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RISK MANAGEMENT

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DOCUMENT REVISION

Revisions to this document are to be noted in the table prior to the issue of a revised document.

Date	Details	Approval
December 2000	First issue	Council 25
December 2005	Entire document reformatted to reflect the IALA documentation hierarchy.	Council 35
October 2008	Editorial and layout changes. New chapter on human factors. Further detail in the introduction.	
May 2013	Edition 3.0 Entire document. Editorial and layout changes. Addresses impacts of electronic Navigation improvements on risk and risk control measures and the need for continued physical AtoN to meet the navigational requirements for all users.	Council 55
June 2022	Edition 4.0 Complete review and rewrite of Guideline.	Council 75

CONTENTS

CONTENTS

List of Tables

List of Figures

1. INTRODUCTION

1.1. SCOPE

This document provides guidance to Marine Aids to Navigation (AtoN) authorities in applying risk management to their activities. Formal Safety Assessment (FSA) has been recommended by the International Maritime Organization (IMO) for use by maritime authorities [1]. The broader concept of organizational risk management, within which FSA should be integrated, is described by the ISO31000 standard [2]. The tools of the IALA Risk Management Toolbox are introduced, indicating how they can support the risk management process.

The intended audience of this Guideline is AtoN authorities and other maritime stakeholders.

1.2. OBJECTIVES

This Guideline has the following objectives in the context of the requirements for competent AtoN authorities:

1 To provide a broad understanding of the risk management process.

2 To strengthen the practice and increase the objectivity of maritime risk assessment by providing standardized tools and procedures.

3 To offer general guidance for the choice of appropriate tools to execute the risk management process.

1.3. RATIONALE OF THE GUIDELINE

Regulation 12 and 13 of SOLAS Chapter V state:

> "Contracting Governments undertake to arrange for the establishment of VTS where, in their opinion, the volume of traffic or the *degree of risk* justifies such services.
>
> Each Contracting Government undertakes to provide, as it deems practical and necessary either individually or in co-operation with other Contracting Governments, such aids to navigation as the volume of traffic justifies and the *degree of risk* requires."

The purpose of this Guideline is to provide guidance to AtoN authorities and other stakeholders in the maritime domain, to support assessment of the above-mentioned degree of risk in their jurisdiction, in order to strengthen the decision-making basis for complying with the above SOLAS obligations. A documented risk assessment could be undertaken for several purposes and due to various internal and external circumstances. These include, but are not limited to:

- Periodic internal safety reviews
- Other decisions, changes, or modifications to the operations of the AtoN authority
- The occurrence of an incident, accident, or emergency
- Developments or changes in the traffic volumes and/or patterns
- Development or changes of man-made offshore installations
- A stakeholder request or complaint

1.4. RELATION WITH OTHER IALA GUIDELINES

This Guideline provides an overview of the risk management process, focusing on how the IALA Toolbox links with FSA. For more elaborate descriptions of these tools, reference is made to other IALA documents throughout the text. Figure 1 illustrates the structure of the IALA guidelines, in particular the specific documents relating to the IALA toolbox.

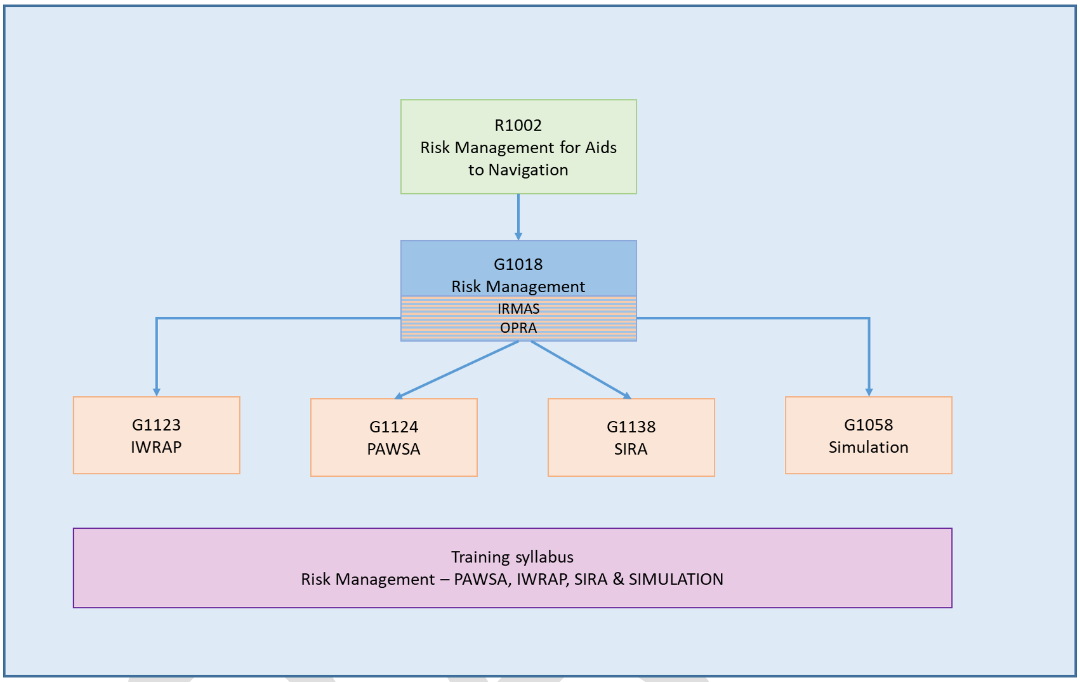


Figure 1 Overview of associated documents

1.5. SUSTAINABILITY

When risk control options are needed, sustainability aspects must be considered in the selection of existing and alternative mitigation measures. The UN Sustainability Development Goals 9 (Resilient infrastructure), 13 (Climate action), 14 (Life below water) and 17 (Global partnership) are particularly relevant goals. Further information and inspiration can be found on the UN website [8].

