In general, earlier life stages appear to be more sensitive to oil than adults. The recovery of a population after an oil spill depends on many factors, such as the level of acute mortality, reproduction capacity and recolonization potential of the population. While it seems that oil spills may have relatively small impacts on many common species in the long term, recovery can be often slow and uncertain in populations of rare species. These typically already suffer from other human-induced impacts and are often nationally or internationally threatened [2].

Spatial oil spill risk analysis aims at estimating the damage that an oil spill may cause to the environmental and socioeconomic values in the area. When conducting risk analysis related to environmental values, we are typically interested in information concerning, e.g. the location(s) and date(s) of oil accident(s), the type and fate of spilled oil, and the distribution of environmental components exposed to oil. All of these factors involve major uncertainties due to the randomness of natural processes, and because of limited knowledge about these processes.

3.15.2 Overview

To analyse risks posed by oil spills to the environmental values, a spatial risk analysis approach has been developed, with focus on the Gulf of Finland and the Archipelago Sea in the Baltic Sea area. This approach combines three elements:

— A probabilistic causal model called Bayesian network (BN), which describes the spill-specific variables such as spill volume, oil type, etc.;
— Probabilistic oil spill maps, which describe the drifting of oil slick after an accident;
— Maps of ecological values at risk.
— The methodology is described in more detail in [3] and [4].

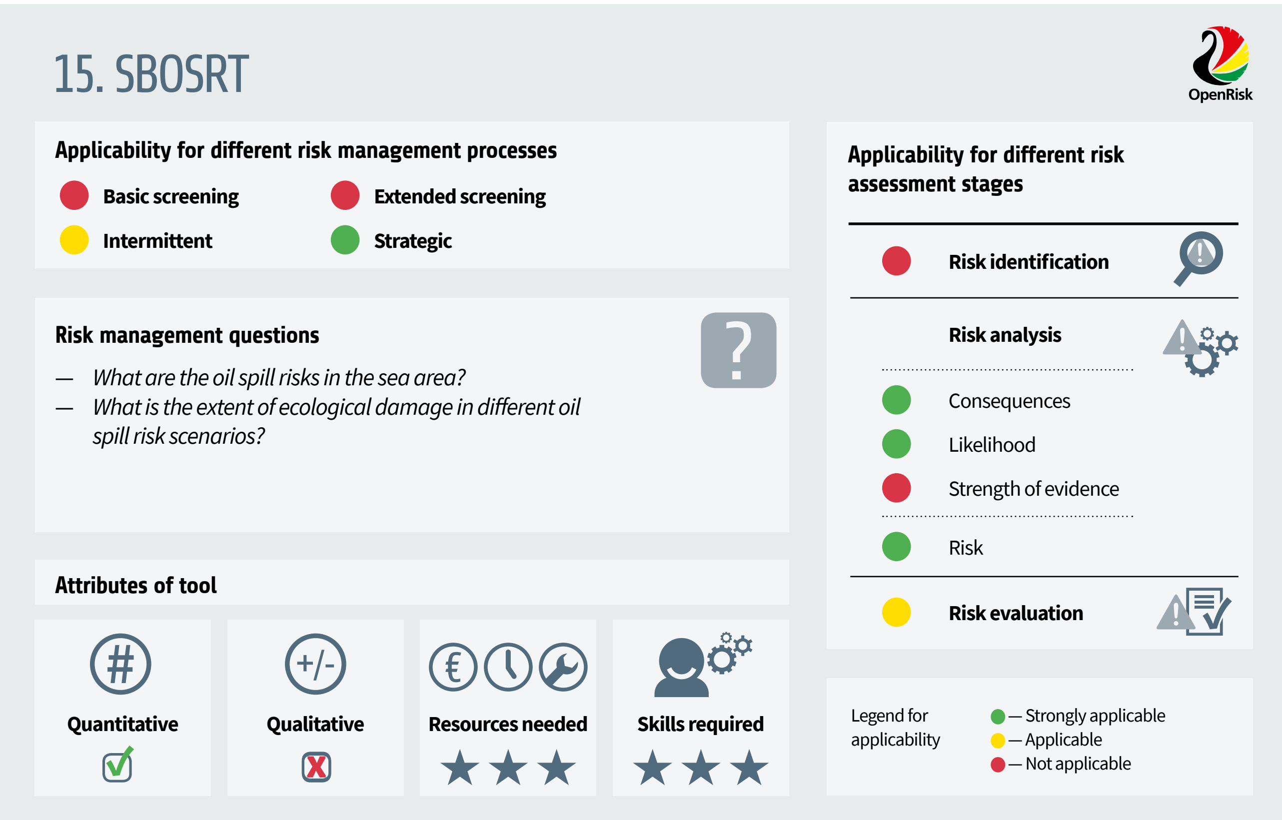


Figure 3.15.1.
Overview of the SBOSRT tool: Risk management questions addressed, tool attributes, and applicability for different risk management processes and risk assessment stages

3.15.3 Use

The Spatial Bayesian Oil Spill Risk Tool can be used to answer the following risk management questions:

- What are the oil spill risks in the sea area?
- What is the extent of ecological damage in different oil spill risk scenarios?

The Spatial Bayesian Oil Spill Risk Tool is primarily useful in the risk analysis stage of the strategic risk management process in the developed PPR risk management framework based on ISO 31000:2018, introduced in Section 2. The SBOSRT may also have a role in the intermittent risk management process, and have a role in risk evaluation through evaluating the effect of implementing selected risk control options. The tool provides quantitative outputs. The process requires a high commitment of resources in terms of finances, and analysts' and experts' time. A significant amount of experience is needed for applying the method, and for extracting results.

In general, understanding the potential consequences of oil spills helps decision-making in real oil combating situations, but risk analysis also supports strategic planning aiming at cost-effective, proactive risk management. For instance, spatial oil spill risk analysis can be used to help the allocation of oil combating resources and to guide marine spatial planning. This holds true also for the application described here. Combining available information into a single framework can help us to find, e.g., the most hazardous parts of shipping routes, not only concerning the areas with high accident likelihood, but also concerning the possible impacts in terms of ecological consequences. This kind of information is valuable when developing more effective accident prevention strategies. The information can be used also in organizing oil combating activities so that more resources are allocated to high-risk areas.

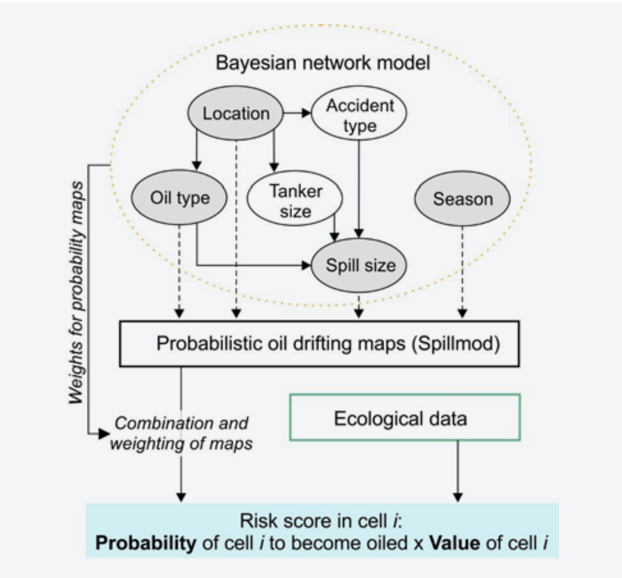


Figure 3.15.2.
The basic elements of the method underlying the Bayesian Oil Spill Risk Tool method, modified from Helle et al. (2016)

3.15.4 Input

The developed methodology uses knowledge about:

- Relative accident probabilities (implemented based on modelling and accident statistics);
- Tanker sizes (implemented based on statistical data);
- Leak sizes (implemented based on modelling);
- The efficiency of offshore oil combating (implemented based on modelling);
- The drifting and fate of oil (implemented based on modelling);
- Ecological values (implemented based on a combination of several databases).

3.15.5 Process

The methodology combines three elements: a Bayesian Network (BN) model describing the spill-specific factors, probabilistic oil spill maps describing the drifting of oil, and maps of ecological values, see Figure 3.15.2.

The first element is the BN model, which is used to describe alternative accident scenarios with several uncertain factors, such as oil type, leak size and season. Instead of commonly used fixed scenarios, the BN is a kind of scenario synthesis, where the possible combinations of accident-specific variables are weighted based on their mutual realization probabilities. The user can evaluate the situation under full uncertainty, but it is also possible to lock selected variables to certain states. For instance, the user can lock the accident location and/or the oil type which are in focus in a specific analysis. In the latter case, the probabilities of the other variables in the network will be automatically updated based on probability calculus. The BN models developed in [3] and [4] differ slightly, but the main variables in both models include accident location, accident type, tanker size, spill volume, season and oil type.

