

# IALA Guideline 1018

On

## Risk Management

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## Document Revisions

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

<b>Date</b>	<b>Page / Section Revised</b>	<b>Requirement for Revision</b>
December 2005	Entire document	Reformatted to reflect the IALA Documentation Hierarchy
October 2008	Entire document	Editorial and layout changes. New chapter on human factors. Further detail in the introduction.

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## **Guideline on Risk Management**

### **1 INTRODUCTION**

This Guideline is intended to outline a general description on risk management methodology for marine Aids to Navigation (AtoN) including Vessel Traffic Services (VTS) so that all types of risks are effectively managed by AtoN authorities. The Guideline may be used when assessing the optimum mix of aids to navigation and other facilities. The annexes to the Guideline include an example of its application as well as definitions for some of the risk management related terms used herein.

In order that different marine AtoN Authorities can consistently apply the Guideline it is important that the process is clearly documented and formally recorded in a uniform and systematic manner. This will ensure the process is transparent and can be easily understood by all parties irrespective of their experience or background in the application of risk assessment and related techniques.

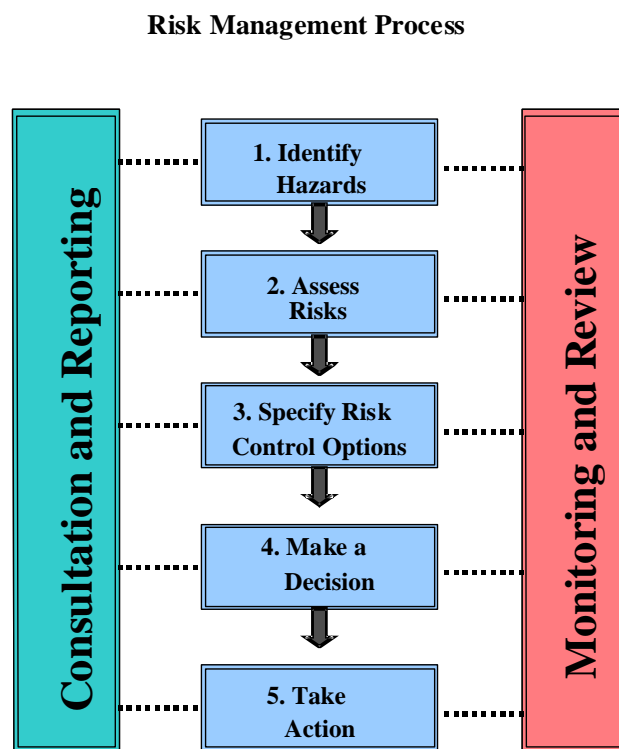
In this version of the guideline the former background section 1.3 – 1.8 on the importance of using a risk management process has been moved to annex IV in order to go from a short introduction straight into the actual elements of the risk management process. In addition some confusion on the use of the words hazards and risk has been corrected. Finally a new section on the importance of applying Human Factors in process and how to do this has been included.

It is important to stress that a correct, efficient and useful result of hazard identification, assessment of risk and establishment of risk control measures, in fact the output of a risk management process, is dependent on the application of Human Factors disciplines. The concept of Human Factors and references to relevant models is therefore included in this guideline. It is recommended that administrations, organisations and persons involved in a risk assessment process have suitable, updated and in-depth knowledge in the application of Human Factors disciplines.

## 2 THE RISK MANAGEMENT PROCESS

The risk management process described in the Guideline comprises five steps that follow a standardized management or systems analysis approach:

- 1 Identify hazards;
- 2 Assess risks;
- 3 Specify risk control options;
- 4 Make a decision; and
- 5 Take action.



*Figure 1 The Risk Management Process*

The central part of the figure above illustrates the five steps in the risk management process. In addition the figure suggests a consultation and reporting element throughout the process. Stakeholders including practitioners and users shall be consulted and receive feed-back continuously to ensure the best possible input to the decision makers, to validate decisions and to ensure ownership of the results and actions taken. The monitoring and review part in the right side of the model is vital to ensure a verification of the decisions, to check if initial conditions have changed and to constantly monitor if control measures are implemented effectively. The various elements in the figure are described in the following text.

A central element is to understand how human factors influence the risk management process.

## **2.1 Step 1 - Identify Hazards**

### **2.1.1 Scope**

The purpose of Step 1 is to identify and generate a prioritized list of hazards, specific to the problem under review. This is achieved by the use of standard techniques to identify hazards, which can contribute to incidents, and by screening these hazards using a combination of available data and judgment. A very important part of the scope is also to set the boundaries of the problem.

### **2.1.2 Define Problem/Trigger**

The problem under analysis and its boundaries should be carefully defined stating associated risk issues. This is often the most difficult phase in the process and is also the most important.

The risk management process may be initiated for a number of reasons, including:

- 1 Periodic safety review;
- 2 Monitoring the system (including the effects of previous systems);
- 3 An emergency, accident or incident;
- 4 A public request or complaint;
- 5 Other decisions, changes, or modifications to the operations of the organization; and
- 6 Any number of internal or external events, including funding, operational and technical changes.

To avoid confusion and problems issues must be specifically defined and documented, and should be dealt with one at a time. It is important to prioritize issues. Issues may also change throughout the process, as more information becomes available. For example, new issues may arise, issues may dissolve, or priorities may change.

### **2.1.3 Consult stakeholders**

During this stage, depending on the situation, it would be beneficial to identify and consult with stakeholders in order to validate or define the scope of the issues. Decision-makers in an organization often perceive the importance of an issue differently from external stakeholders.

Obviously, it is not necessary to involve all outside stakeholders in the validation of every identified issue. However, the greater the effect of a decision, the greater the concern, and the greater their involvement should be. When dealing with a more complex problem, in order to explain the resulting decision better, greater stakeholder involvement is required.

### **2.1.4 Hazard Identification Methodology**

The approach used for hazard identification generally comprises a combination of both creative and analytical techniques, the aim being to identify as many relevant hazards as possible. The creative element is to ensure that the process is proactive, and not confined only to hazards that have materialized in the past. It typically consists of structured group reviews aimed at identifying the causes and effects of accidents and relevant hazards. Consideration of functional failure may assist in this process. The group carrying out such structured reviews should include experts in the various appropriate aspects, such as navigational aid design, and specialists to assist in the hazard identification process and incorporation of the human element. A structured group review session may last over a number of days. The analytical element ensures that previous experience is properly taken into account and typically makes use of background information (e.g. applicable regulations

and codes, available statistical data on incident categories and lists of hazards to personnel, hazardous substances, and ignition sources).

A coarse analysis of possible causes and outcomes of each accident category should be made using standard techniques that are chosen according to the problem under review.

#### 2.1.4.1 *Types of Hazards*

In general terms, five types of hazards generate risks:

- 1 Natural hazards such as floods, wind storms, earthquakes, biological hazards, and other natural phenomena;
- 2 Economic hazards such as inflation, depression, and changes in tax and fee levies;
- 3 Technical hazards such as system or equipment failure, fire, explosion, obsolescence, and air/water pollution;
- 4 Human factors such as errors or omissions by poorly trained, fatigued or stressed persons, or violations, sabotage or terrorism; and
- 5 Operational hazards such as groundings, collisions, striking and other unwanted events.

#### 2.1.4.2 *Types of Losses*

The five types of hazards have the capability to generate seven different types of losses:

- 1 Health losses including death and injury;
- 2 Property losses including real and intellectual property;
- 3 Economic losses leading to increased costs or reduction to revenues;
- 4 Liability loss resulting when an organization is sued for an alleged breach of legal duty, such cases must be defended even if no blame is assigned. Liability losses are capable of destroying or crippling an organization;
- 5 Personnel loss when services of a key employee is lost;
- 6 Environmental losses (negative impact on land, air, water, flora or fauna); and
- 7 Loss of reputation or status.