1.6. TERMINOLOGY

In this Guideline, the terminology commonly used in risk communication is utilized. The most important terms are defined here to facilitate understanding of the document. The full list of terms can be found on the IALA website (see *IALA Dictionary (General Terms – 1.5 Safety)*):

- *Accident:* An unintended event involving fatality, injury, ship loss or damage, other property loss, damage or environmental damage.
- *ALARP:* As Low As Reasonably Practicable; the minimal level of risk that may be achieved, when the costs of further reduction would be grossly disproportional to the benefit
- *Allision:* a vessel striking a fixed man-made object such as a wind turbine (OWG), pier or berthing dolphin (See *Collision*)

- *Collision:* two or more vessels striking each other unintentionally (see also *Allision*).
- *Consequence, Impact:* The outcome of an accident, the damage expressed as e.g., monetary value or loss of lives.
- *FSA:* Formal Safety Assessment, the methodology promulgated by IMO to control maritime risk.
- *Hazard:* A potential to threaten receptors, including human life, health, property or the environment.
- *Incident:* Used to indicate an unwanted event which does not necessarily involve damage or harm (compare: *Accident*).
- *Likelihood:* the probability of an event, frequently used within the context of a qualitative risk assessment (compare: *Probability*)
- *Probability:* the statistical expectance of the number of occurrences per unit of time (frequency) – term used within the context of a quantitative risk assessment (compare: *Likelihood*)
- *Risk:* The combination of the expected frequency (*probability*) of accidents and the severity of the consequences. Quantitatively: the product of both.
- *Risk Assessment*: The activity of assessing the frequency or probability and consequence of risk scenarios, including a consideration of the uncertainty of the estimates.
  - *qualitative risk assessment* – risk expressed in terms of acceptability, usually based on expert's opinion
  - *quantitative risk assessment* – risk expressed in terms of expected losses per year, as an outcome of frequency x consequence, usually based on model calculations
- *Risk Control:* Taking actions (Risk Control Measures, Risk Control Options) in order to reduce risks
- *Risk Evaluation:* The process by which risks are examined in terms of magnitude and distribution, and evaluated in terms of acceptability considering the needs, issues, and concerns of stakeholders.
- *Risk Management:* The systematic application of management policies, procedures, and practices to the tasks of analysing, evaluating, controlling, and communicating about risk issues.

2. THE RISK MANAGEMENT PROCESS

The Formal Safety Assessment (FSA) adopted by the International Maritime Organization (IMO) is a structured and systematic process, recommended for assessment and control of maritime risks. Recognized elements are, a.o., risk analysis and cost-benefit assessment. FSA is briefly described in section 2.1.

The International Standard on Risk Management *ISO 31000* adopted by the International Organization for Standardization, provides a generic description of the risk management process. It is based on best practices, extensive consultation and expert input, and links the risk assessment with organizational processes. It is used in many industries, including various maritime sectors. The key concepts of *ISO31000* are outlined in section 2.2.

2.1. THE IMO FORMAL SAFETY ASSESSMENT: FOCUS ON RISK ASSESSMENT

The Formal Safety Assessment (FSA) is a process for supporting decision making, making use of risk analysis and cost benefit assessment. It aims to achieve a balance between various technical and operational issues, including the human element, maritime safety and protection of the marine environment, and costs. The International Maritime Organization has first adopted FSA in 2002, through *MSC/Circ.1023/MEPC/Circ.392*, recommending the use of FSA for the maritime sector. The current version of the procedure is described in *MSC-MEPC.e/Circ.12/Rev2*.

In Table 1, the five steps of the FSA process are listed. The table also lists some key questions addressed in each step, and outputs that are obtained by executing the different phases.

Table 1 Formal Safety Assessment process: Steps, key questions, and outputs

Step	Name	Key question	Outputs
1	Hazard identification	What might go wrong?	A list of all relevant potential accident scenarios with potential causes and consequences
2	Risk analysis	How likely is the risk to occur? If it happens, how severe would be the consequence	Estimation of likelihood and consequences of the potential accident scenarios, ranking of these scenarios
3	Risk control options	Can matters be improved?	Potential measures to reduce the likelihood of occurrence of the identified risks, or limit their consequences should they occur
4	Cost-benefit assessment	What would it cost? How much better would it be?	Costs associated with the different risk control options, and an assessment of how cost-effective they are compared to how much they reduce the risk
5	Decision-making recommendations	What actions should be taken?	Documented information about the hazards, their associated risks and the cost effectiveness of alternative risk control options is provided to decision makers

Figure 2 shows the process flowchart of the different steps in FSA. First, the *hazard identification* (Step 1) is performed. From this step, the relevant potential accident scenarios and their causes and consequences are found. With this information, the *risk analysis* (Step 2) is performed. The likelihood and consequences of the different identified accident scenarios are estimated, and a ranking is made. For the scenarios determined as priority, usually the highest ranked scenarios, *risk control options* are identified (Step 3). This means that potential measures to reduce the likelihood of accident occurrence, or the severity of their consequences, are thought of and their effects on reducing the risk estimated. In other words, there is an iteration between Step 3 and Step 2. At this point, there are three main strategies to follow.

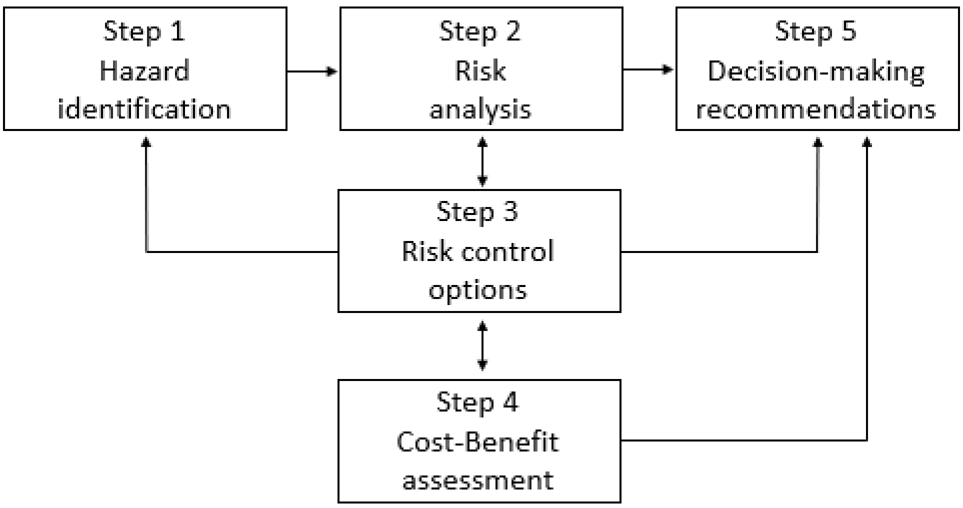
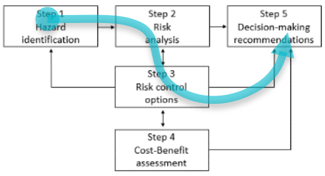
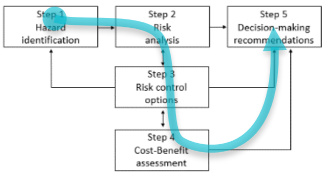