The second element is the maps describing the spreading and drifting of oil after an accident. Oil drifting modelling was done with the oil spill simulation software Spillmod. Spillmod produces maps where each grid cell (3 x 3 km) is provided with the probability to become oiled, given the spill-specific parameters (e.g. location of the spill, spill volume, oil type, weather conditions) and drifting time (set to 240 h).

A separate data set was produced for each combination of the relevant variables of the BN, i.e. location, spill volume, oil type and season (e.g. for spring, weather data from March to May were used). The weather data used in the analysis comprise data for the years 1996–2001. Hence, there were over 2500 data sets describing all the possible combinations of the four variables related to the spill in a six-year period.

The years were combined to describe the average situation in a given season, and separate maps describing different scenarios were combined using the weights calculated with the BN. Hence, the result is a probabilistic map for an uncertain oil spill scenario. However, if all variables in the BN are set to known states, the map represents a fixed scenario.

The third element is the data on ecological values at risk. The data were gathered from different sources. In the current model implementation, the focus is on threatened species and habitats, as they are typically affected already by multiple human activities, and e.g. the recovery of threatened and rare species can be slow and uncertain compared to common species [2]. The most important data sources for habitats were the INSPIRE1 and MH SutiGis databases (maintained by the Finnish Environment Institute and Metsähallitus Parks and

Wildlife Finland), and for species Hertta and Tiira databases (maintained by the Finnish Environmental Administration and Birdlife Finland). The data was stored in a new database, which included, e.g. the names and locations of habitats/species, their conservation status (i.e. their class in the framework of the International Union for Conservation of Nature (IUCN): "Critically endangered", "Endangered" or "Vulnerable"), and the VAL number, which is a numerical value given to a specific IUCN class [2].

The overall risk calculation is done as follows: The risk score of the cell i is calculated as the product of the cell's probability of oiling $P[oil_i]$ and the value of the cell $Value_i$:

$$Risk_i = P[oil_i] \cdot Value_i \qquad \text{(Eq.3.15.1)}$$

In addition, in order to compare the overall risk when, for instance, an accident is supposed to happen in a certain location, the total risk score was calculated as the sum of risk scores of all cells (n) affected by oil:

$$Risk_{TOT} = \sum_{i=1}^{n} (\Pr(oil)_i \times Value_i) \qquad \text{(Eq.3.15.2)}$$

The value of each cell ($Value_i$) was calculated as the sum of the conservation values of habitats and species present in the cell.

3.15.6 Output

The results can be studied both visually (Figure 3.15.3) and numerically (Figure 3.15.4). The visual risk map shows, by using colour coding, the risk level for each grid cell across the study area. Total risk scores related to specific scenarios can be also calculated, which enables the comparison of the total risk associated, e.g. to different accident locations, or transported oil types.

3.15.7 Strengths and limitations

Some strengths of the Spatial Bayesian Oil Spill Risk Tool include:

- It takes into account the main dimensions of risk, i.e. the probability and consequences, in a coherent manner;
- It accounts for several components which contribute to the overall risk, i.e. accident probabilities, oil drifting after an accident, as well as ecological values affected by oil;
- Bayesian networks offer a convenient way to combine different scenarios, and can incorporate knowledge from different sources (e.g. statistical data, modelling results, expert knowledge, etc.) and with different accuracies. In addition, BNs can be updated easily when new information comes available;
- Risk maps are a visual and user-friendly way to communicate the output.

Some limitations of the Spatial Bayesian Oil Spill Risk Tool include:

- Assessing realistically the probability of a certain location to become oiled requires a large number of oil spill model runs, which can be time-consuming and costly. Also e.g. long-term weather data is needed. These constraints may limit e.g. the number of accident locations that can be included in the analysis;
- The ecological value of a grid cell is based on threatened species and habitat types. However, also other important attributes (both environmental and socio-economic) need to be considered in risk management, but these are not implemented in the current model;
- The ecological value database covers the Finnish coast in the Gulf of Finland and the Archipelago Sea, although in the Baltic Sea oil spills rarely affect only one country;
- The relative values of species and habitats are based on expert judgement. Especially if other environmental and socio-economic attributes are taken into account, valuation itself can become challenging due to the differing perceptions of different stakeholder groups.

Notes and practicalities

Currently, the SBOSRT model and web application are applicable only for Finnish waters, but the approach can be easily modified for other sea areas as well.

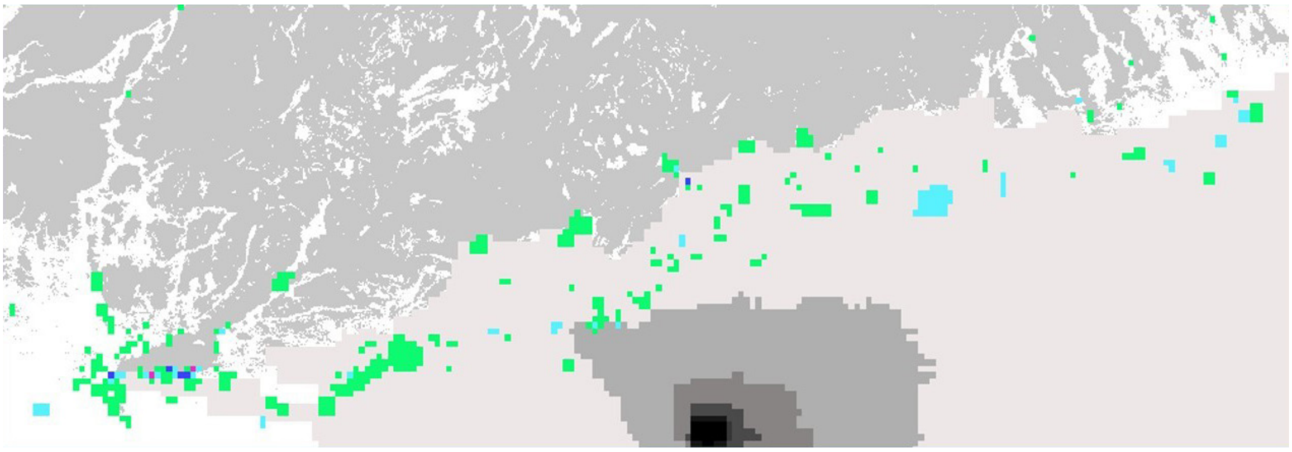


Figure 3.15.3.
Visualization of the combination of spatial data, i.e. the ecological value of grid cells (colour scale) and the probability of grid cells to become oiled (greyscale). In this example, the accident is assumed to take place in the central Gulf of Finland. Illustration by Ari Jolma.

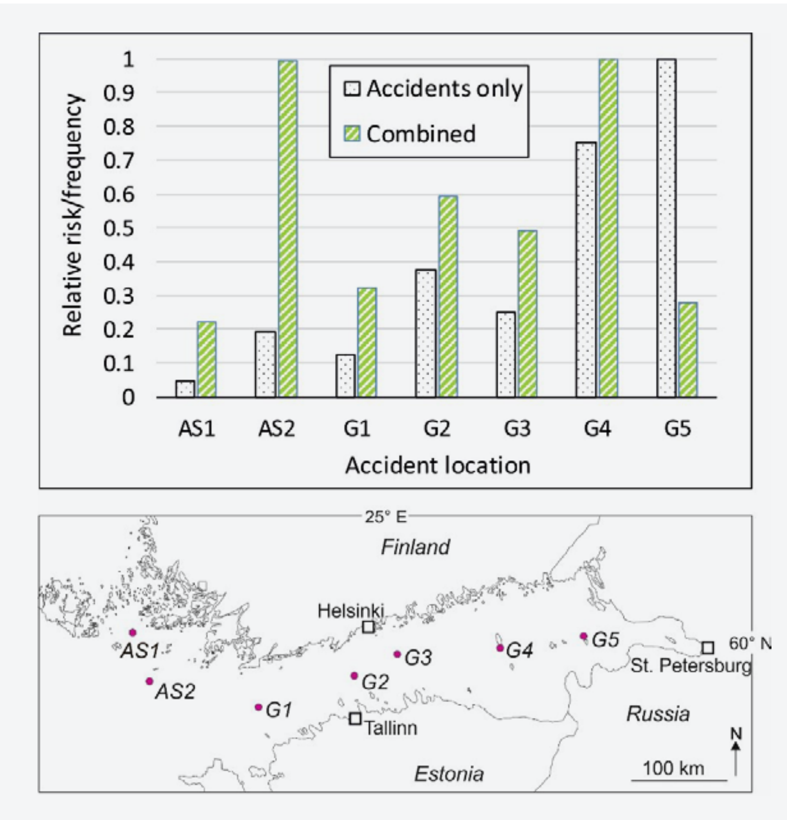


Figure 3.15.4.

Upper figure: Comparison of different accident locations using different risk approaches. White dotted columns: Only accident frequencies are considered; Green striped columns: Accident frequencies are combined with knowledge related to drifting of oil and ecological values.