#### 2.1.4.3 *Hazard Identification*

Hazard identification can be summarized in terms of four sub-tasks:

- 1 Structured and comprehensive consideration of known sources of hazards or initiating events, usually identified by reviewing past incidents and losses;
- 2 Brain-storming by a team that understands all aspects of the system under consideration. Led by a team leader, this includes following the structured list of hazards to identify how a hazard might lead to a risk;
- 3 Preliminary assignment of frequency and consequence to the risk scenarios. This task is useful in assisting the decision-maker in selecting those scenarios to be analyzed further in the Risk Estimation Step (for action or a more detailed estimation of frequency and consequence), and for those risk scenarios to be set aside; and
- 4 Qualitative simulation. During a ship simulation study it is possible to provide the participants with a holistic overview of a given operation. This often provides important input and can reveal hazards that otherwise would not be identified.

#### *2.1.4.4 Coastal Landfall and Waterway Risk Factors*

A risk analysis associated with a coastal landfall, waterway or port approach might consider a range of factors that contribute to the overall risk exposure. Table 1 provides an indication of the factors that could be taken into consideration when identifying hazards.

*Table 1 Indicative risk factors relating to marine navigation.*

<b>Ship traffic consideration</b>	<b>Traffic volume</b>	<b>Navigational conditions</b>	<b>Waterway configuration</b>	<b>Short-term consequence</b>	<b>Long-term consequence</b>
Quality of vessels	Deep draught	Night/Day operations	Depth	Injuries to people	Health and safety impacts
Crew competency	Shallow draught	Sea state	Channel width	Oil spill	Lifestyle disruptions
Traffic mix	Commercial fishing vessels	Wind conditions	Visibility obstructions	Hazardous material release	Fisheries impacts
Traffic density	Recreational boats	Currents (river, tidal, ocean)	Waterway complexity	Property damage	Endangered species
Nature of cargo	High speed craft	Visibility restrictions	Bottom type	Denial of use of waterway	Shoreline damage
		Ice conditions	Stability (siltation)		Reef damage
		Background lighting			Economic impacts
		Debris			

#### 2.1.4.5 Major Contributors to Risk

Care should be taken to ensure that the list of hazards includes items such as failure of management to have adequate change management procedures; lack of investigation and follow-up when process failures occur; the lack of an incident investigation protocol within the organization.

#### 2.1.5 Results

The output from Step 1 comprises:

- 1 Prioritized list of hazards/unwanted events; and
- 2 Preliminary description of the hazards / unwanted events.

### 2.2 Step 2 – Assess Risks

Risk assessment is assumed to include two major sub-activities, risk estimation and risk evaluation.

#### 2.2.1 Step 2a – Risk Estimation

##### 2.2.1.1 Scope of the Risk Estimation Sub-Activity

In this step of the decision process, the frequency and consequences associated with each risk scenario selected for analysis are estimated.

##### 2.2.1.2 Methods for Estimating Frequency and Consequences

The first step in this process is to identify the method or methods that will be used for any analysis. The estimates should be based on historical data, models, professional judgment, or a combination of methods. Preferably an established scientific or statistical protocol should be followed. It is necessary to explicitly define these applied methods to avoid conflict between technical experts and laypersons when judging the technical merit of the results. The choice of method will reflect the accuracy needed, cost, available data, the level of expertise on the team, and the acceptability of the method to stakeholders.

It is essential that technical experts clearly explain the methods that will be used in the technical analysis. It is not necessary that laypersons understand these methods in detail, as long as they know that they can have the analyses reproduced and vetted by their own experts. The process should be open and transparent at all times to build trust between decision-makers and other stakeholders, and provide confidence in the results.

There are a number of methods and associated measures that are used to estimate risk/expected loss (i.e. the combined effect of the frequency<sup>1</sup> and consequences of hazards or unwanted events):

#### 1 Monetary Estimates

Technically, risk is defined as the likelihood (chance, probability) of an unwanted event or hazard times its impact (consequence).<sup>2</sup> Such a product produces an estimate of the expected or likely losses associated with the unwanted events or hazards. If the probability is expressed as a frequency of occurrence, for example, the mean number of occurrences per year, and the impact, given that it occurs, is expressed in monetary terms, then the product yields the mean expected or average monetary loss per year. For example, if it is estimated that one grounding would occur once every ten years, on average, and that it would produce losses totalling \$500,000 each time it did occur, the average expected loss would be \$50,000 per year (\$500,000/10 years).

#### 2 Count Estimates

It is not always easy to estimate possible losses in monetary terms, however. Sometimes, simple physical loss counts are more appropriate. For example, where monetary values are difficult to assign to wildlife losses, it is sometimes easier to simply estimate the number of individuals that could be lost each year.

#### 3 Risk Matrix Estimates

Even more often, resort must be made to assigning relative scores to the frequency and consequences associated with the identified hazards (e.g. low, medium, high) and plot these on a risk matrix – see Figure 2. Usually, these assessments must be based on intuition, experience and expert knowledge where no data are available or quantitative analysis is not warranted (e.g. where the risk is expected to be low).

#### 4 Index Estimates

Sometimes it is possible to compute an index for different waterway areas of interest such that the index represents the relative rank of the risk in these areas (i.e. the combination of frequency and consequences). This index approach is often called *Multi-Criteria Decision Analysis (MCDA)* and is commonly used for policies, options and strategies. Risk index values for given waterways can then be compared to study area expenditures and potential anomalies identified.

#### 5 Simulation

Simulation offers a relative low cost method to help ensure that the solution provided meets the users' requirements in an effective and efficient manner. Simulation can incorporate both physical and digital methods. Simulation can provide an overall improvement in safe and efficient operation by assisting in demonstrating the operation of the waterway, channel design and associated AtoN before the reality of navigating a vessel in the area. For further information see IALA Guideline No 1058 "On the Use of Simulation as a Tool for Waterway Design and AtoN Planning".

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1 IALA is currently developing the quantitative IWRAP MKII model and has adopted the qualitative PAWSA model.

2 While, technically, risk is defined as probability x impact, the term risk is also commonly used to refer to the unwanted event itself, which is defined formally as a hazard.

### *2.2.1.3 Estimating Frequency*

The purpose of frequency analysis is to determine how often a particular scenario might be expected to occur over a specified period of time. These estimates are often based on historical data, where judgments about the future are based on what has occurred in the past. If there are no relevant historical data available, or if these data are sparse, other methods such as fault-tree, or event-tree analysis, or other mathematical or econometric models may be used. Estimates may also be based on expert experience and judgment. Most often, frequency estimates are based on a combination of these methods.

What usually results from this analysis is an expected range of frequencies with some estimate of uncertainty, rather than a single number.

### *2.2.1.4 Estimating Consequences*

Consequence analysis involves estimating the impact of various scenarios on everyone and everything affected by the activity. The impact of the consequence on the needs, issues, and concerns of stakeholders is the consideration, and it should be noted that consequences could be both negative and positive.

Consequences are often measured in financial terms, but they can also be measured by other factors: numbers of injuries or deaths, numbers of wildlife affected, impact on quality of life or on lifestyle, impact on an organization's reputation, and others. The benefit of measuring consequences in financial terms is that it provides a common measure for comparing dissimilar conditions. Another strong benefit of using a monetary measure is that it motivates decision-makers to take action.

It should be noted that non-financial consequences, especially loss of reputation, could be much more damaging to an organization than initially thought. It is important to try to quantify these types of consequences.

There are numerous scientific and statistical methods available for making these estimates of frequency and consequence, and the literature associated with estimation technologies is extensive. It is recommended that the decision-maker employ a technical expert or experts familiar with these techniques.