Figure 2 Formal Safety Assessment process steps and information flows

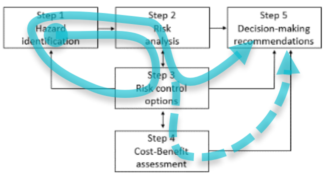


In the simplest strategy (*Strategy 1*), the information about hazards, the estimated risks (likelihood and consequences) and their ranking, and the risk control options and their estimated risk-reducing effect, is gathered and summarized as an input for decision makers. In this strategy, the sequence in the process flowchart is Step 1, Step 2, Step 3, Step 5.

A more elaborate strategy (*Strategy 2*) is essentially the same as Strategy 1, but after estimating the risk-reducing effect of the risk control options (Step 3), a cost-benefit assessment is performed. This means that the costs of implementing the risk control options is estimated. This information is combined with their estimated risk-reducing effects. Finally, an estimate is obtained of how much the different risk control options help to reduce the risk, in relation to how much they cost. As in Strategy 1, the produced information about hazards, risks, and risk control options, including their cost-effectiveness, is gathered and summarized as an input for decision makers. In this strategy, the sequence in the process flowchart is Step 1, Step 2, Step 3, Step 4, Step 5.



In the most comprehensive strategy (*Strategy 3*), the same process is followed as in Strategy 2, but in addition, an iteration is performed after risk control options are identified (Step 3). This means that at that point, a new hazard identification step is taken (Step 1), because it is possible that new risk control options introduce new hazards and risks to the system. The risk levels of the system with these new hazards are estimated (Step 2), and if necessary additional risk control options specified (Step 3). Usually, at most one iteration of steps 1 to 3 is performed. At this point, Strategy 3 can either proceed directly to gather the produced information as inputs for decision makers, as in Strategy 1. Otherwise, a more elaborate process can be followed similar as for Strategy 2, by adding an additional step where the cost-benefit of implementing the risk control options is assessed (Step 4).



In the FSA process, several risk assessment tools can be used to support the different steps. Such tools thus help with hazard identification, risk analysis, and estimating the effects of risk control options. Some tools are dedicated to only one of these steps, while other tools may have a role in different steps. Tools can be different for instance in the kind of input data required, the level of expertise and training needed to use the tool, and the resources needed for executing it (time, people, etc.).

In section 3 an overview of the IALA toolbox is given, highlighting in which steps of the FSA process the different IALA tools primarily have a role. It is worth noting that the IALA tools focus specifically on methods for identifying hazards (Step 1), analysing risks (Step 2), and estimating the effects of risk control options (Step 3) related to ports, waterways, and sea areas. Also, IMO's FSA document proposes the use of some generic risk assessment methods. Section 4 mentions a few with associated tools.

2.2. THE ISO 31000 STANDARD ON RISK MANAGEMENT: FOCUS ON ORGANIZATIONAL RISK MANAGEMENT

Once a risk assessment is made using appropriate tools, there are additional processes needed to ensure that the recommendations to decision-makers are acted upon. These processes, as recognized by *ISO31000*, are represented in Figure 3. In this *ISO31000* standard, the first process following the FSA concerns the decision making. Here, the recommendations of the risk analysis or the risk-cost benefit analysis (depending on which Strategy of section 2.1 is followed) are considered along with other information relevant to the decision. For instance, stakeholder concerns, legal or financial constraints, or practical challenges are considered alongside the recommendations of the FSA process. Then, it is decided through a managerial judgment whether the risks are acceptable, and if not, what risk control option(s) will be implemented.

Furthermore, this judgment may lead to the implementation of risk management actions, where the practicalities of the implementation of the risk control options are decided (e.g., budgets, timelines, responsibilities, procedures, etc.) and practical action is taken to implement the selected risk control options.

In the *ISO31000* standard, attention is also given to communication and consultation, to ensure that stakeholder concerns are appropriately considered, and so that all relevant end-users and stakeholders are aware of the decisions and when and how they will affect them. Relevant stakeholders may be e.g., mariners, shipping companies, pilotage authorities, and search and rescue and pollution response authorities.

A separate organizational process in *ISO31000* concerns the monitoring and review, which aims to ensure that the risk analysis and cost-benefit analysis are appropriately executed, with comments and review by relevant stakeholders. This process also includes monitoring the implementation of the risk management, so that quality results are achieved.

Finally, the monitoring and review process aims to periodically revisit the risks of the system, to monitor if changes in the system may lead to new or changed hazards. If this is the case, this may mean that a new risk assessment needs to be performed so that new risk control options can be selected, as needed.