Lower figure: Accident locations used in the analysis shown in the upper figure. Modified from Helle et al. (2016)

3.16. Integrated Strategic Risk Analysis Methods

3.16.1 Background

In risk management for pollution preparedness and response, it is important to appropriately plan major investments, for instance relating to renewal or upgrades of navigational infrastructure, or procurement of oil spill response vessels and equipment [1]. For supporting such decisions with long-term impacts and requiring additional investments, several quantitative risk analyses of the accident risk in particular sea areas have been performed. Such analyses aim to provide a holistic insight into the current and projected future risk levels, in terms of location-specific ship accident probabilities and corresponding consequences in terms of amounts of oil spilled from a damaged vessel or offshore facilities, how the oil drifts in the sea area, and the impacts it has on the ecosystem and socio-economic health of the affected regions. These analyses can include an estimate of the risk-reducing effect of risk control options (e.g. procurement of additional oil response equipment in a specific location). Along with an assessment of the costs of realizing these risk control options, their cost-effectiveness can be estimated and risk-informed decisions made.

The general approach for such a holistic risk analysis and cost-effectiveness evaluation of the risk control options is applied in the International Maritime Organization as Formal Safety Assessment (FSA). This is a structured and systematic methodology, aimed at enhancing maritime safety, including protection of life, health, the marine environment and property. In IMO context, FSA is used for evaluating new or revised regulations, balancing various technical and operational issues, including the human element, and between maritime safety or protection of the marine environment and costs [2].

In the scientific literature, several reviews have been made of available models for quantitative maritime risk analysis [3, 4, 5]. In practical applications in European waters, an integrated approach based on a static maritime traffic flow model has been used in various high-profile projects, such as the BRISK/BRISK-RU project for the Baltic Sea [6] and the BE-AWARE I and II projects for the North Sea [7, 8]. The Mediterranean decision support system for maritime safety (MEDESS-4MS) is also based on the same approach [9].

The complexity of such holistic risk analyses is such that specialized contractors are tasked to execute the analysis, in collaboration with relevant authorities for the considered sea areas. The purpose of this appendix is to provide a high-level overview of the elements of such holistic risk analyses, and the steps included in the process. The applied methods are very similar between the BRISK/BRISK-RU and BE-AWARE projects. Nevertheless, the below description is based on the analyses performed in BE-AWARE.

3.16.2 Overview

Figure 3.16.2 provides a high-level overview of the main elements of the risk analysis as executed in the BE-AWARE and BRISK/BRISK-RU projects. The analyses focus on oil spills and hazardous liquid substances from shipping accidents or from other offshore activities. Several sub-models are linked together, providing a holistic view on the maritime activities, the types of spills, the spreading of oil in the sea area, and the ecological and socio-economic impacts

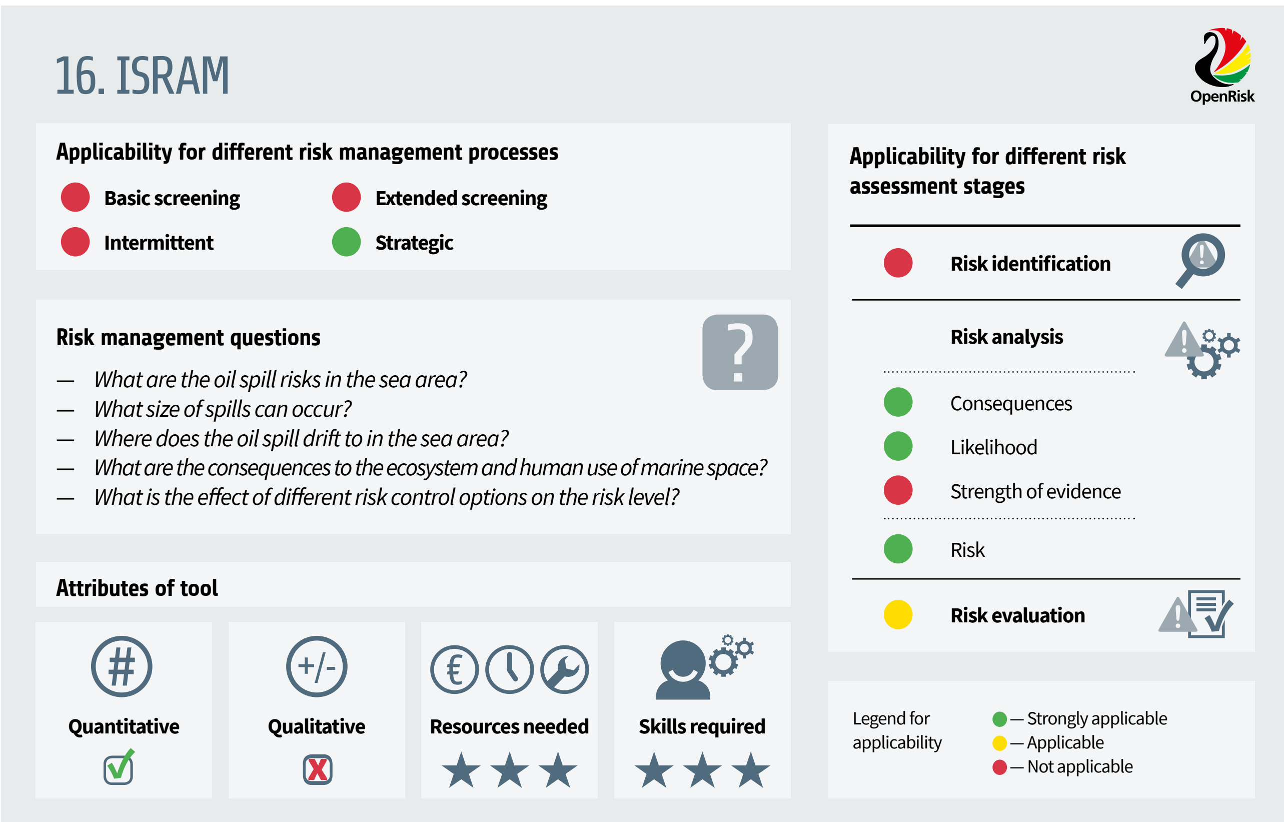


Figure 3.16.1.
Overview of the ISRAM tool: Risk management questions addressed, tool attributes, and applicability for different risk management processes and risk assessment stages

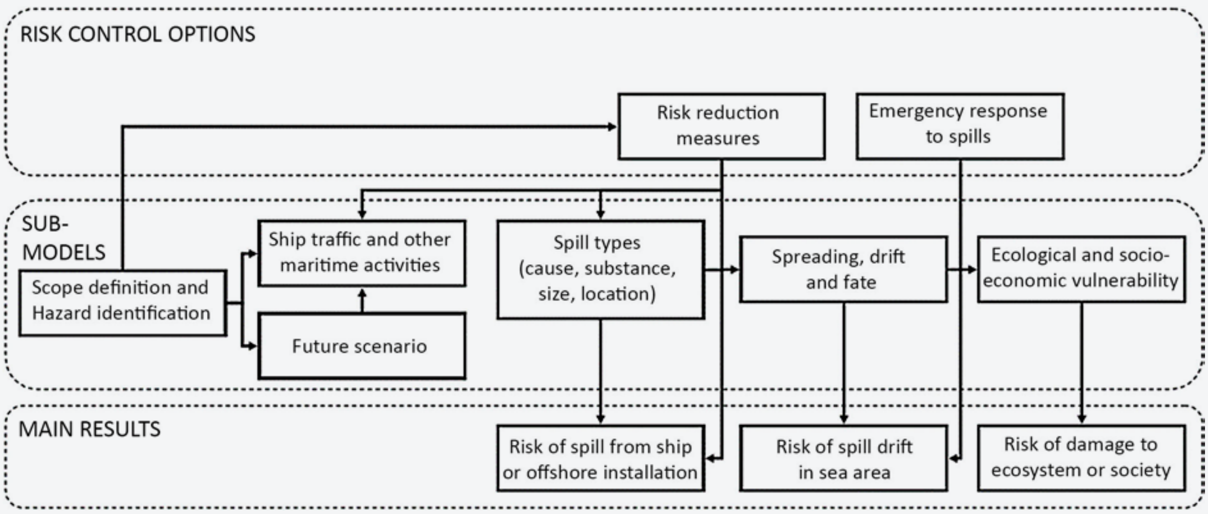


Figure 3.16.2.
Integrated strategic risk analysis methods: overview of risk control options, sub-models, and main results of methods applied in [6, 7, 9]

of the spills. There is a degree of flexibility as to which specific sub-models are used in a specific analysis, as several models have been proposed for the different elements, but the overall process is as follows:

1. Definition of traffic flows and future scenarios for shipping and other maritime activities. This is performed based on AIS data, e.g. [10], along with studies focusing on the types of oil and hazardous substances transported in the area, e.g. [6], and studies analyzing the future developments of maritime transport in a given sea area, e.g. [11].
2. The probabilities of various accident types are calculated based on dedicated accident models, e.g. [12], which lays at the basis of the IWRAP tool described in Section 3.5.
3. The accidental oil outflow consequence models, e.g. [13] are applied to the impact scenarios resulting from those models, from which the characteristics of the spill are assessed.
4. The spill is analyzed using a sea dynamics model, e.g. [14], under different atmospheric conditions, from which the spreading, drift and fate is assessed.
5. The ecological and/or the socio-economic vulnerability of the sea or coastal area to the drifted spills are calculated, e.g. [15].
6. In the various parts of the analysis, the effects of risk reduction measures and/or the influence of decisions related to emergency response to spills can be evaluated, by using models which affect the probabilities of occurrence of certain events in the model. For instance, preventive measures can reduce the accident risk, as modeled for the implementation of a new navigation service [16]. Also e.g. models for assessing the impact of the location of oil response vessels can be used [17].
7. As outputs of the integrated modeling, the risk of oil spill from ships or offshore installations, the risk of spill drift in the sea area, and the risk of damage to the ecosystem or society, can be obtained.
8. Combining the quantified effects of the risk control options to the resulting risk levels with the costs associated with implementing those, a cost-benefit analysis can be made in support of the decision making process.