### *2.2.1.5 Presenting Frequency and Consequence Estimates*

Sometimes data resulting from frequency and consequence analyses are presented separately, but often the results are combined (multiplied together) in what is termed the expected value of the loss. The expected value of the loss is often used to compare one risk to another and is also incorporated in the analysis of the benefits of risk control options. The expected value of the loss can give some indication of how much should be spent on risk control to correct a situation. For example, if the expected loss is \$1,000 per annum, it is probably not prudent to spend \$10,000 per annum to reduce it. The expected value also provides a baseline from which to measure the performance of risk control strategies. A measure of the change in expected value, brought about by control measures, is compared to the cost of implementing the control option. In this case, the change in expected value acts, in a benefit/cost analysis, as a measure of the benefit of the risk control option. It is beneficial to include an economist on the team to perform these and other economic analysis.

	SEVERE			
<b>IMPACT</b>	MODERATE			
	MINOR			
		LOW LIKELIHOOD	MEDIUM	HIGH

Figure 2 Risk Matrix

#### 2.2.1.6 Third-Party Review

Having technical analysis reviewed and validated by trusted outside experts lends further credibility to the results. Universities and government agencies tend to be trusted because of the public perception that they are independent and, therefore, unbiased. It is important for the decision-maker to understand whom stakeholders trust vis-à-vis the particular issue being considered. This is accomplished through dialogue with stakeholders and is an important component of the stakeholder analysis.

It is recommended that a formal third-party review be used to confirm the integrity of the analysis process. This review can be accomplished using internal or external resources, depending on the situation, but not by the analysts themselves. For example, it can save the organization embarrassment if analyses are vetted internally for accuracy prior to the information being given to outside stakeholders. It may also be necessary to have the analyses vetted by some credible external body as a matter of policy, and especially if trust is an issue for stakeholders.

#### 2.2.1.7 Validation

Validation should include the following steps:

- 1 checking that the scope is appropriate for the stated objectives;
- 2 reviewing all critical assumptions and ensuring that they are credible in light of available information;
- 3 ensuring that the analysts use appropriate models, methods, and data;
- 4 checking that the analysis is reproducible by personnel other than the original analyst(s);
- 5 checking that the analysis is not sensitive to the way data or results are formatted; and
- 6 checking to ensure that all assumptions and uncertainties associated with the estimation process have been acknowledged and documented.

Analysts should ensure that all analyses and methods employed by technical experts are fully documented and explained. A distinction should be made between estimations based on related historical data and those based on derived models.

#### 2.2.1.8 Results

The output from Step 2a comprises:

- 1 the expected range of frequency with an indication of uncertainties; and
- 2 the potential consequence of the risk.

#### 2.2.2 Step 2b - Risk Evaluation

##### 2.2.2.1 Scope of the Risk Evaluation Sub-Activity

The purpose of Risk Evaluation is to identify the distribution of risk, thus allowing attention to be focused upon high-risk areas, and to identify and evaluate the factors, which influence the level of risk.

The risks, as estimated in section 2.2.1, are evaluated in terms of the needs, issues, and concerns of stakeholders, the benefits of the activity, and its costs. The result of this exercise is a determination of the acceptability of these risks.

One of three conclusions will result from the risk evaluation exercise:

- 1 the risk associated with the activity is acceptable at its current level;
- 2 the risk associated with the activity is unacceptable at any level; or
- 3 the activity might be acceptable but risk control measures should be evaluated.

If the risk is considered acceptable, then the activity can move forward as proposed and no further action is required. The decision process ends here, although there will still be a need to monitor the activity for possible changes in the risk.

If no level of risk is considered acceptable, and if the activity is not a mandatory or inevitable one, the activity as proposed may need to be abandoned. Again, the decision process ends here.

If the decision is that the activity might be acceptable if the risk can be reduced, then proceed to Step 3 in the decision process and specify risk control options.

There may be a need to return to a previous step(s) if the current information is deemed inadequate for making decisions about the acceptability of the risk.

##### 2.2.2.2 Acceptability of the Risk to Stakeholders

Once all the risks are assessed they are then evaluated in terms of the documented needs, issues, and concerns of the stakeholders, and the benefits of the activity, to determine the acceptability of the risk.

Zero risk is something that is not often realized, unless the activity generating the risk is abandoned. Rather than striving to reduce risk to zero, Authorities should strive to reduce risk to "As Low As Reasonably Practicable". This concept is known as ALARP (see Figure 3).

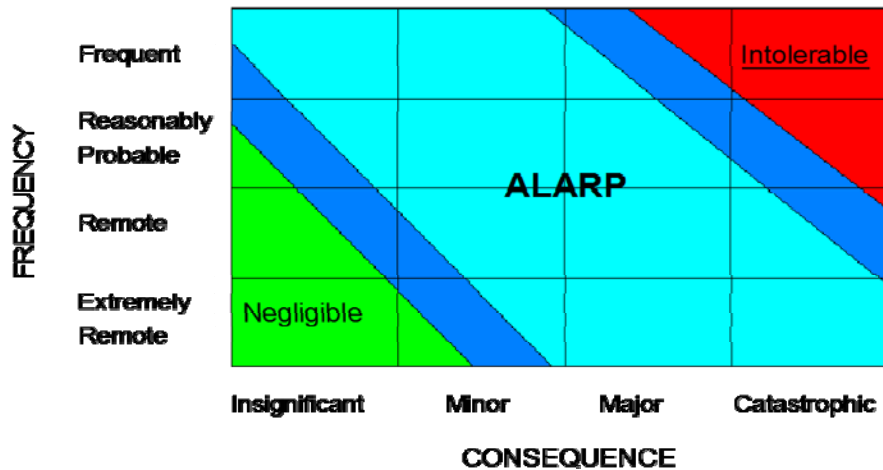


Figure 3 ALARP Matrix

Note. The Risk level boundaries (Negligible / ALARP / Intolerable) are purely illustrative.

### 2.2.2.3 Risk Perceptions

There are a number of factors, other than expected value of the loss, that effect stakeholder acceptance of risk. This introduces the area of risk perception, that is, what factors affect a person's perception of risk, and how do perceptions affect decision-making around the acceptability of risk?

While experts emphasize technical factors, such as the probability of an event or its consequences on human health or safety, the public emphasizes factors such as:

- 1 The degree of personal control that can be exercised over the activity - people are less accepting of risks over which they have little or no control (public transportation vs. driving their own car);
- 2 The potential of an event to result in catastrophic consequences – one versus multiple deaths;
- 3 Whether the consequences are "dreaded" - people are less accepting of risks where the consequences are dreaded; they would prefer to die quickly from a stroke than from a long, painful (dreaded) battle with cancer, although the ultimate consequence is the same;
- 4 The distribution of the risks and benefits - people accept higher risk if they also receive benefits from the activity (e.g. recreational boating, swimming); they are less accepting of uncompensated loss;
- 5 The degree to which exposure to the risk is voluntary - voluntarily moving next to a chemical plant vs. having the plant move next to you; and
- 6 The degree of familiarity with the activity - people are less accepting of risks associated with activities with which they are not familiar (e.g. irradiation of food).

One additional factor is that people tend to accept higher levels of risk if the manager of that risk is trusted. Again, this speaks to the need for effective and open communications with stakeholders to develop and maintain this trust.

An event or issue that is characterized by an extremely low probability may be disregarded by experts because of the low value resulting from an expected-value calculation. However, it may become a major source of concern for the public because of the perceived severity of the consequences and/or because of inequity in the distribution of the associated gains and losses.