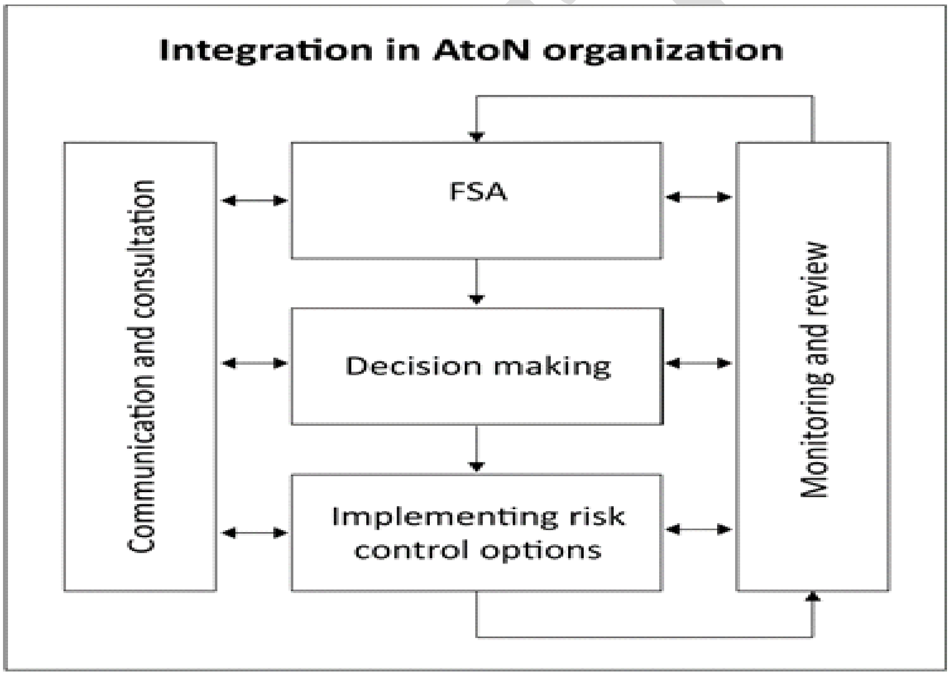


Figure 3 Risk management process in an organization

2.3. IALA RISK MANAGEMENT SUMMARY (IRMAS)

The IALA Risk Management Summary (IRMAS) has been designed as a standardized approach to document the process of risk assessment, which also provides for a repository of operational risk assessments undertaken for small scale applications (e.g., change of specification for an individual Marine Aid to Navigation, reaction to change in bathymetry, wreck, etc.). It is important that organizations document safety considerations, actions and decisions based on the principles of risk management. To facilitate this, IALA has designed a standardized IRMAS form in which all relevant information may be recorded.

In summary, the IRMAS form follows risk management principles as it:

- provides an auditable record of completed risk assessments and decisions made by an organization; and
- informs the decision on risk mitigation measures required for small scale risk assessments.

One section of IRMAS is reserved for the One Page Risk Assessment (OPRA), see section 3.4.

For the most simple examples of a SIRA, operational assessment of risk could be undertaken using OPRA. In more complex situations, the findings of a more detailed study, supported by a full SIRA and/or other IALA risk management tools, are summarized in the standardized IRMAS form together with a reference to the full study reports.

The IRMAS form is designed to be a straightforward record to document the results and actions of risk assessments and enables accurate storage of information such that historical risk assessments can be easily accessed by organizations. Moreover, IALA members may share their forms with IALA for general information and knowledge sharing.

The form contains a number of selectable options and free text fields and is split into four sections:

- Section 1: Risk Assessment Details
- Section 2: Documentation of Assessment Approach
- Section 3: One Page Risk Assessment (*OPRA*)
- Section 4: Actions

An example of a completed IRMAS form can be found in annex A. See section 3.4 for an explanation of the OPRA format.

3. THE IALA TOOLBOX

For supporting risk assessment, IALA suggests the use of a number of supportive tools:

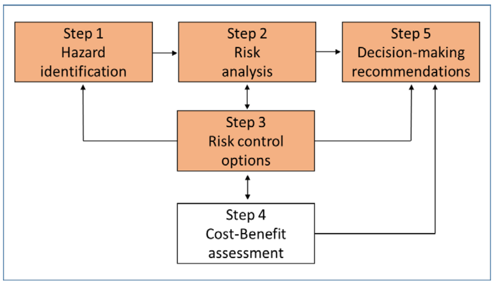
- Ports and Waterways Safety Assessment (PAWSA)
- IALA Waterway Risk Assessment Program (IWRAP)
- Simplified IALA Risk Assessment method (SIRA); and
- Navigational simulation.

These are described in more detail below. Some tools may be characterized as quantitative when they result in numeric risk figures, whereas a tool that produces results in terms of acceptability may be called qualitative. However, it can be argued that no numerical result can be accepted as "the truth" but instead is a starting point for expert evaluation.

3.1. PAWSA MKII

PAWSA (see IALA Guideline *G1124 The use of PAWSA* [3]) provides a (strict) framework for performing an expert session on navigational risks. Originally developed by USCG to evaluate the benefit of coastal VTS the method has matured into a generic tool for the evaluation of navigational risk and effectiveness of mitigating measures.

3.1.1. APPLICATION AREA



PAWSA supports steps 1, 2, 3 and 5 of the FSA process. The hazards are first identified and evaluated (assuming there are no risk control options effective) by a group of experts, and then the risk is evaluated again when risk control options are in place. If the risk is still considered too high, additional mitigation measures are evaluated.

The PAWSA process has been completed in many ports and waterways to decide whether additional risk mitigating measures were required.

It is a generic tool for the evaluation of navigational risk and effectiveness of mitigating measures.

3.1.2. HOW IT IS USED

Typically, a PAWSA session involves a group of about 30 experts, led by an experienced facilitator assisted by an operator, carried out over two days. The tool includes a mathematical engine to weigh the experts' opinions against each other, resulting in a qualification of risk categories in terms of acceptability.

3.1.3. TYPE OF RESULTS

The assessment by this tool indicates whether the existing risk level in the waterway is:

- *Acceptable* and no further work is needed unless changes occur in important criteria, such as the traffic pattern or the types of ships using the waterway; or
- *Not Acceptable* but the risk control options necessary to make the risk level of the waterway acceptable have been identified adequately; or
- *Not Acceptable* and more detailed study is necessary to enable the risk control options that will make the risk level of the waterway acceptable to be identified adequately.

The mathematical engine does produce a numerical value, but this should only be interpreted in the qualitative terms as indicated.

3.1.4. INPUT REQUIREMENTS

The tool itself is fed by the responses of the workshop participants. However, for a successful workshop, all usable data should be collected prior to the workshop, and ready to be presented at the workshop in an easy to understand and flexible manner. Smartboards with electronic nautical charts (ENC) can be used effectively.

3.1.5. STRENGTHS

Using PAWSA, all available local expertise and information may be utilized. The method takes into account the different levels of expertise across the workshop participants. As all stakeholders take part in the process, they are inclined to support the results.