3.16.3 Use

The Integrated Strategic Risk Analysis Methods (ISRAM) are used to answer the following risk management questions:

— What are the oil spill risks in the sea area?
— What size of spills can occur?
— Where does the oil spill drift to in the sea area?
— What are the consequences to the ecosystem and human use of marine space?
— What is the effect of different risk control options on the risk level?

The Integrated Strategic Risk Analysis Methods are primarily useful in the risk analysis stage of the strategic risk management process in the developed PPR risk management framework based on ISO 31000:2018, introduced in Section 2. ISRAM also has a role in risk evaluation through evaluating the effect of implementing selected risk control options. The tool provides quantitative outputs. The process requires a high commitment of resources in terms of finances, and analysts' and experts' time. A significant amount of experience is needed for applying the method, and for extracting results.

As opposed to, e.g. the Ports and Waterways Safety Assessment (PAWSA) process, described in Section 3.6, the quantitative analyses are in principle well-suited for making risk-cost benefit analyses, providing quantitative insights into which risk control options would have the largest risk reducing effects at a minimum cost, as introduced in Section 3.20. However, as in all quantitative risk analyses, it is important to consider the effects of uncertainties on the model outcomes, both in relation to the strength of evidence of the data, expert judgments, and models underlying the analysis results, as well as the impact of additional assumptions [18], see Section 3.17.

3.16.4 Inputs and Outputs

The Integrated Strategic Risk Analysis Methods rely on various kinds of information, which often need rather extensive post-processing. Here are some examples of useful sources:

- Traffic information, in particular AIS data and data on types of transported goods in the sea area;
- Hydrographic information;
- Maritime accident and incident reports and analyses;
- Wind direction and/or sea dynamics data;
- Ecological vulnerability data;
- Expert knowledge.

As outputs, the risk analyses provide the probabilities of different spill types and sizes in the sea area, the probabilities of drifting spills, the probabilities of given environmental and/or socio-economic impacts due to oil or other liquid noxious substances, and the probabilities associated with different possible risk control options.

3.16.5 Strengths and limitations

Some strengths of the Integrated Strategic Risk Analysis Methods include:

- The analysis provides a holistic insight in the risk of maritime pollution, with insights relevant for prevention, preparedness, and response;
- The analysis enables a cost-benefit analysis, through which the relative efficacy of different possible risk control options can be evaluated;
- Several analyses have been executed successfully in the past, through international collaboration projects. Expertise is thus available and costs of an analysis can be quite well estimated.

Some limitations of the Integrated Strategic Risk Analysis Methods include:

- Quantitative risk analyses are complex and highly technical, and specific expertise is required to execute an analysis;
- The analyses are time-consuming, resource-intensive and costly;
- In international sea areas, the risk analysis needs support from the appropriate authorities, to gain access to required data and expertise, and to lead to credible results;
- Several risk models applied in earlier projects involve rather large uncertainties, e.g. the accident probability models based on traffic flow theory are known to lead to significantly different high-risk areas compared to other risk models available in the scientific literature, see e.g. [19];
- The analyses often produce rather lengthy reports, whereas the numerical results should be interpreted alongside a clear understanding of the assumptions, model limitations and uncertainties. Hence, adequate time to reflect on the meaning of the results is needed in the risk assessment phase;
- The analyses are typically conducted by commercial companies, and the methods used in the analyses are not always transparent.

Notes and practicalities

The results of BRISK/BRISK-RU, BE-AWARE I and II, and MEDESS-4MS projects are openly available on the projects' websites, including short descriptions of methodologies.

3.17. Strength of Evidence Assessment Schemes

3.17.1 Background

As outlined in Section 1.1, the consideration of uncertainties is one of the basic principles of risk management, and in Section 1.3 it is presented as an essential element of risk analysis, in line with recent recommendations in professional societies [1] and academic literature [2]. Apart from the analysis of probabilities and consequences of a possible event, this primarily concerns the strength of the evidence (SoE) on which the analysis is based.

Several schemes have been proposed to assess the strength of evidence. In first implementations, the focus was on the uncertainties in the knowledge on which the risk analysis is based [3], but in contemporary work this focus has shifted to directly assessing how much evidence there is for making the risk analysis, and how good this evidence is [4, 5].

The strength of evidence assessment schemes provide a qualitative understanding of how much the results of the risk analysis can be relied on, based on how much data is available, how good the models used, how well the experts agree, and how reasonable the assumptions made. The strength of evidence assessment can also be used as a starting point for gathering better information for those parts of a risk analysis which are based on relatively poor evidence, if the results are strongly affected by this.

3.17.2 Overview

3.17.2.1. Strength of Evidence assessment scheme 1: overall evidence rating

The first strength of evidence assessment scheme provides an overall rating of the evidence, considering how good the data, models, judgments and assumptions are for making the risk analysis. The combined rating applies a 3-level qualitative scale, with categories 'Strong Strength of Evidence', 'Medium Strength of Evidence', and 'Weak Strength of Evidence'. The following descriptions serve as a guideline for making the assessment, based on [4], with further specification in [6].

Strong Strength of Evidence

All of the conditions are met:

- The phenomena involved are well understood; the models used are known to give predictions with the required accuracy;
- The assumptions made are seen as very reasonable;
- Much reliable data are available;
- There is broad agreement among experts.

Medium Strength of Evidence

One or more of the conditions are met:

- The phenomena involved are not well understood; models are non-existent or known/believed to give poor predictions;

Figure 3.17.1.
Overview of the SoE tools: Risk management questions addressed, tool attributes, and applicability for different risk management processes and risk assessment stages

— The assumptions made represent strong simplifications;
— Data are not available, or are unreliable;
— There is lack of agreement/consensus among experts.

Weak Strength of Evidence
Conditions between those characterizing strong and weak strength of evidence, e.g.:
— The phenomena involved are well understood, but the models used are considered simple/crude;
— Some reliable data are available

3.17.2.2. Strength of Evidence assessment scheme 2: separate evidence rating

The second strength of evidence assessment scheme provides a separate rating of the different evidence types, namely the data, models, judgements, and assumptions. The ratings are based on a 3-level qualitative scale, with categories 'Strong Strength of Evidence', 'Medium Strength of Evidence', and 'Weak Strength of Evidence'. The descriptions provided in Table 3.17.1 and Table 3.17.2 provide a guideline for making the assessment, based on [5].

Table 3.17.1.
Evidential characteristics and criteria for strength-of-evidence rating for data and model evidence types, from [5]

Evidence type		Strong evidential characteristics	Weak evidential characteristic
Data	Quality	Low number of errors High accuracy of recording High reliability of data source	High number of errors Low accuracy of recording Low reliability of data source
	Amount	Much relevant data available	Little data available
Models	Empirical validation	Many different experimental tests performed Existing experimental tests agree well with model output	No or little experimental confirmation available Existing experimental tests show large discrepancy with model output
	Theoretical viability	Model expected to lead to good predictions	Model expected to lead to poor predictions

Table 3.17.2.
Evidential characteristics and criteria for strength-of-evidence rating for judgment and assumption evidence types, from [5]

Evidence type		Strong	Medium	Weak
Judgments		Broad intersubjectivity: more than 75% of peers support the judgment	Moderate intersubjectivity: between 25% and 75% of peers support the judgment	Predominantly subjective: less than 25% of peers support the judgment
As-sump-tions	Agreement among peers	Many (more than 75%) would have made the same assumption	Several (between 25% and 75%) would have made the same assumption	Few (less than 25%) would have made the same assumption
	Influence on results	The assumption has only local influence	The assumption has wider influence in the analysis	The assumption greatly determines the results of the analysis

3.17.3 Use

Strength of Evidence assessment schemes are used to answer the following risk management questions:

— How much can the results of the risk analysis be relied on?
— How much evidence is there for the elements in the risk analysis?