Whether a risk is considered acceptable or not is based on stakeholders' needs, issues, and concerns. These needs, issues, and concerns derive from an individual's or organization's basic objectives and values, as well as the social environment within which the individual or organization exists. If people are concerned about the trustworthiness of an organization they may be less accepting of risks associated with these entities.

#### *2.2.2.4 Influences on Perception of Risk*

It is important for the risk management team to remember that, when communicating with stakeholders about risk issues, perception is reality. The public will make judgments of the acceptability of a risk based on its perceptions of the consequences of the risk, rather than on scientific factors like probability.

The public's perception of risk may be influenced by many things, including age, gender, level of education, region, values, and previous exposure to information on the hazard or activity of interest. Public perceptions of risk may differ from those of technical experts. Discrepancies may result from differences in assumptions, conceptions, and the needs, issues, and concerns of stakeholders as they relate to the hazard or activity under discussion.

#### *2.2.2.5 Other Risk Identification Tools*

Risk may also be established by using the identified hazards and a variety of more comprehensive tools, including:

- failure mode and effects analysis;
- analysis of historical incident data, utilizing existing experience and reports if possible;
- fault-tree analysis;
- event-tree analysis;
- hazard and operational studies;
- professional judgment (of internal and external experts);
- personal observation (e.g. site visits); and
- qualitative simulation.

Because most issues are quite complex, it is unlikely that all risks will be identified. There will usually be some risks that will only be identified following an incident.

#### *2.2.2.6 Results*

The output from Step 2b comprises:

- 1 An identification of the high risk areas needing to be addressed,
- 2 An identification of the primary influences within the overall system that effect the level of risk, and,
- 3 A determination of whether the risk is acceptable and whether there is a need to reduce the estimated level of expected loss associated with the identified risk.

### **2.3 Step 3 – Specify Risk Control Options**

#### **2.3.1 Scope**

The purpose of Step 3 is to propose effective and practical risk control options, comprising the following three principal stages:

- 1 Focusing on areas of risk needing control;
- 2 Identifying potential risk control measures and their associated costs; and
- 3 Grouping risk control measures into practical regulatory options.

If the decision at the risk assessment step is that the risk is unacceptable and should be reduced, then at the risk control step, options are considered to reduce the risk. The effectiveness of risk control options is evaluated by estimating the risk before and after control options have been applied. The costs, benefits, and risks associated with the proposed control measures, as well as the residual risk, are considered in the evaluation. The residual risk, and any other actions taken to manage the residual risk, should also be evaluated.

The risk control step can proceed in a batch mode or a sequential mode. In batch mode, all of the control options being considered are evaluated in a comparative manner. In sequential mode, control options are evaluated one at a time. The process stops when an option results in an acceptable evaluation of the residual risk and the conclusion that other options are not likely to be significantly better.

### 2.3.2 Areas Needing Control

The risk control options must be focused on the areas most needing risk control. The main aspects to making this assessment are to review:

- 1 Risk levels, by considering frequency of occurrence together with the severity of outcomes. Incidents with an unacceptable risk level become the primary focus;
- 2 Probability, by identifying the areas of risk that have the highest probability of occurrence. These should be assessed irrespective of the severity of the outcome;
- 3 Severity, by identifying the areas of risk that contribute to high severity outcomes. These should be assessed irrespective of their probability; and
- 4 Confidence, by identifying areas where risk has considerable uncertainty either in risk, severity or probability.

### 2.3.3 Identifying Risk Control Options

Risk control options are designed to reduce either the frequency of the loss or the consequences of the loss should it occur, or both. It should be remembered that new strategies should be acceptable to stakeholders and that application of control options may introduce new risks, new stakeholders, or new issues.

There are six broad strategies for controlling risk:

- 1 Avoid the exposure altogether, thereby reducing the probability (frequency) of a loss to zero;
- 2 Reduce the frequency of the loss (e.g. through training, ongoing monitoring and maintenance programs, use of higher quality materials);
- 3 Reduce the consequence of the loss should it occur (e.g. emergency response plans and capability, evacuation plans, digging and ditching around hazardous materials containers, wearing protective safety equipment);
- 4 Separate the exposures (e.g. traffic separation schemes, land-use controls around hazardous facilities);
- 5 Duplicate assets, including redundancy in safety systems (e.g. backing up computer records, keeping important materials in several locations, maintaining several suppliers of critical materials, arranging with other organizations to provide backup capability); or
- 6 Transfer the obligation to control losses to some other party through a contractual arrangement. This is a transfer of the risk and not a risk reduction strategy. The benefits accrue to the organization transferring the risk and not necessarily to other stakeholders.

There is usually more than one control option available to manage a particular risk, and most often control strategies will consist of implementing several risk control options. To be effective, the full range of feasible control options should be considered and evaluated.

#### 2.3.4 Evaluating Risk Control Options

Alternative strategies for controlling risk are evaluated in terms of their effectiveness in reducing losses, the cost to implement the option(s), and the impact of control measures on other stakeholder objectives, including the introduction of new risks or issues.

Until the control options have actually been applied, and results observed, estimates of their effectiveness are conjecture. The same methods used to estimate frequency and consequence in the risk estimation step can be applied to estimate the potential change in these parameters expected to result from the application of risk control measures: e.g. historical data, fault- and event-tree analysis, professional judgment. As with other estimates, all associated assumptions and uncertainties should be acknowledged and documented.

Not only should control measures be effective in reducing risk, they should also be cost-effective. The cost of the control measure should not normally exceed the reduction in the expected value of the loss.

Implementing a control option may also generate new risks. The new risk scenario generated by the control option should be assessed like other scenarios, beginning with the risk assessment step.

In general, preferred risk control options are those that cost the least, effect the greatest reduction in losses, and create the least adverse side effects.

#### 2.3.5 Costing Risk Control Options

The control options identified above must now be costed – whether they are intended to reduce risk and therefore most likely to cost the program more or whether they are intended to save money and likely to maintain/increase risk.

The cost of an option should be evaluated over a timeframe equivalent to the economic or useful life of the facilities and assets associated with the option. Because most options involve assets with differing economic lives, it is usually recommended that the analytical time frame be set to the useful life of the most durable assets. However, some assets, such as civil works, can perform satisfactorily for 40 years, a timeframe that is unnecessarily long. Because most electronic and other equipment has a useful life in the 10 to 15 year range, 15 to 20 years appears to be a reasonable timeframe for analysis, with adjustments made for any residual asset values at the end of the period.

Option costs must cover capital, labour and other resources needed for planning and implementation, as well as costs related to the maintenance and operation of the option throughout the life-cycle period under review. In other words, those costs that would be avoided if the option were not to proceed should be included, no matter who incurs them.

Past expenditures, which are not affected by an option, are not relevant and can be regarded as "sunk" costs, provided they have no opportunity cost (alternative use). Land or a building in a remote location that is already owned but with no alternative use could be considered a "sunk" cost. However, the same land or building in a metropolitan area, which has an alternative use, would have to be costed at the value of this alternative use.

Costs can be divided into three broad categories:

##### 1 Planning Phase

This category includes all costs incurred prior to procurement, construction, or implementation. Typical costs would include those related to planning, engineering and design, including costs related to a project team and any simulation studies.

## 2 Construction/Development

A large number of costs items will be involved at this stage. They could include some of the following (as well as others):

- a land acquisition and/or the opportunity cost of land already held;
- b construction costs (related to both new and existing facilities);
- c aids to navigation and other equipment purchases, including spares;
- d other capital expenditures;
- e training related to implementation;
- f moving expenses; and
- g other start-up costs.