3.1.6. LIMITATIONS

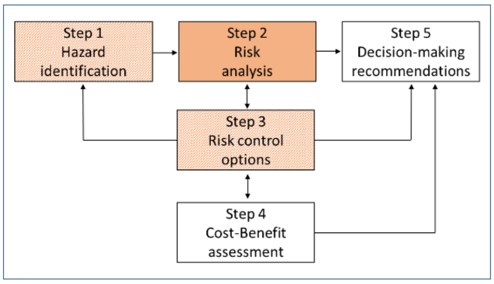
The workshop needs professional preparation and facilitation. A relatively large number of experts are required for the, typically, two-day long workshop.

The success of the workshop builds on the relevant factual information to be at hand in a presentable way at the workshop. Finding the right participants may be a challenge.

3.2. IWRAP

The IALA Waterway Risk Assessment Program (IWRAP, see IALA Guideline *G1123 The use of IWRAP* [4]) is characterized as the quantitative risk assessment tool. From the density and composition of traffic flows within the layout of the fairway and its environment, the likelihood of occurrence of different accident types is calculated.

3.2.1. APPLICATION AREA



IWRAP supports steps 1 (to some extent), 2 and 3 (to some extent) of the FSA process. The hazards that can be identified are groundings, allisions and collisions. The calculated likelihood of those accidents can be differentiated by ship type and ship size class and be presented as a "heat map" on top of an ENC or chart Bitmap.

3.2.2. HOW IT IS USED

Starting from AIS data[1], IWRAP can be used to reveal "hotspots" in an area where the traffic density distribution leads to relatively high risk levels. Moreover, considering changes in the traffic layout (maybe due to mitigating measures or external claims), the resulting change in risk level and risk distribution is clearly shown. However, expertise is still needed to interpret the results, appreciating the limitations of the manual input and the calculation model itself.

3.2.3. TYPE OF RESULTS

Results are numerical, hence the qualification as a quantitative tool. The statistical expectance of the number of occurrence of groundings and collisions per year for the entire study area is produced. The geographic distribution groundings and collisions can also be shown in colours, indicating the annually expected number of groundings per m stranding line or the annually expected number of collisions per m^2 fairway area.

3.2.4. INPUT REQUIREMENTS

- *Traffic density* - Assuming AIS data is available: the recorded AIS data over significant period of time and the entire area of interest. The desired extent of this period depends on the traffic intensity and possible weekly or seasonal changes. Both the static and dynamic AIS ship messages are used and are imported and processed by IWRAP.
- *Geographical description of the study area* - Normally a digital chart or otherwise a paper nautical chart is used as a basis, as this significantly improves the interpretation and presentation of traffic data and results of the calculations. However, for the calculations only the geographic contours of potential grounding areas (if any) are Incorporated into the IWRAP model. If a simple scan of a paper chart is used, geographic reference points can be indicated to be incorporated in the model.

3.2.5. STRENGTHS

- Quick results
- Analysis of traffic patterns, including characterization with fitted lateral distribution function.
- Presentation of areas with relative high density of allisions/collisions and groundings.
- The ability to compare different scenarios.

3.2.6. LIMITATIONS

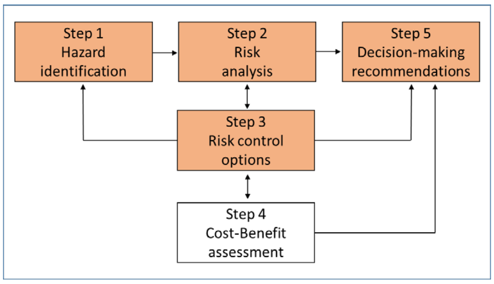
- As the analysis is based on AIS data, the traffic pattern relates to a past period. To evaluate the risk in a future situation, e.g., after the effectuation of a risk control option, the changes in traffic pattern must be entered by the users based on their expertise.
- The effectiveness of risk control options that would affect causation factors cannot be demonstrated, unless the causation factors are altered by hand, based on an assumed effectiveness.
- The likelihood of allisions/collisions and groundings is calculated, not the consequences.

3.3. SIRA

Compared to PAWSA, SIRA (IALA Guideline *G1138 The Use of SIRA* [5]) provides a much easier tool with which to structure an expert panel risk assessment. The basis of the method is the risk matrix, in which the probabilities and consequences of the most relevant accident scenarios are entered.

1 Theoretically, traffic data can be entered by hand if AIS data is not available. However, the amount of work involved and data quality issues make this very impracticable.

3.3.1. APPLICATION AREA



When using PAWSA is beyond the possibilities of an administration, application of SIRA may provide a suitable alternative. In other cases, SIRA can also be used as additional tool.

Being a structured approach for an expert session, all relevant hazards and associated risks may be covered. The effectiveness of risk control options is evaluated by the same expert group. Based on this outcome, a recommendation for the decision makers is formulated. In this way the FSA steps 1, 2, 3 and 5 are covered. An explicit cost-benefit assessment is not included in the method, the recommendation of risk control options is primarily based on their perceived effectiveness.

3.3.2. HOW IT IS USED

A group of experts discusses types of hazards, possible accident scenarios and rate likelihood as well as the magnitude of consequences. The process is structured as a number of consecutive steps. By using hazard categories and checklists, the discussion is fed, so that the chance of missing relevant scenarios is minimized.

3.3.3. TYPE OF RESULTS

The risk figure of all scenarios considered are plotted in a risk matrix. If there are risks that need mitigation, the expected effect of recommended measures is displayed in another risk matrix. Besides the matrices, the report reflecting the process to these matrices is an essential part of the results.

3.3.4. INPUT REQUIREMENTS

All relevant, factual data on traffic composition and density, fairway layout, traffic services, maritime accidents etc. is required for a successful expert session. As for other methods of assessment where individual opinion could dominate if not managed correctly, it is stressed that only robust, validated data should be used, such as traffic records, official accident records, AIS data etc., and not observations that may be coloured by opinion.