The Strength of Evidence (SoE) assessment schemes can be applied in the risk analysis stage of all risk management processes in the developed PPR risk management framework based on ISO 31000:2018, introduced in Section 2. Hence, the schemes have a role in basic and extended screening, intermittent, and strategic risk analysis. The schemes provide qualitative outputs. The process requires few resources, and is easy to apply and therefore requires limited prior skill.

There are two use types for the strength of evidence assessment schemes: i) assessment separated from the risk analysis results, and ii) assessment integrated into the risk analysis results.

In the first use type, the strength of evidence assessment scheme is applied, considering the different evidential categories. Its results are then communicated alongside the results of the application of the risk analysis tools, as in [5, 7]. In Section 3.18, specific designs of probability-consequence diagrams are presented in line with this use type.

In the second use type, the strength of evidence assessment scheme is applied, considering the different evidential categories, reaching an overall rating of the strength of evidence. Its results are then used to update the outcomes of the risk analysis, as in [4, 6]. In particular, in case a weak or medium strength of evidence score is assigned, the risk score can be moved up one category, i.e. from medium to high risk, or from low to medium risk. In Section 3.18, specific designs of probability-consequence diagrams are presented in line with this use type.

3.17.4 Strengths and limitations

Some strengths of evidence assessment schemes include:

— The schemes are easy and fast to apply, requiring little resources;
— The schemes provide relevant information about how much the results of the risk analysis can be relied on, and guide efforts for seeking additional evidence where appropriate [2].

Some limitations of evidence assessment schemes include:

— The ratings resulting from the schemes are inevitably judgments of an analyst or a group of analysts, and hence are subjective [3];
— There is a lack of knowledge about the reliability of the evidence assessment schemes, whereas arguments have been made that ambiguities and limitations of the schemes may lead to unreliable results [7].

Notes and practicalities

No special software programme is needed to assess the Strength of Evidence.

3.18. Risk Matrices and Probability-Consequence Diagrams

3.18.1 Background

For communicating risks to different stakeholder groups and decision-makers, visual representations provide useful means. Risk matrices (RMs) are widely used in various organizations across different industries [1], commonly displaying risks in ordinal categories on the likelihood and consequence dimensions. Usually, the elements in the risk matrix are assigned a color code to illustrate the risk level and/or indicate the acceptability of the risk, in line with the ALARP principle presented in Section 3.19. Whereas risk matrices are regularly used as risk analysis tools, i.e. to directly assess the risk levels of particular events and consequences, this approach is hampered by several shortcomings. Hence, there is a growing consensus in the academic literature that risk matrices are particularly useful in the risk evaluation phase, i.e. as the result of a rigorous risk analysis process [1, 2]. If sufficiently accurate schemes are developed to classify specific risk events for particular situations, such as in the ERC-M tool introduced in Section 3.7, risk matrices can be used to classify the information as a basis for further analysis.

Also probability-consequence diagrams (PCDs), which are a generalization of risk matrices accounting for continuous scales of measurement on the likelihood and consequence dimensions, are regularly used to display the results of a risk analysis [3, 4]. Such diagrams have some benefits over risk matrices, and have recently been argued to better serve the purpose of risk communication and decision-making [4, 5]. For instance, they easily allow for introducing linear or logarithmic scales for the likelihood and consequence dimensions, do not suffer from the problem of risk ties as risk matrices do, and can more easily be integrated with risk acceptance criteria such as criterion lines in line with the ALARP principle, introduced in Section 3.17.

3.18.2 Overview

3.18.2.1. Risk matrices

Risk matrices are graphical representations of the two primary dimensions of risk: the likelihood and consequence, as illustrated in Figure 3.18.2. Relying on ordered classes of increased likelihood and consequence severity, risk events can be assigned to different categories. The assignment is based on the results of an earlier performed risk analysis, and the matrix can be augmented with a colour code to clearly indicate the combined importance of the risks, and/or their acceptability [1]. The strength of evidence underlying the risk analysis can be illustrated using another colour code for the different risk events, as illustrated in Figure 3.18.2, based on ideas presented in [2]. In the shown example, a combined 3-level strength of evidence rating is applied, as introduced in Section 3.17.2.1.

3.18.2.2. Probability-consequence diagrams

Probability-consequence diagrams (PCDs) are graphical representations of the two primary dimensions of risk: the likelihood and associated consequences, as illustrated in Figure 3.18.3. PCDs

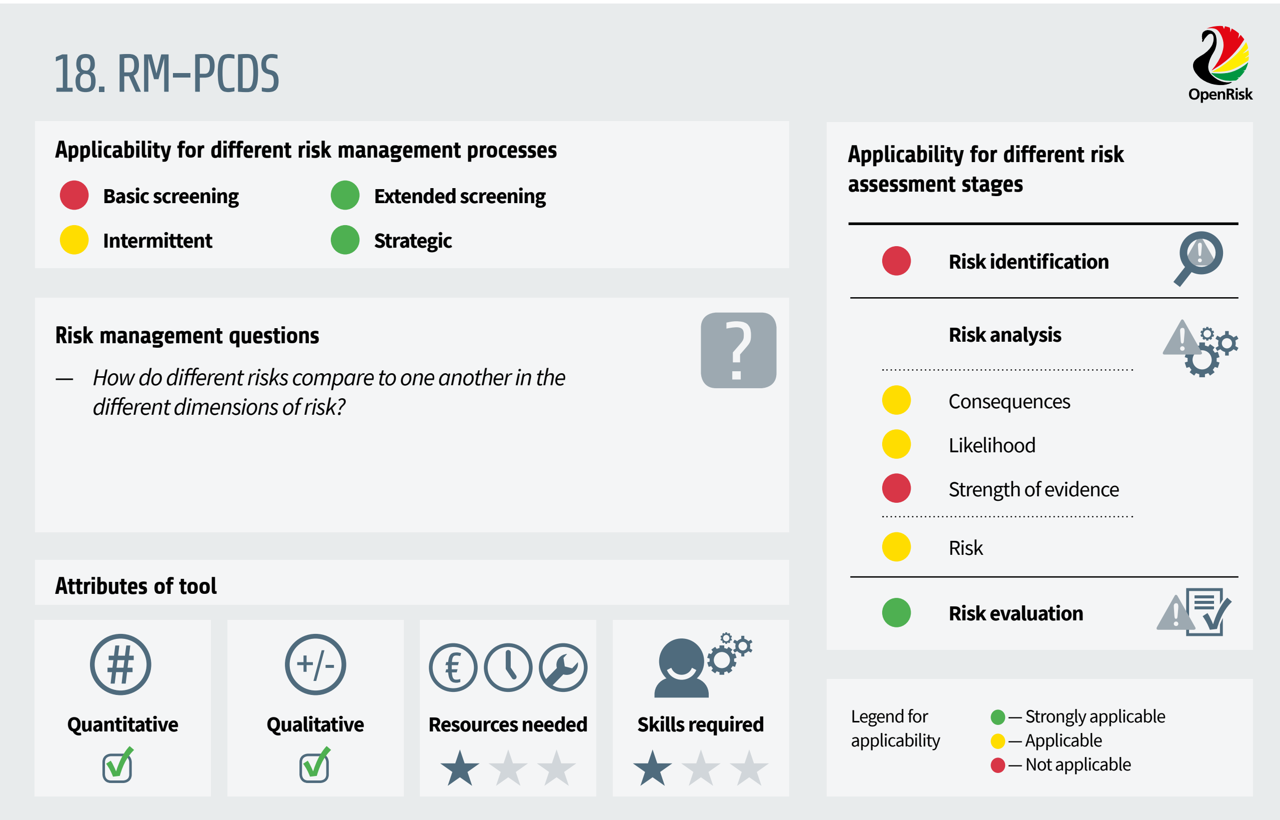


Figure 3.18.1.
Overview of the RM-PCDS tools: Risk management questions addressed, tool attributes, and applicability for different risk management processes and risk assessment stages

utilize a continuous, monotonically increasing or decreasing scale for the consequence and likelihood. The latter is often expressed using probabilities [3], but also ranked ordinal scales can be applied [4]. Risk events can be displayed in different areas of the PCDs, based on the results of an earlier performed risk analysis. The strength of evidence underlying the risk analysis can be illustrated using another colour code for the different risk events, as illustrated in Figure 3.18.3, based on ideas presented in [2, 5]. In the left example of Figure 3.18.3, a combined 3-level strength of evidence rating is applied, as introduced in Section 3.17.2.1. In the right example, a separated 3-level strength of evidence rating is used, as introduced in Section 3.17.2.2.

3.18.3 Use

Risk matrices and probability-consequence diagrams are used to answer the following question:

— How do different risks compare to one another in the different dimensions of risk?

Risk matrices (RMs) and probability-consequence diagrams (PCDs) are useful primarily in the risk evaluation stage of the extended screening, strategic, and intermittent risk management processes in the developed PPR risk management framework based on ISO 31000:2018, introduced in Section 2. RMs and PCDs can also have a role in risk analyses, when the results of tools focusing exclusively on probability (e.g. IWRAP) or consequences (e.g. ADSAM) are combined. Depending on how the RMs and PCDSs are implemented, they can provide quantitative or qualitative outputs. The process requires few resources, and is easy to apply and therefore requires limited prior skill.