## 3 Operational Phase

Once the option is in place, an estimate must be made of its life-cycle costs. These could include:

- a salaries (including regular wages, overtime, bonuses, allowances and fringe benefits);
- b maintenance of equipment, electronics and civil works;
- c periodic capital outlays (such as mid-life refits);
- d operating expenses (e.g. removal and placement of aids to navigation);
- e on-going training;
- f lease costs (e.g. landlines); and
- g other operation and maintenance costs.

Costs should be recorded in a spreadsheet format, with a column representing each year in the life-cycle period, and rows representing cost items. Discounting, using appropriate rates, should be applied in order to treat all costs, whether incurred early or late in the planning period, in an equitable manner.

### 2.3.6 Assessing Stakeholder Acceptance

Before risk control decisions are made, they should be communicated through the stakeholder consultation process. A proposed option may appear acceptable to the decision-maker, in terms of its effectiveness and costs, but may be unacceptable to other stakeholders because of other factors. There is a need to evaluate any proposed control or financing strategy in terms of the needs, issues, and concerns of affected stakeholders.

### 2.3.7 Residual Risk

Any risk left after the implementation of risk control options is termed residual risk. The residual risk must be evaluated by returning to the risk assessment step, to determine if it is acceptable. If the residual risk is not acceptable, then the activity may need to be abandoned or alternative risk control strategies implemented to reduce the risk to an acceptable level.

One means of increasing acceptability is to increase the benefits associated with the activity. The risks are evaluated in terms of the overall needs, issues, and concerns of stakeholders. Therefore, if concerns about risk can be balanced against gains in other areas of stakeholder interest (e.g. greater income, cleaner water, fewer incidents), then the activity may be seen as acceptable.

Determining the level of acceptable risk is best achieved through effective dialogue with stakeholders. In deciding whether or not a risk is acceptable, it may be useful to determine whether the risk:

- 1 Is so great or the outcome so unacceptable that it must be refused altogether;
- 2 Is, or has been made, so small as to be negligible; or
- 3 Falls between (1) and (2), and it has been reduced to the lowest achievable or practicable level.

#### 2.3.8 Results

The output from Step 3 comprises:

- 1 A range of risk control options, along with their costs, which are assessed for their effectiveness in reducing risk;
- 2 A list of factors and stakeholders affected by the identified risk control options; and
- 3 The residual risks deemed acceptable to the stakeholders.

## 2.4 Step 4 – Make a Decision

### 2.4.1 Scope

The purpose of Step 4 is to define, in consultation with stakeholders, the recommendations that should be considered. The recommendations should be based upon the comparison and ranking of risks and their underlying causes; the comparison and ranking of the risk control options as a function of associated costs and benefits; and the identification of those risk control options which keep risks As Low As Reasonably Practicable (ALARP).

### 2.4.2 Estimate Option Benefits

The risk-reduction benefits that would be derived from implementing each of the options identified and costed in step 3 above must now be estimated. This is probably the most difficult and problematic activity of the entire risk management process.

If the current levels of risk in the area of interest were estimated in terms of annual expected monetary losses, then it must be determined what proportion of this existing risk is eliminated by each option (in order to calculate a monetary benefit for each option). Conversely, if it is proposed to eliminate aids to navigation or reduce availability or otherwise reduce service levels, then it must be determined by what proportion existing risk is increased (in order to estimate the monetary value of the increased risk). Once determined, comparisons of the monetary value of the program risk change to the cost or savings resulting from the option can be made (as discussed in section 2.4.3).

In most cases, however, it will only be possible to say whether or not the option produces no change in risk levels, increases/decreases it somewhat, significantly and so on. In this case, where it is possible only to project a non-monetary value to changes in the aids to navigation addressable risk, it becomes more difficult to evaluate the net societal benefit/cost of the option(s). If an option is projected to save the aids to navigation program \$1,000,000 per year, and it has been determined that no change in risk will follow, the net benefit to the option is \$1,000,000. But, if it has been estimated that risk will increase marginally or somewhat, what is the value of this increase? Threshold analysis can be used here to help answer this question.

*A threshold analysis is designed to establish the amount of benefit required to make any particular option cost-beneficial. In using this technique, a judgment is required on the likelihood that the benefit would exceed these thresholds. These thresholds are also known as “switching values”, because they are the values at which the decision could switch from one option to another.*

For example, let us assume that the studies have identified three options that will cost, respectively, \$1,000,000, \$800,000 and \$500,000 annually. In threshold analysis, expert opinion must be used to determine firstly, if each option is likely to reduce annual risk by at least annual costs, and secondly, which of the options will produce the greatest return.

### 2.4.3 Compare Costs to Benefits and Make a Decision

When monetary estimates of benefits and costs are available, discounting can be used to rank options in terms of benefit/cost ratios, net present values, and so on. Where monetary estimates of the benefits are not directly available, threshold values can be used to at least rank the options. Even so, balancing estimated risk-reduction benefits against option costs is never straightforward. Society usually demands more risk-reduction effort where human life and health are at risk than where only property is involved; and the public usually demands a high level of effort be expended to prevent environmental damages. Public perception of the risks involved often plays as much or more of a role as does the actual estimate of the expected losses.

Balancing risk-reduction benefits against risk-reduction costs is an important issue today. In a risk-averse organizational setting, people minimize expected losses, to the extent possible, irrespective of the probability or impact of the risk. In a risk-taking environment, people compare expected risk-reduction benefits to the cost of the initiative which would produce these benefits. They take actions that would optimize the overall benefit to society (e.g. keeping in mind the type of losses involved, whether associated with life, health, property, the environment, revenue). A risk-smart organization does not simply take more risks; it takes calculated risks that optimize the benefits derived from its risk-reduction activities.

It is important here to consider more than the obvious, hard, financial benefits and costs of the activity. There may also be a number of associated indirect benefits and costs that may not be readily recognized - for example, ecosystem health, sustainable development, employment benefits or other spin-off benefits. These so-called soft benefits and soft costs should also be considered, in the Risk Assessment process.

It is important that both direct and indirect effects of an activity be considered and factored into any analysis of acceptability. The use of a multidisciplinary risk management team, coupled with an extensive consultation program, may aid this effort.

In summary, the following considerations are usually involved when comparing benefits and costs:

- 1 consider the risks assessed, both in terms of frequency and consequence, in order to define the base case in terms of risk levels of the situation under consideration;
- 2 arrange the risk control options in a way to facilitate understanding of the costs and benefits resulting from the approval of an option;
- 3 estimate the pertinent costs and benefits for all risk control options;
- 4 estimate and compare the cost effectiveness of each option, in terms of the cost per unit risk reduction by dividing the net cost by the risk reduction achieved as a result of implementing the option; and
- 5 rank the risk control options from a cost-benefit perspective in order to facilitate the decision making recommendations.

### 2.4.4 Results

Output from Step 4 can provide an objective comparison of alternative options, based on potential reduction of risks and cost effectiveness. Recommendations should be easily usable by decision-makers at all levels, in a variety of contexts, without a requirement for specialist expertise. This step should also provide feedback information for reviewing the results generated in the previous steps.

To facilitate the common understanding and use of the Guideline, a report should be produced that:

- 1 Provides a clear statement of all recommendations;
- 2 Lists the principle hazards, risks, unwanted events, costs and benefits identified;
- 3 Explains the basis for significant assumptions, limitations, data models and inferences used or relied upon in the assessment or recommendations;
- 4 Describes the sources, extent and magnitude of significant uncertainties associated with the assessment or recommendations; and
- 5 Describes the composition and expertise of the group that performed the risk management process.

Timely and open access to relevant and supporting documents should be provided. A reasonable opportunity to incorporate comments should also be provided.