3.3.5. STRENGTHS

- Very flexible; any risk may be discussed
- No minimal size of expert group

3.3.6. LIMITATIONS

- Assessment of likelihood and consequence solely based on expert opinion
- Risk score as multiplication of ordinal numbers has no direct relation with the “real” estimated risk

3.4. ONE PAGE RISK ASSESSMENT (OPRA)

The One Page Risk Assessment forms part of the IRMAS summary document (see section 2.3) and can be used to support and record the most simple examples of a SIRA. It is designed to support operational small-scale assessments of navigational risk, such as those associated with temporary marking of a wreck, the small change of a Marine Aid to Navigation characteristics (e.g., light characteristic of a lighthouse/beacon/buoy), or the establishment of a virtual Marine Aid to Navigation.

See annex A for an example of the use of the OPRA methodology.

3.5. NAVIGATIONAL SIMULATION

Navigational simulation (IALA Guideline *G1058 The Use of Simulation* [6]) may provide both quantitative and qualitative data, and can be applied in two different modes:

- Fast-time simulation
- Real-time simulation

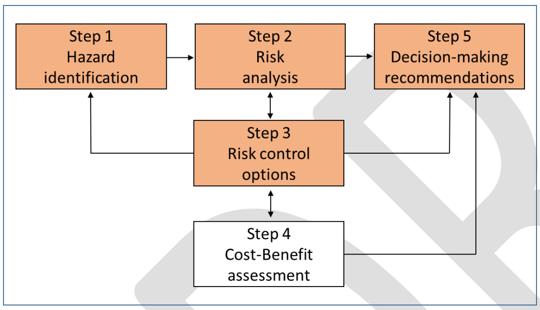
which may be combined, as part of the risk assessment process.

Fast-time simulation is carried out by a virtual navigator that sails a vessel through a specific area, navigational channel, etc. in fast time, producing a large number of sailings for each possible scenario of ship types, weather conditions, loading conditions, etc. within a short period of time, hence the quantitative approach.

In real-time simulation, the vessels are controlled by a real navigator, typically producing fewer simulations, not necessarily covering all possible scenarios, hence the qualitative approach. Which type of simulation is to be used, depends on the objectives that the simulation needs to address. Especially, real-time simulation may be useful to demonstrate possible effects to stakeholders. However, when used as an instrument to determine risk levels and effectiveness of risk control options, it is essential to verify that the simulation setup is able to replicate the relevant aspects.

As an example, the vessel, the environment such as bathymetry, waves, current and wind, and AtoN should be modelled with adequate accuracy. AtoN should be displayed properly by the simulator setup and enabled by the developed software features.

3.5.1. APPLICATION AREA



Navigational simulation can be a valuable tool to assess the value of risk control options being considered.

A navigational simulator is frequently used for evaluation of the design of fairways and harbour entrances, to check whether the task of bringing a specific ship in (or out), in various environmental and traffic conditions, can safely be completed under human control.

If the provision of AtoN is one of the factors that need investigation, care must be taken to ensure that the information provided for the navigator regarding the presentation of simulated AtoN, accurately resembles the real-world situation. As such, care must be taken when assessing various AtoN solutions.

The use of AIS data may also support visualization of traffic patterns when assessing potential routeing measures and traffic behaviour. Maritime Autonomous Surface Ships (MASS) may also be represented within the simulated scenarios.

3.5.2. HOW IT IS USED

A fast-time simulation is typically used to assess the fairway space that is physically necessary to follow a predefined route. The role of the helmsman is then taken by a virtual navigator, which may be fed by the exact (simulated) position, heading and velocities of the vessel. A well-designed virtual navigator algorithm will replicate the behaviour of a large number of navigators with varying skills and competencies.

Frequently, a fast-time simulation is used to identify the critical parts of a passage – by simulating many combinations of vessel types and sizes, environmental conditions such as wind, current, waves, and tide. The critical parts may then be modelled for a real-time simulation with a human navigator "in the loop". The position, heading and velocities of the vessel in the simulated world are conveyed to those human controllers through bridge instruments and the outside view, including AtoN.

Typically, fewer scenarios are simulated by use of real-time simulations, where the human navigator's subjective evaluation of the risk plays a significant role in the final decision and conclusion of potential risk control options.

3.5.3. TYPE OF RESULTS

The results of fast-time simulations are a large number of recorded tracks and time series of position, speed, rudder position, engine settings, etc. The recorded time series can be analysed statistically, hence calculating the probability of an incident occurring, such as grounding, collision, allision, crossing of fairway borders, etc. The statistical results, in combination with the chosen accident frequency criteria (i.e., one grounding per 50 years) enables the decision on the safety margins for the fairway design, including the configuration of AtoN providing spatial awareness.

The same data in terms of recorded tracks and time series of various parameters can be made available when simulating in real time. However, these data are usually used to support the conclusions and recommendations made by the navigator(s) participating the real-time simulations. Hence the results of real-time simulations are far more subjective compared to results of fast-time simulations.

3.5.4. INPUT REQUIREMENTS

Dependent on the type of simulation; for fast-time simulation the definition of a desired track (position and speed profile), vessel manoeuvring model, autopilot parameters, environmental model, (land, bathymetry, wind, waves, tide, and current) is necessary.

For real-time simulation, a visual model of the surroundings is added to the before mentioned input requirements along with an environment model updated with AtoN.

3.5.5. STRENGTHS

Using simulation techniques, the reaction of a human controller whether being virtual or real (i.e., navigator, helmsman and/or pilot) on simulated scenarios may be analysed. In particular, real-time simulation provides the opportunity to bring stakeholders (pilots, port authorities, operators/ship owners, national authorities, etc.) together, hence leading to consensus on decisions.

3.5.6. LIMITATIONS

One should always bear in mind that a simulator is only a model of real life and not real life itself. When using a ship manoeuvring simulator, a large number of assumptions are made that to smaller or larger extent reduce the accuracy – or, in other words, how close the simulated scenarios are to real life. There will always be a discrepancy between the simulated/modelled world and real life. Hence, the goal is to always stay conservative when doing simulations and to know to what level a given assumption will impact the outcome and the conclusions. A ship manoeuvring simulator can provide conclusions and recommendations only to a certain level where each assumption made should be considered carefully.