3.18.4 Strengths and limitations

Some strengths of risk matrices and probability-consequence diagrams include:

— They provide a simple and readily understandable visual representation of the different risks;
— The visual display can help users to prioritize risks and judge the acceptability;
— The diagrams can be used alongside with the strength of evidence assessment schemes;
— The diagrams can be used alongside with the ALARP principle, see Section 3.19.
— Some limitations of risk matrices and probability-consequence diagrams include:
— Diagrams can become crowded if many risk events are to be displayed, especially when also the strength of evidence dimension is shown on the figures;
— Risk matrices with limited resolution can lead to “risk-ties”, i.e. situations where qualitatively different risks are grouped together in the same risk matrix element;
— The assignment of a single consequence scale for risk events with different consequence dimensions (life, ecological value, economical value) may not be feasible. Applying different matrices or diagrams provides a solution, but makes the results more difficult to interpret.

Notes and practicalities

Several commercial software applications have been developed to create Probability-Consequence Diagrams. Although these applications may be useful, PCDs can be created without a specific software.

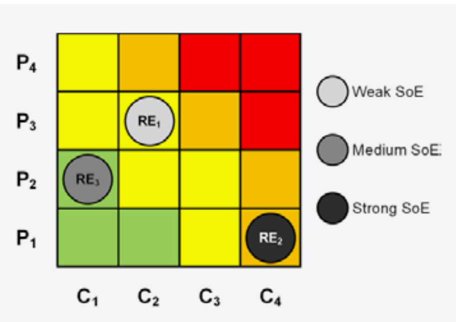


Figure 3.18.2.
Illustrative risk matrix with four likelihood categories (P1–P4) and four consequence categories (C1–C4), based on [2]

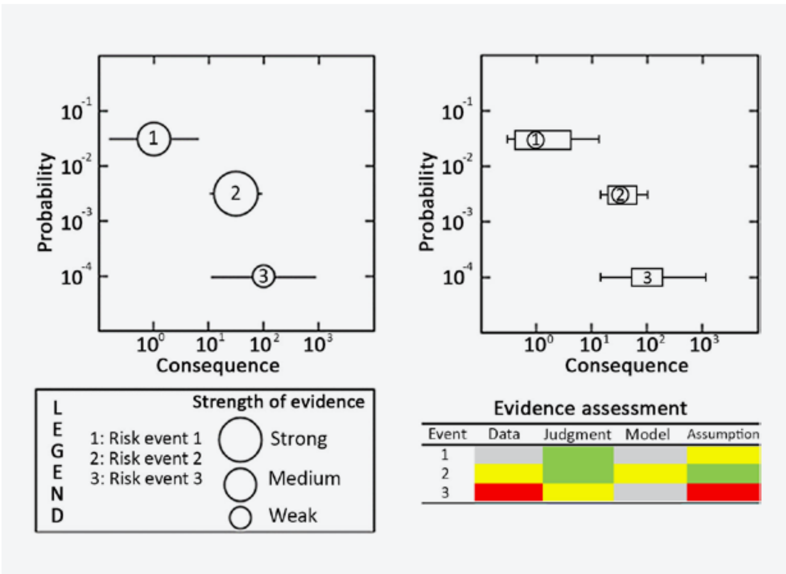


Figure 3.18.3.
Probability consequence diagrams with strength of evidence (SoE) assessment, combined SoE rating (left), separate SoE rating (right), based on [2, 5]

3.19. As Low as Reasonably Practicable Principle

3.19.1 Background

In risk management, it is possible that risks are regarded as 'too high' or 'intolerable'. Such risks may be associated with a very high probability of occurrence and/or very severe consequences if they do occur. But exactly how high is 'too high'? This often varies between different systems and processes, and is often based on the preferences of decision makers or stakeholder perceptions.

The ALARP (As Low as Reasonably Practicable) principle is based on the fundamental thinking of 'acceptable' or 'tolerable' risks. It allows analysts and decision makers to define boundaries to combined probability-consequence scales. These boundaries can be used to delineate acceptable and intolerable risks. This allows decision makers to evaluate whether a system or process poses certain risks which need to be treated using risk-control options [1]. The ALARP principle can easily be combined with tools such as Risk Matrices and Probability-Consequence diagrams to graphically represent the boundaries of risk tolerability [2], see Section 3.18.

The ALARP principle is widely used in many different high-risk industries such as the chemical industry, aviation, nuclear, and rail and road transport. ALARP has also been recommended by the International Maritime Organization (IMO) as part of the implemented risk-based rule-making process, known as Formal Safety Assessment [3].

Tools based on the ALARP principle can also be very useful for Pollution Preparedness and Response authorities as it allows them to evaluate different risks, determine and identify the risks which are above the tolerability threshold of stakeholders, and implement risk-control measures to target those risks specifically. This allows evidence- and value-based allocation of resources.

3.19.2 Overview

The primary aim of ALARP is to determine the risks which are intolerable to different stakeholders. For this, it is important to first determine the tolerability criteria. Both the risks and the tolerability criteria should be determined explicitly in terms of probabilities (P) and consequences (C), either qualitatively or quantitatively.

The P and C values of each risk can then be visualized in risk matrices or probability-consequence diagrams (PCDs), as introduced in Section 3.18. An example of an implementation of the ALARP principle on a FN-diagram (a type of PCDs) is shown in Figure 3.19.2 below. In Figure 3.19.2, the probabilities of exceeding a given consequence level are given on the vertical y-axis, and the associated consequences (here in terms of human fatalities), are given on the horizontal x-axis. The ALARP region is bounded by an upper and a lower diagonal line. The upper line, labelled the 'local tolerability line', marks the boundary between ALARP (green) and intolerable (red) risks. Combinations of probabilities and consequences above this line are considered to be the intolerable. Similarly, the lower diagonal line marked the 'negligibility line' marks the boundary between ALARP and negligible (blue) risks. Any risks with a probability and consequence combinations below this line are considered negligible for stakeholders, i.e. they do not require further management in terms of risk control options. For risks in the ALARP region, further risk control options should be implemented, unless it can be shown that their associated costs are grossly disproportionate compared to the risk-reducing benefits. For establishing this, cost-benefit analysis can be used, see Section 3.20.

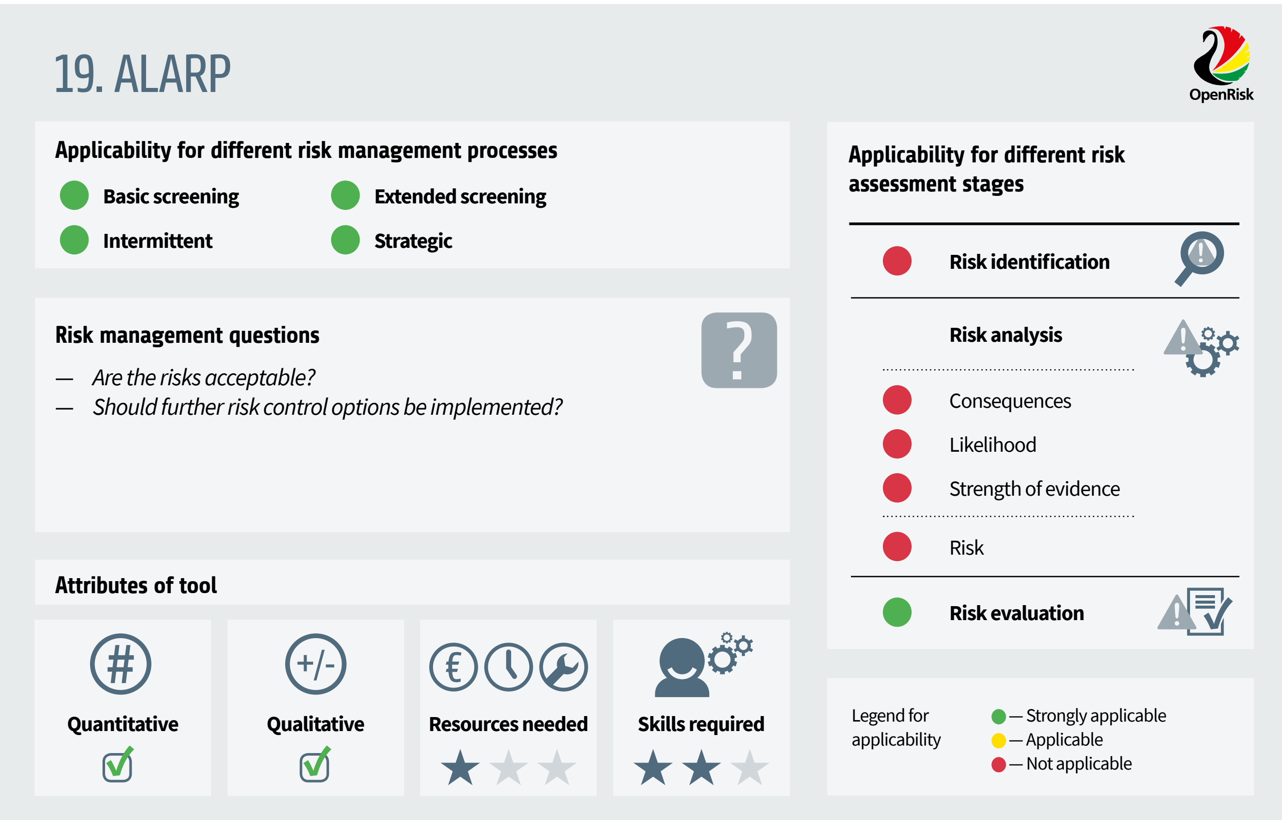


Figure 3.19.1.
Overview of ALARP: Risk management questions addressed, tool attributes, and applicability for different risk management processes and risk assessment stages

3.19.3 Use

The ALARP principle can be used to answer the following risk management questions:

- Are the risks acceptable?
- Should further risk control options be implemented?