## **2.5 Step 5 – Take Action**

### 2.5.1 Scope

The purpose of Step 5 is to implement the chosen risk control option or options; evaluate the effectiveness of the decision process; and to establish a monitoring and evaluation program to monitor the outcome of implementation (an explicit decision to take no action constitutes action as defined here). If a decision were taken to implement a new risk-reduction process or control, then the usual planning and implementation activities necessary for the introduction of a new activity would have to be undertaken. Monitoring, reporting, communication and review must be planned and introduced. It is equally important to periodically review all existing risk-reduction activities to ensure that they are still relevant and beneficial. Furthermore, an Authority must always be aware of residual risk, and if appropriate, loop back in the process to determine if it should be further reduced.

### 2.5.2 Implementation Plan

Prior to implementing any of the chosen risk control options, it is important to develop an implementation plan. In the organization's implementation plan, the decision-maker should consider the technical decisions that need to be made in order to execute chosen strategies (e.g. the timing of implementation, resource availability and technical decisions to set up monitoring programs). Managerial decisions that are made in co-operation with other managers and staff also need be considered (e.g. training requirements, staffing requirements, job shifting or new positions, financing requirements).

### 2.5.3 Implementation

During implementation, selected risk control options are implemented, and the stakeholder outreach, dialogue, media contact, and key messages are delivered using contacts developed throughout the risk management process. A broader public communication effort (e.g. through the media and community meetings) may be necessary in order to facilitate delivery of messages related to the decisions being made and implemented.

## **2.6 Monitoring and review**

### 2.6.1 Primary Functions

Monitoring is a key function of the risk management process and has four primary functions, these are to:

- 1 Detect and adapt to changing circumstances;
- 2 Ensure that the risk control options are achieving the results expected of them;
- 3 Ensure proper implementation of control and communication strategies; and

4 Verify the correctness of assumptions used in the various analyses.

#### 2.6.2 Changing Conditions

When monitoring for changes in the system, six broad issue categories should be considered:

- 1 The environment in which the activity takes place, including the regulatory environment;
- 2 The potential losses, e.g. to health, property, income, the environment;
- 3 The hazards causing the losses (natural, economic, technical, human);
- 4 The acceptability of the losses (a function of needs, issues, and concerns);
- 5 Stakeholders; and
- 6 New technology.

A change to one or more of these parameters changes the risk. Hazards often change with the seasons and there may be a need for ongoing seasonal adjustments.

Over a time, the value (market or replacement) of assets may change, either rising (due to inflation) or falling (due to depreciation or obsolescence). These changes in the value of assets will affect the consequence of a loss should it occur, and there may be a need then to change control and financing strategies.

New technologies may be made available that affect the choice of risk control, or communication strategies.

Any changes to these factors may necessitate a return to the Risk/Hazard Identification step if new issues result. Stakeholders may also change, and will need to be kept informed about the ongoing risk management program.

#### 2.6.3 Monitoring Performance

To ensure that the risk management program, including specific control measures, is effective in achieving the results expected of it, the decision-maker should:

- 1 Establish standards of what constitutes acceptable performance;
- 2 Compare the actual performance of the program against these established standards; and
- 3 Make corrections for substandard performance.

Performance standards may be goals the organization wishes to achieve, such as a 50% reduction in incidents within two years. The realized incident rate is compared to the goal to determine whether the program was successful. If actual performance does not meet the established goal, it may mean that the goal was too high (or too low), or that some new control strategy may need to be considered.

If performance is less than expected, before developing new strategies, it is best to ensure that the chosen strategy has been implemented properly. Improper implementation is often the cause of substandard performance.

#### 2.6.4 Correctness of Assumptions

Assumptions are guesses about what may happen in the future and, as such, are subject to varying levels of uncertainty. It is important that all assumptions used throughout the analysis be verified where possible. If the assumptions prove correct, this lends strength to the decisions arising from the process. If assumptions prove not to be valid, then the analysis may need to be redone.

Assumptions should be routinely reviewed to avoid costly mistakes. The monitoring function should be an ongoing responsibility for the risk management team, providing for continuous improvement within the risk management program.

The financial and non-financial benefits of monitoring include:

- 1 The identification of new or changing risks;
- 2 The accumulation of evidence to support assumptions and results of analyses;
- 3 The development of a more accurate portrait of the risks; and
- 4 Reduction in costs associated with improper or redundant implementation of risk control measures.

#### 2.6.5 Timing

All risk management strategies should be reviewed periodically. Sometimes a "sunset" date is established, where a particular control option, such as a regulation, will cease to exist unless extended. Extension requires an analysis to justify the continuation of the control option. If no justification can be established, the control option is terminated. "Sunsetting" aids in ensuring that ineffective or unnecessary actions are not continued indefinitely.

#### 2.6.6 Risk Management Decision Process Evaluation

After having undergone the extensive decision process, it is prudent to evaluate the effectiveness of the risk management process in satisfying the objectives of the decision-maker. This facilitates continuous improvement in the decision-process itself, creating efficiencies for future efforts.

This review also provides for greater defensibility of decisions made throughout the process.

### **2.7 Incorporation of the Human Factors**

The Human Factors are one of the most important contributory aspects to the causation and avoidance of incidents. Human Factors issues should be systematically treated within the Risk Management framework, associating them directly with the occurrence of incidents, underlying causes or influences. Appropriate techniques for incorporating human factors should be used.

Some of the most common techniques used are listed below:

- Questionnaires;
- Observations;
- Interviews;
- Simulation studies;
- Hierarchical Task Analysis;
- Cognitive Walk-Through (CWT);
- Cognitive Task Analysis (CTA);
- Expert Judgment / Expert Evaluation;
- Human Reliability Assessment (HRA).

Without the application of Human Factors based techniques and taking Human Factors aspects into consideration in any of the five steps in the risk management there is a great risk that vital elements will be inadequately carried out. When missing the Human Factors elements it is also likely that the result of a risk assessment, related to any incident, accident, near miss or observations of undesired conditions, will fail as e.g. the root causes may be completely missed.

To understand the concept of Human Factors in a socio-technical system and what it includes you could refer to the following Septigon Model. The model describes seven basic

areas to be considered as well as the interaction between any of the elements. The model can be used as a checklist in identifying hazards.