The translation of the results produced by a limited number of navigators, who are confronted with the same situation within a limited time span, to the entire population of mariners that may see this situation for the first time, may in theory, lead to conclusions resulting in too small safety margins. In practice, this is taken into account by the requirement that there should at all times be sufficient controlling options left to cope with unforeseen situations or to correct errors of judgement. In other words, that the available controls (rudder and engine, tugs) are at no stage required to their full potential during a prolonged time. Hence, conclusions and recommendations will most likely always be conservative with sufficient safety margin.

4. SELECTION OF SUITABLE TOOLS

There is not a "one size fits all" method to perform a risk assessment. It can be helpful to recognize three phases in the process: data collection, data processing, and expert discussion and evaluation. Most tools apply to the second phase but provide the experts in the third phase with valuable information. Depending on the nature of the case to be assessed, the data available, and the financial and human resources, the most suitable tool(s) or method(s) may be selected. The third phase cannot be skipped, the results of a risk calculation always must be interpreted by an expert. Documentation of all three phases is very important – use of the summary form IRMAS (section 2.3) is regarded as a minimum.

Each risk assessment should be based on factual data, as far as available. Important sources are:

- Nautical Chart and pilot data. Additionally: hydrographic surveys, environmental sensitivities, habitation, recreation activities, etc.
- AIS data (but be aware of traffic without AIS transponder)
- VTS reports, recordings and interviews
- Hydro-meteo data: statistics of wind, waves and currents
- Traffic volumes, differentiated by ship type and size, dangerous or harmful cargo
- Marine accident data and reports

For all geographic data, analysis and presentation is facilitated by using a GIS tool. AIS data tends to be very bulky and may need some pre-processing to extract the needed information. In fact, the licenced version of the IWRAP tool includes an AIS processing facility that characterizes traffic data with a lateral distribution on traffic legs.

The IALA Toolbox has been assembled to provide such a range of tools that most risk assessment needs are covered. However, other methods and tools exist that may fit better to a specific situation. The following table provides some guidance to the available methods and examples of associated tools.

Table 2 Risk assessment methods and supportive tools

Method	Tools (examples)	IALA Toolkit	Remarks
Check against recommendations and guidelines	IALA Guidelines PIANC Guidelines		Harbour Approach Channels Design Guidelines (MARCOM rep.no. 121)
	POLARIS		IMO Polar Operation Limits
Calculate probability from traffic intensity	IWRAP	X	AIS data needed Causation factor (default from literature)
	SAMSON / MarinRISK		Some similarity to IWRAP approach. Casualty rate (determined from recorded accident data)
	AISyRisk		AIS data needed
Structured expert elicitation	PAWSA	X	relatively large group of experts needed
	(e-)DELPHI		Basis of PAWSA; using an expert panel in consecutive rounds to achieve consensus

Bow-tie analysis	BowTieXP		A bow-tie diagram is used to represent all chains of events that may lead to a certain unwanted event (located in the tie knot) and the chains of events that may follow from that top event. Barriers are designed on each chain to control the risk. Used as a basis for expert group discussion.
	DNVGL Synergi		See above.
	THESIS		See above
Fault tree analysis	Isograph reliability workbench		Top-down analysis to identify the chain of events that may lead to an accident
Risk matrix	SIRA	X	See IALA Guideline (not: Safety Issue Risk Assessment, as defined in ICAO's ARMS methodology)
	OPRA	X	Basis risk matrix for simple risk assessments, as part of the IRMAS documentation standard
	ERC-M		Event Risk Classification (adapted from aviation), see OpenRisk report
Simulation	Traffic simulation		May in some cases provide input for risk analysis (route choice, traffic hot spots)
	Fast time simulation	o	To study the physically needed manoeuvring space of a vessel under autopilot control
	bridge simulator	o	To study the behaviour of a vessel under human control
	AtoN simulation	o	Is the simulator facility capable of necessary display fidelity?

5. DEFINITIONS

Specific definitions have been provided in section 1.5. The definitions of other terms used in this Guideline can be found in the *International Dictionary of Marine Aids to Navigation* (IALA Dictionary) at http://www.iala-aism.org/wiki/dictionary and were checked as correct at the time of going to print. Where conflict arises, the IALA Dictionary should be considered as the authoritative source of definitions used in IALA documents.

6. ABBREVIATIONS

AIS	Automatic identification system
AtoN	Marine Aids to Navigation
ENC	Electronic nautical chart
FSA	Formal Safety Assessment
IMO	International Maritime Organization
IRMAS	IALA Risk Management Summary
ISO	International Organization for Standardization
IWRAP	IALA Waterways Risk Assessment Program
OPRA	One Page Risk Assessment
PAWSA	Ports and Waterways Risk Assessment
SIRA	Simplified IALA Risk Assessment
SOLAS	Safety of Life at Sea Convention 1974 as amended
VTS	Vessel traffic services

7. REFERENCES

[1] IMO MSC-MEPC.2/Circ.12/Rev.2, Revised guidelines for Formal Safety Assessment (FSA) for use in the IMO rule-making process, https://wwwcdn.imo.org/localresources/en/OurWork/Safety/Documents/MSC-MEPC%202-Circ%2012-Rev%202.pdf

[2] ISO. (2018) ISO 31000 Risk management – Guidelines https://www.iso.org/obp/ui#iso:std:iso:31000:ed-2:v1:en

[3] IALA. Guideline G1124 The Use of PAWSA

[4] IALA. Guideline G1123 The Use of IWRAP

[5] IALA. Guideline G1138 The Use of SIRA

[6] IALA. Guideline G1058 Use of Simulation as a Tool for Waterway Design and AtoN Planning

[7] OpenRisk Guideline for Regional Risk Management to Improve European Pollution Preparedness and Response at Sea (2018) - https://helcom.fi/media/publications/OpenRisk-Guideline-for-pollution-response-at-sea.pdf

[8] UN. Sustainable Development Goals (SDG) - https://sdgs.un.org

ANNEX A IRMAS / OPRA METHODOLOGY

A.1. INTRODUCTION

This annex contains the methodology, example completed form and blank form for the IRMAS (see section 2.3 above) and OPRA (see section 3.4).

The IRMAS form should be used to capture information for all risk assessments undertaken, and the OPRA section of the form should be used if a small-scale assessment of risk is required – it is envisaged that the OPRA will be conducted by an individual (i.e., the responsible marine manager).