The ALARP principle can be applied in the risk evaluation stage of all risk management processes in the developed PPR risk management framework based on ISO 31000:2018, introduced in Section 2. Hence, the schemes have a role in basic and extended screening, intermittent, and strategic risk management. Depending on how the ALARP principle is implemented in practical applications, quantitative or qualitative outputs can be obtained. The process requires few resources, but some experience with the methods is needed to properly implement and apply the principle to support decision making.

3.19.4 Input

In order to define the ALARP limits, it is necessary to gather stakeholder views on the tolerability limits of risks. Thus, the input for ALARP often comes from stakeholder consultations, as well as a review of past accidents and incidents to gauge the reaction of society towards certain undesirable events. Different stakeholders may have different views of the acceptable levels of probability and consequences of different risks, so it is the responsibility of the end-users to find an optimum balance from their feedback when defining tolerability limits. Inspiration concerning typically applied ALAPR limits can also be obtained from the FSA guidelines [3] or from other literature [4].

3.19.5 Process

Once the ALARP limits have been determined, it is necessary to choose an appropriate diagram on which to visually overlap the boundaries. Any selected diagram must be able to capture the different probability and consequence values, as well as the different natures of risk. As an example, FN-diagrams only capture the nature of consequences in term of fatalities; in reality, consequences may be economical, environmental, or societal.

After the ALARP limits have been implemented in a risk matrix of a probability-consequence diagram, the next stage is to display the risks using their constituent P and C values on the same diagram. Following this, if any risks are found to exceed the tolerable limit line, further risk evaluation is needed to define risk control options, analyze their risk-reducing potential, and determine their cost-effectiveness, e.g. using cost-benefit analysis, see Section 3.20. Subsequently, the effect of these risk-control measures must be accounted for and the P and C values of each risk must be updated on the diagram with the ALARP overlay. This cyclical process continues until stakeholders are satisfied that risks have been made as low as reasonably practicable. Often, stakeholders and end-users will avoid pushing the risks into the negligible region, as doing so may entail significant financial costs which may not be justified by the benefits.

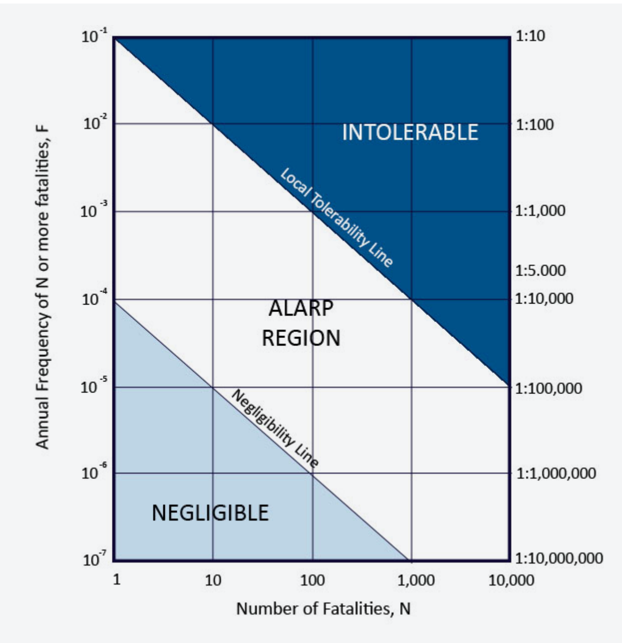


Figure 3.19.2.
ALARP overlap on an FN-diagram.

3.19.6 Output

Application of the ALARP principle involves combining probability and consequence values obtained in the risk analysis stage in intolerable, ALARP and negligible risk regions. These regions can be defined in a quantitative or qualitative manner, depending on how the risks have been analyzed. The outputs of the risk analysis stage is often overlaid on risk matrices or probability-consequences diagrams, which include criterion lines corresponding to the three regions defined in the ALARP principle. These diagrams help decision makers and stakeholders to evaluate the acceptability of risks, allowing them to determine if additional risk control measures are needed for certain risks. Together with cost-benefit analysis, ALARP allows decision makers to facilitate discussions on cost-effective allocation of resources for successful risk management.

3.19.7 Strengths and limitations

Some strengths of ALARP include:

- It provides a common understanding of the intolerable risks associated with a system or process;
- It can allow decision makers to use limited resources in a systematic and reasoned manner, both financially and in terms of risk;
- It can be used to visualize and evaluate the impact of risk treatment options for a diverse range of activities, systems and processes.

Some limitations of ALARP include:

- It is easy for internal and external biases to be present in defining ALARP, if the stakeholder consultations are not done properly;
- It requires decision makers to place and evaluate monetary values on highly sensitive issues, such as human lives or environmental damages;
- Its output may be equally understood, but not equally accepted by different stakeholders.

Notes and practicalities

Several commercial software applications have been developed to create Probability-Consequence Diagrams. Although these applications may be useful, PCDs can be created without a specific software.

3.20. Cost-Benefit Analysis

3.20.1 Background

In risk management, decision makers often need to manage risk through implementing risk control-options. Risk control options are measures which allow decision makers to reduce the probability and/or consequences of a particular risk. These may be physical, technical, procedural, or of any other nature.

Risk control measures, however, come with an economic cost. Thus, decision makers have to decide between different scenarios to find a reasonable solution where risk is at an acceptable level, and also at a reasonable economic cost. In order for decision makers to decide on an appropriate risk control measure, it is necessary for both the risk and the measure to be quantified or described in economic terms. Once this is done, the net cost of reducing a unit of risk can be calculated. Tools like cost-benefit analysis (CBA) play an important role in such calculations, as they allow decision makers to calculate the cost per unit benefit [1].

CBAs have been extensively used in high-risk industries such as the chemical industry, aviation, and nuclear power. CBAs have also been recommended by the International Maritime Organization (IMO) as part of their recommended decision- and rule-making process, through the Formal Safety Assessment [2].

Pollution Preparedness and Response authorities often need to make decisions about optimum allocation of resources, and rational use of limited financial resources is an important element in this. Cost-benefit analysis can be a useful tool for such purposes, as it allows decision makers to estimate the benefit gained for each unit of currency spent.

3.20.2 Overview

The primary aim of a cost-benefit analysis is to assist decision makers to reduce the system risks in an economically feasible manner. Thus, in a CBA, the financial costs of various risks and risk control options have to be quantified. It is also important to quantify the effect of risk control measures on the risks themselves, i.e. one must understand the effect that risk control measures have on various risks in terms of probabilities and consequences. This allows decision makers to evaluate whether a risk control measure is worth the extra financial cost, or if its implementation costs are grossly disproportionate to the benefits.

CBAs often are combined with other risk evaluation tools, such as the ALARP principle [3], see Section 3.19. This is because risk control measures only need to be implemented if certain risks are found to be unacceptable in terms of probabilities and consequences, or if uncertainties are high. Risk reduction measures can be implemented when the risks are in the ALARP region, unless gross disproportion can be shown regarding their cost effectiveness.

Figure 3.20.1.
Overview of the CBA tool: Risk management questions addressed, tool attributes, and applicability for different risk management processes and risk assessment stages

3.20.3 Use

Cost-benefit analysis can be used to answer the following risk management question:

— How cost-effective are different risk control options?

Cost-benefit analysis can be applied in the risk evaluation stage of all risk management processes in the developed PPR risk management framework based on ISO 31000:2018, introduced in Section 2. However, it is most applicable to the strategic risk management process, when possible investments on new risk control options may require significant resources. Cost-benefit analysis provides quantitative outputs, and requires a medium commitment of resources in terms of funds and analysts' and experts' time, and some experience with the method is needed for executing the analysis and drawing conclusions.

3.20.4 Input

The input for a CBA often comes from sources such as stakeholder consultations, in combination with cost estimates from market values or insurance companies. The stakeholder consultations play an important role in identifying the risks and risk control measures to be considered. Stakeholders may also provide an insight as to how, and to what extent, the different risk control measures effect various risks. Stakeholders may also be able to provide initial financial cost estimates for the various risks and risk control options.