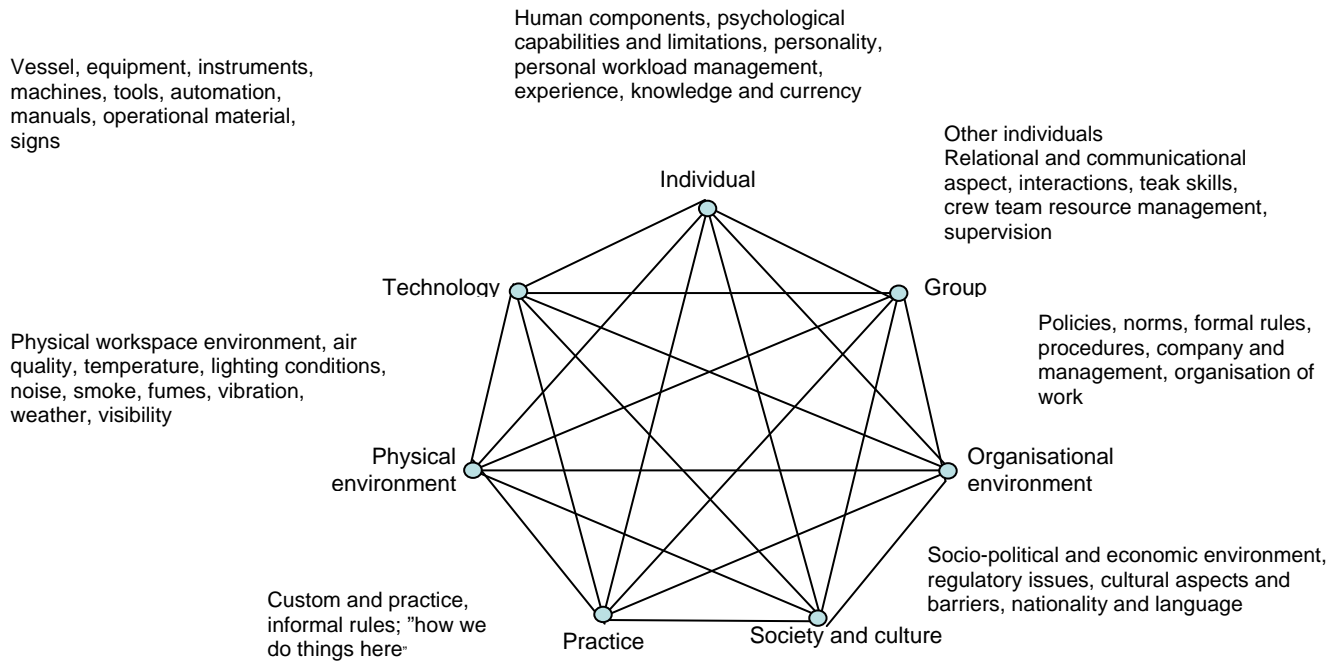


Figure 4 The Septigon Model

Ref.: Koester, T. (2007). *Terminology Work in Maritime Human Factors. Situations and Socio-Technical Systems*. Copenhagen: Frydenlund Publishers.

\* Septigon refers to Society and Culture, Physical Environment, Practice, Technology, Individual, Group and Organisational Environment Network. Septigon is also the name of a shape with 7 sides – the outline of the model.

For further information on Human Factors please refer to the book *Human Factors in the Maritime Domain*, ISBN 9781420043419, CBS Press, 2008 by Michelle Grech, Tim Horberry and Thomas Koester. The application of the Septigon Model and other relevant Human Factors aspects are described in this book.

## ANNEX I RISK TERMINOLOGY

**Aid to navigation** – any device or system, external to a vessel, which is provided to help a mariner determine position and course, to warn of dangers or of obstructions, or to give advice about the location of a best or preferred route.

**Cost benefit analysis** – an approach, used to assess the gains and losses resulting from a set of alternative actions, that helps one decide whether any of the actions should be undertaken.

**Decision-maker** – a person or group with the power or authority to make decisions.

**Dialogue** – a process for two-way communication that fosters shared understanding. It is supported by information.

**Hazard** – an unwanted event or occurrence, a source of potential harm, or a situation with a potential for causing harm, in terms of human injury; damage to health, property, the environment, and other things of value; or some combination of these.

**Hazard identification** – the process of recognizing that a hazard exists and defining its characteristics.

**Loss** – an injury or damage to health, property, the environment, or something else of value.

**Organization** – a company, corporation, firm, enterprise, authority, agency or institution, or part thereof, whether incorporated or not, public or private, that has its own functions and administration.

**Residual risk** – the risk remaining after all risk control strategies have been applied.

**Risk** – the chance of injury or loss as defined as a measure of the probability and severity of an adverse effect to health, property or the environment or other values.

**Risk acceptance** – a decision to accept a risk.

**Risk assessment** – as used here, it is meant to include the overall process of risk estimation and risk evaluation.

**Risk consultation** – any two-way communication between stakeholders about the existence, nature, form, severity, or acceptability of risks.

**Risk control option** – an action intended to reduce the frequency and/or severity of injury or loss, including a decision not to pursue the action.

**Risk control strategy** – a program that may include the application of several risk control options.

**Risk estimation** – the activity of estimating the frequency or probability and consequence of risk scenarios, including a consideration of the uncertainty of the estimates.

**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 analyzing, evaluating, controlling, and communicating about risk issues.

**Risk perception** – the significance assigned to risks by stakeholders. This perception is derived from the stakeholders' expressed needs, issues, and concerns.

**Risk reduction** – actions taken to lessen the frequency, negative consequences, or both, of a particular risk.

**Risk retention** – acceptance of the expected loss associated with the consequences of a particular risk.

**Risk scenario** – a defined sequence of events with associated frequencies and consequences.

**Stakeholder** – any individual, group, or organization able to affect, be affected by, or believe it might be affected by, a decision or activity. The decision-maker(s) is a stakeholder / are stakeholders.

## **ANNEX II DETAILED LIST OF DATA AND INFORMATION THAT SHOULD BE CONSIDERED IN EVALUATING RISK SPECIFIC TO MARINE AIDS TO NAVIGATION**

### **1 MARITIME TRAFFIC**

#### **1.1 Traffic statistics to be obtained**

- 1 Traffic safety record in general or changes in maritime safety (including AtoN) throughout the years.
- 2 The number of vessel traffic movements in the area (or part of the area) concerned, including trends in the number of vessel movements, based on e.g. AIS-data covering the past 3-5 years at least.
- 3 The break-down of vessel traffic in types and sizes of vessels and categories of cargoes carried, including navy and/or other Government owned vessels, fishing vessels, recreational craft, local ferries, sea going or inland high speed craft, inland craft/barges, tugboats, pilot tenders and other service craft.
- 4 Complexity of the traffic pattern.
- 5 Vessels with hazardous cargoes as defined in IMO Res. A.857(20), Annex- 1, paragraph 1.1 under.11.
- 6 Is there any (statistical) information available on the above five bullet points?
- 7 Are there any recent traffic surveys and an evaluation of these surveys available?
- 8 Does any ship-to-ship cargo transfers take place in or in the proximity of the fairway either at anchor or moored to buoys and do these activities interfere with the safe and efficient flow of traffic? If so, is it possible to quantify this interference?
- 9 If appropriate, is there any interference by vessel traffic with other marine based activities?

#### **1.2 Accident data to be obtained**

- 1 Is there an up-to-date and complete record, covering a period of at least 5 years, available on accidents or incidents with vessels in the area, including information on the economic consequences?
- 2 Were thorough accident and incident investigations performed and by whom?
- 3 What are the main recorded causes of the accidents and incidents?
- 4 Are there any "black spots" in relation to these accidents and incidents?
- 5 Where recommendations were contained in reports on accidents and incidents, were these recommendations implemented in full or only in part or not at all?
- 6 Is any information available on the mariners or navigators opinions regarding traffic safety in the area concerned?
- 7 Is any other relevant data on accidents or incidents available?
- 8 In some areas the number of small local craft, usually without any capability to communicate by radio to a VTS or to other vessels, is very high compared to the other traffic. In addition, this local traffic may show "remarkable" behaviour and may not be aware of navigational limitations of larger power-driven vessels. If this is the case, it might be necessary to develop, implement, promulgate and maintain (or enforce)

special local rules to ensure the unobstructed and safe passage of the (larger) commercial vessels.

- 9 The human element is one of the most important contributory aspects to the causation and avoidance of accidents or incidents. Human element issues throughout the "integrated system of safe and efficient traffic management", within a sound environmental content, should be systematically treated within the risk assessment methodology to be used, associating them directly with the occurrence of accidents, underlying causes or influences. Appropriate techniques for incorporating human factors should be used.

### **1.3 Data on traffic delays to be obtained**

- 1 Efficiency of maritime traffic in general.
- 2 Are there any traffic delays?
- 3 What are the main causes?
- 4 Are there any specific locations in the area concerned where congestion occurs regularly?
- 5 Is there a relation or relations between this congestion and the number of vessel movements and/or with specific conditions in the navigable waters in the area and with any black spots as mentioned above?
- 6 What is the view of shipping companies and mariners regarding the efficiency of traffic?
- 7 Are there any complaints and, if so, how are these handled and addressed?
- 8 Is it possible to quantify the additional costs to the maritime industry, to port operations, onward transport of goods and late delivery of cargoes as a result of congestion and delays?
- 9 Is any other relevant data on efficiency of traffic available?