The IRMAS / OPRA form contains a number of selectable options and free text fields and is split into four sections:

- Section 1: Risk Assessment Details
- Section 2: Documentation of Assessment Approach
- Section 3: One Page Risk Assessment (OPRA)
- Section 4: Actions

A.2. SECTION 1: RISK ASSESSMENT DETAILS

Section 1 Risk Assessment Details section provides a standard set of risk assessment parameters. It is anticipated that personal and organization details could be hidden if the form is shared outside an organization (i.e., with IALA).

A.3. SECTION 2: DOCUMENTATION OF ASSESSMENT

Section 2 of the form details the documentation undertaken as part of any risk assessment, including listing what IALA risk tools have been used (if any).

A subjective qualification should be indicated of the level of confidence in the assessment undertaken – a table is provided at Table 3 showing the assessment confidence levels.

Table 3 Assessment confidence levels.

Assessment Confidence Score Action Required	
Very High	Assessment confidence threshold met.
High	Confirm confidence is acceptable
Medium	Review uncertainty and address issues
Low	Seek more information

A.4. SECTION 3: OPRA RISK ASSESSMENT

The following process of assessment for the OPRA is:

- *Step 1:* Identify hazards causes and outcomes and list in the OPRA form.
- *Step 2:* Score hazards based on likelihood and consequence tables and use the risk matrix to individually score each hazard.

Table 4 Risk Matrix

RISK MATRIX		LIKELIHOOD				
		Very Rare	Rare	Occasional	Frequent	Very frequent
		1	2	3	4	5
CONSEQUENCE	Catastrophic - 5	5	10	15	20	25
	Major - 4	4	8	12	16	20
	Severe - 3	3	6	9	12	15
	Minor - 2	2	4	6	8	10
	Insignificant - 1	1	2	3	4	5
CLASSIFICATION SCORES	Likelihood			Consequence		
	Very Rare = 1			Insignificant = 1		
	Rare = 2			Minor = 2		
	Occasional = 3			Severe = 3		
	Frequent = 4			Major = 4		
	Very Frequent = 5			Catastrophic = 5		

- *Step 3:* Determine the need for risk mitigation measures based on the OPRA Action Table as identified below. If risk mitigation measures are necessary then apply to hazard and re-assess the risk score with it in place.

Table 5 OPRA Action Table

Action Tables	Risk Value	Risk.	Risk Score Actions Required
	01 to 04	Green	Low Risk: Hazard acceptable / No mitigation
	05 to 08	Yellow	Moderate risk: Reduce to ALARP with mitigation
	09 to 12	Amber	High Risk: Significant mitigation needed / stop activity
	15 to 25	Red	Very High Risk: Immediate action to stop required

A.5. A4. SECTION 4: ACTIONS / DOCUMENTATION

Section 4 provides a list of actions from the risk assessment (whether as a result of a detailed assessment using the IALA risk tools, or as part of a small-scale assessment based on the OPRA). It is intended that the form provides a repository for documented and periodic review of actions to ensure they are completed, and an accurate record is kept.

Table 6 IRMAS / OPRA Example

IRMAS / OPRA			
Section 1: Risk Assessment Details			
Assessor Name:	John Smith	Date:	01-01-2021
Department.:	Aids to Navigation Department	Organization:	Lighthouse Authority
Assessment Name:	Marking of sunken container	ID #:	0001
Assessment Overview:		Location:	Sandy Bay
A recent incident report from the master of a cargo vessel notified the Lighthouse Authority that a container was lost overboard in adverse weather on 31-01-20 whilst on transit through Sandy Bay. The manifest shows the container was loaded with spare engine parts and machinery.		Co-ordinates:	Lat: 48.892950° Long: 2.072148°
Incident Details:	Container resting on seabed in shallow water.	Incident (ref. # / link)	#001

Section 2: Documentation of Assessment Approach						
Type of assessment		OPRA	Hazards Assessed (cross out not applicable)	~~Collision~~	Tools Used (cross out not applicable)	~~Vessel Analysis~~
Mitigation Measures Identified	Buoy	X		Allision		~~PAWSA~~
	Light	X		~~Grounding~~		~~IWRAP MkII~~
	Info.	X		~~Foundering~~		~~SIRA~~
				~~Other~~		~~Simulation~~
	Other					OPRA (see below)
Confidence in Assessment Findings		Very High	~~High~~	~~Medium~~	~~Low~~	~~Other (please specify)~~
Review of Results - Results as shown below in OPRA sections.						

Section 3: OPRA Risk Assessment					
# Hazard	Description/Causes	Outcomes	Risk Score (before mitigation)	Risk Mitigation Measures	Risk Score (after mitigation)
1: Allision with submerged container – Recreational Vessel	Sunken container in area of high recreational vessel density.	Allision causing damage to vessel and environment and may leading to sinking involving loss of life.	L = 3 C = 4 Score = 12	1. Deploy lighted isolated danger buoy. 2. Issue Notices to Mariners (consider promulgation to local clubs) and Marine Information Notice.	L = 2 C = 4 Score = 8
2: Allision with submerged container – Commercial Vessel	Sunken container in area of low commercial vessel density.	Allision causing damage to vessel and environment.	L = 2 C = 3 Score = 6	1. Deploy lighted isolated danger buoy. 2. Issue Notices to Mariners and Marine Information Notice.	L = 1 C = 3 Score = 3
3:					
OPRA Assessment Results Recommendations		Date:	01-01-21	Signature:	*John Smith*
The assessment demonstrates the need for risk mitigation measures to ensure navigation risk remains at acceptable levels. Removal of the container will be undertaken following agreement with vessel insurers once salvors are appointed.					

Section 4: Actions / Documentation				
Actions	#	Action	Completion Date	Person/Entity Responsible
	1.	Deploy lighted isolated danger buoy – ASAP	02-01-21	John Smith
	2.	Issue Notices to Mariners (and ensure promulgation to local recreational clubs) and ensure Marine Information Notice is broadcast.	01-01-21	John Smith
	3.	Removal of container when possible	31-03-21	Salvors
	4.	Archive IRMAS / OPRA assessment on removal of container	17-04-21	John Smith
	5.			