The cost estimates from insurance figures or market values are a vital validation component of CBAs, since the entire premise of this tool is to calculate the financial feasibility of different risk control options, and to optimally reduce the risk in as cost-effective a manner.

3.20.5 Process

The primary purpose of a CBA is to compare the costs of averting a risk against the benefits of averting that risk, in economic terms. For such a comparison, it is necessary to assign financial values to various risks. Often, the costs of the risks are calculated as a function cost of the consequences; for instance, the cost of an oil spill risk may be calculated in terms of the cost of spill clean-ups. The cost of the risk control options, such as oil dispersants or pollution response vessels must also be calculated. The unit effect of these risk control measures on the risk itself should also be quantified.

After both the financial cost of adding risk control options, and the changes in risk values have been calculated, metrics like the Gross Cost of Averting a Fatality (GCAF) or Net Cost of Averting a Fatality (NCAF) can be produced. As defined by IMO, GCAF is a cost effectiveness measure in terms of ratio of marginal (additional) cost of the risk control option to the reduction in risk to personnel in terms of the fatalities averted [2]. It is determined as follows:

$$GCAF = \frac{\Delta Cost}{\Delta Risk} \qquad \text{(Eq.3.20.1)}$$

NCAF is a cost effectiveness measure in terms of ratio of marginal (additional) cost, accounting for the economic benefits of the risk control option to the reduction in risk to personnel in terms of the fatalities averted [2]. It is determined as follows:

$$NCAF = \frac{\Delta Cost - \Delta EconomicBenefit}{\Delta Risk} = GCAF - \frac{\Delta EconomicBenefit}{\Delta Risk} \qquad \text{(Eq.3.20.2)}$$

It is also important to account for the change in monetary values over time. Hence, the costs should factor in discount rates and net present values, which are measures of currency depreciation and currency worth at a given time, respectively. The CBA process can be summarized in following 10 steps [1]:

1. Describe the goals and objectives of the project/activities;
2. Identify alternative projects/programs;
3. Identify stakeholders;
4. Determine the risks to be analysed and measure all associated cost/benefit elements;
5. Forecast outcome of cost and benefits over relevant time period;
6. Convert all costs and benefits into a common currency;
7. Apply discount rate;
8. Calculate net present value of project options;
9. Perform sensitivity analysis;
10. Adopt recommended choice.

3.20.6 Output

The output of a cost-benefit analysis is often a value or a metric that is used by decision makers to evaluate the feasibility of different risk control options. In this regard, CBAs have a purely quantitative output. The values provided by a CBA are often sensitive to the cost models and data used, however, and given these uncertainties, must be treated with caution.

The output of a CBA can also be visualized in combination with ALARP criteria, to depict the change in risk (probability and/or consequences) which can be achieved by implementing a risk-control option. If the diagram also allows to depict the cost of each risk-control option, it can help to facilitate discussions on optimizing allocation of resources for risk management.

3.20.7 Strengths and limitations

Some strengths of CBA include:

— It provides a common understanding of the costs and benefits associated with different risk control options for a system or process;
— It can allow decision makers to use limited resources in an optimum manner, both financially and in terms of risk;
— It can allow decision makers to understand that costs related to implementing additional safety measures can be cheaper than the costs associated with accidents, thus promoting safer and more reliable systems;
— It can be used to model risk treatment options for a diverse range of activities, systems and processes.

Some limitations of CBA include:

— It is resource intensive and requires significant expertise;
— It requires analysts and decision makers to place and evaluate monetary values on highly sensitive issues, such as human lives or environmental damages;
— It is highly sensitive to economic costs, which can be volatile and changing based on perceptions of stakeholders;
— Its output may be equally understood, but not equally accepted by different stakeholders.

Notes and practicalities

Several commercial software applications have been developed for the Cost Benefit Analysis. Although these applications may be useful, CBAs can be created without a specific software.


Booms in the Baltic Sea © Jouko Pirttijärvi/SYKE

Terms and definitions

accident - an unintended event that causes death, injury, environmental or material damage [1]

accident scenario - imagined progression from the actual outcome or the triggering event/hazard release to the accident outcome [1]

communication and consultation - continual and iterative processes that an organization conducts to provide, share or obtain information and to engage in dialogue with stakeholders regarding the management of risk [2]

consequence - outcome of an event affecting objectives [2]

control - measure that is modifying risk [2]

establishing the context - defining the external and internal parameters to be taken into account when managing risk, and setting the scope and risk criteria for the risk management policy [2]

event - occurrence or change of a particular set of circumstances [2]

event risk classification (ERC) - classification of operational safety events, using the ERC matrix [1]

exposure - people, property, systems, or other elements present in hazard zones that are thereby subject to potential losses [3]

external context - external environment in which the organization seeks to achieve its objectives [2]

hazard - a source of potential harm, or a situation with a potential to cause loss; 'A source of possible damage or injury' [4]

internal context - internal environment in which the organization seeks to achieve its objectives [2]

level of risk - magnitude of a risk or combination of risks, expressed in terms of the combination of consequences and their likelihood [2]

likelihood - chance of something happening [2]

marine casualty - an event, or a sequence of events, that has resulted in any of the following which has occurred directly in connection with the operations of a ship [1]:

1. death of, or serious injury to, a person;
2. loss of a person from a ship;
3. loss, presumed loss or abandonment of a ship;
4. material damage to a ship;
5. stranding or disabling of a ship, or the involvement of a ship in a collision;
6. material damage to marine infrastructure external to a ship, that could seriously endanger the safety of the ship, another ship or an individual; or
7. severe damage to the environment, or the potential for severe damage to the environment, brought about by the damage of a ship or ships.

marine incident - an event, or sequence of events, other than a marine casualty, which has occurred directly in connection with the operations of a ship that endangered, or, if not corrected, would endanger the safety of the ship, its occupants or any other person or the environment [1]

monitoring - continual checking, supervising, critically observing or determining the status in order to identify change from the performance level required or expected [2]

noxious liquid substance - any substance referred to in appendix II of the MARPOL Annex II or provisionally assessed under provision of regulation 3(4) as falling into Category A, B, C or D [5]

oil - petroleum in any forms including crude oil, fuel oil, sludge, oil refuse and refined products (other than chemicals which are subject to the provisions of Annex II of the present MARPOL Convention) and, without limiting the generality of the foregoing, includes the substances listed in appendix I to Annex I [5]

oil fuel - any oil used as a fuel in connection with the propulsion and auxiliary machinery of the ship in which such oil is carried [5]

oily mixture - a mixture with any oil content [5]

organizational resilience - ability of an organization to anticipate, prepare for, and respond and adapt to incremental change and sudden disruptions in order to survive and prosper [6]

risk - effect of uncertainty on objectives [2]

risk analysis - process to comprehend the nature of risk and to determine the level of risk [2]

risk assessment - overall process of risk identification, risk analysis and risk evaluation [2]

risk criteria - the terms of reference against which the significance of a risk is evaluated [2]

risk evaluation - process of comparing the results of risk analysis with risk criteria to determine whether the risk and/or its magnitude is acceptable or tolerable [2]

risk identification - process of finding, recognizing and describing risks [2]

risk management - coordinated activities to direct and control an organization with regard to risk [2]

risk management process - systematic application of management policies, procedures and practices to the activities of communicating, consulting, establishing the context, and identifying, analyzing, evaluating, treating, monitoring and reviewing risk [2]

risk management framework - set of components that provide the foundations and organizational arrangements for designing, implementing, monitoring, reviewing and continually improving risk management throughout the organization [2]

risk map - a map that portrays levels of risk across a geographical area. Such maps can focus on one risk only or include different types of risks [1]

risk owner - person or entity with the accountability and authority to manage a risk [2]

risk source - element which alone or in combination has the intrinsic potential to give rise to risk [2]

risk treatment - process to modify risk [2]

risk value (risk index value) - a numerical weighting given to each square of a risk matrix to enable differentiation of risk for the purpose of quantitative analysis [1]

review - activity undertaken to determine the suitability, adequacy and effectiveness of the subject matter to achieve established objectives [2]

safety - safety refers to the ability of a system or process to mitigate the negative consequences of undesirable events that arise due to a combination of passive hazards and active failures [1]

safety issue - a manifestation of a hazard or combination of several hazards in a specific context [1]

sensitive area - area of ecological, social, economic, cultural, scientific and/or educational significance that would greatly be affected by an oil spill and for which pollution prevention and/or cleaning is high priority [7]

ship - a vessel of any type whatsoever operating in the marine environment and includes hydrofoil boats, air-cushion vehicles, submersibles, floating craft and fixed or floating platforms [5]

stakeholder - person or organization that can affect, be affected by, or perceive themselves to be affected by a decision or activity [2]

very serious marine casualty - a marine casualty involving the total loss of the ship or a death or severe damage to the environment [1]

vulnerability - the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard [3]

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