## **2 THE MARITIME AREA CONCERNED.**

The geography of the area:

- 1 Provide an outline of the maritime area concerned;
- 2 Describe the area in terms of its geography, e.g. narrow and winding fairways, port basins, piers, quays along the fairway;
- 3 Shallows shifting shoals;
- 4 Specific navigational hazards;
- 5 Geology of the sea/estuary/bottom and shoreline;
- 6 Stability of the bottom profile;
- 7 Dredging operations in the fairway;
- 8 Locks, including their operations;
- 9 Bridges with restricted air-draught;
- 10 Climatic conditions (e.g. prevailing winds, fog, ice conditions);
- 11 Tidal conditions, negative surges, currents;
- 12 Hydrological/meteorological conditions;
- 13 State of hydrographic surveys;

### **3 ANALYZE THE DATA ON THE GEOGRAPHY OF THE AREA CONCERNED THOROUGHLY**

Data on present traffic management resources:

- 1 National or IMO adopted ships' routing measures, including if appropriate associated rules and recommendation.
- 2 Conventional aids to navigation,
- 3 Differential GNSS and if appropriate, LORAN-C/Chayka.
- 4 Number, size and location of anchorages, including not only a description of the use of these anchorage(s) by vessels but also reasons for vessels anchoring and the average duration of vessels being at anchor. Is any information available on the quality of the holding-ground in the anchorages? Are there any specific local rules" applicable for vessels using the anchorages?
- 5 Pilotage, including disembarking locations; and how are the pilots transferred?
- 6 Ship reporting requirements, availability of adequate tug assistance.
- 7 Local navigation rules and recommendations in the area.
- 8 Any other relevant instruments and information.

### **4 PROTECTION OF THE MARINE ENVIRONMENT**

The following items should be addressed:

- 1 Is the area concerned, or part of it, a formally declared "Particular Sensitive Sea Area" (PSSA) based on either IMO Res. A.720(17)[, as amended] 14, or regional/national legislation?
- 2 Is there such a PSSA area regardless of the formal status of that area in the proximity where, due to the prevailing wind and current conditions, any marine pollutants, as a result of shipping accidents or incidents, may end up.
- 3 Is the wider area an important fishing ground in particular for local fishermen? Are there any fish farms? Is it possible to quantify these interests to some extent?
- 4 Is there any other formal protection of the area based on international, national or local rules and regulations; e.g. "special area" under MARPOL Annex I?
- 5 Are there any records available concerning marine pollution because of shipping accidents or incidents and the resulting damage to the environment, in terms of clean-up costs, dead birds and other wildlife and e.g. damage to fish stocks?
- 6 Is there an established national or regional policy on the protection of the marine environment?
- 7 Is there any criterion set regarding pollution in that national and/or regional policy?
- 8 What is the attitude of the general public on the environment issue and the marine environment in particular?
- 9 Is pollution abatement or an emergency response organization available on short notice?
- 10 Is sufficient equipment and qualified manpower available on short notice to fight an accidental pollution of any substantial size?
- 11 Is the protection of the marine environment in the wider area as such, considered to be sufficient reason that it warrants the implementation of a VTS? If not, is it possible to

categorize the importance of the protection of the marine environment in the wider area?

- 12 Protection of the environment is very often a matter of national priority. This priority should be considered along with other relevant considerations.

## **5 PROTECTION OF THE SURROUNDING AREA**

Protection of bridges and other works, work-sites, protection of human life and infrastructure in urban and/or industrial areas in the proximity of busy fairways is very often a valid reason for attempting to counteract against/abate the possible negative effects of maritime traffic. Implementing VTS or improving existing traffic management resources could be an example to reduce risk associated with high traffic.

- Is any statistical information available on damage, in the widest sense, including loss of human lives, to the surrounding area as a result of maritime accidents or incidents in the area concerned? Is it possible to quantify the consequential costs?
- Is it possible to categorize the importance of the protection of the surrounding area?

## ANNEX III Example of an Aids to Navigation Risk Assessment

### 1 BAY OF FUNDY

The Management Board of the Canadian Coast Guard commissioned Consulting and Audit Canada (CAC) to create a display and risk index computer system containing about 150 columns of marine risk-related data covering 100+ waterways/ports. The data were subdivided into four categories: *frequency* (e.g. number of cargo vessel movements, number of ferry movements); *impact* (e.g. tonnes of petroleum transported, number of passenger trips); *modifiers* (e.g. visibility and wind speed); and *history* (e.g. vessel groundings and loss of life). A computer system could allow a user to automatically display data in bar chart, map or scattergram format and to weight and combine criteria data into a risk index.<sup>3</sup>

**Please note that some of the conditions in this example may have changed and the result indicated does not apply for current conditions.**

### 2 THE RISK MANAGEMENT PROCESS

This example assessment follows the five major steps specified in Section 2 of the *IALA Guideline on Risk Management*.

#### 2.1 Step 1 Identify Hazards

Canadian Coast Guard (CCG) records for Fundy LOS Area 3 covering Saint John harbour and the upper Bay of Fundy (see Figure 5) show that aids to navigation in this area were not functioning properly on 279 occasions over the last 5 years. As a result, the 82 involved aids to navigation, out of a total of 127, were “down” for 2,389 days (see Table 2). The review outlined in this Annex was triggered by the realization that the level of service reflected by this record over the last five years does not meet current objectives.

Table 2 Nav aids Level of Service History for Fundy LOS Area 3

Navaid Importance Rating	Total No of Nav aids in LOS Area	No. of Nav aids Down in Period	Total Down Occurences	Total Days Down	Avg. Days Down per Occurrence
1	20	17	106	887	8.4
2	71	56	160	1,231	7.7
3	36	9	13	272	20.9
Total	127	82	279	2,390	8.6

A large number of stakeholder groups use the aids to navigation in LOS Area 3 and would need to be consulted (e.g. operators of ferries, fishing vessels, commercial ships, tugs, port authorities, recreational boaters, environmentalists and so on).

<sup>3</sup> All dollar values mentioned in this example refer to Canadian currency unless otherwise noted.

## 2.2 Step 2 Assess Risks

(Aids to Risk & Criteria Analysis system). A total of 45 groundings were reported to have occurred in our area of interest over the last 25 years. There were no deaths, serious navigation are primarily directed toward the prevention of vessel groundings, although collisions can sometimes be prevented by an appropriate aid to navigation. In this review, however, only groundings as reported by the Transportation Safety Board (TSB) occurring in LOS Area 3 were extracted from the CCG's ORCA system (Oceans Risk & Criteria Analysis system). A total of 45 groundings were reported to have occurred in our area of interest over the last 25 years. There were no deaths, serious injuries, significant spills or serious vessel damages associated with these 45 groundings. Furthermore, after reviewing the circumstances associated with these occurrences, it does not appear that any were caused by a "down" aid to navigation (see Table 3).

*Table 3 Grounding Occurrences for the Years 1976 – 2000 for Fundy LOS Area 3\**

<b>Vessel Type</b>	<b>Total No of Groundings</b>	<b>Persons Missing or Dead</b>	<b>Groundings Caused by Down Nav aids</b>
Barge	1	0	0
Bulk Carrier	6	0	0
Container Ship	1	0	0
Ferry	3	0	0
Fishing Vessel	16	0	0
General Cargo	3	0	0
Research Vessel	1	0	0
Tanker	2	0	0
Tug / Other	12	0	0
<b>Total</b>	<b>45</b>	<b>0</b>	<b>0</b>

\* As reported by the TSB and recorded in ORCA

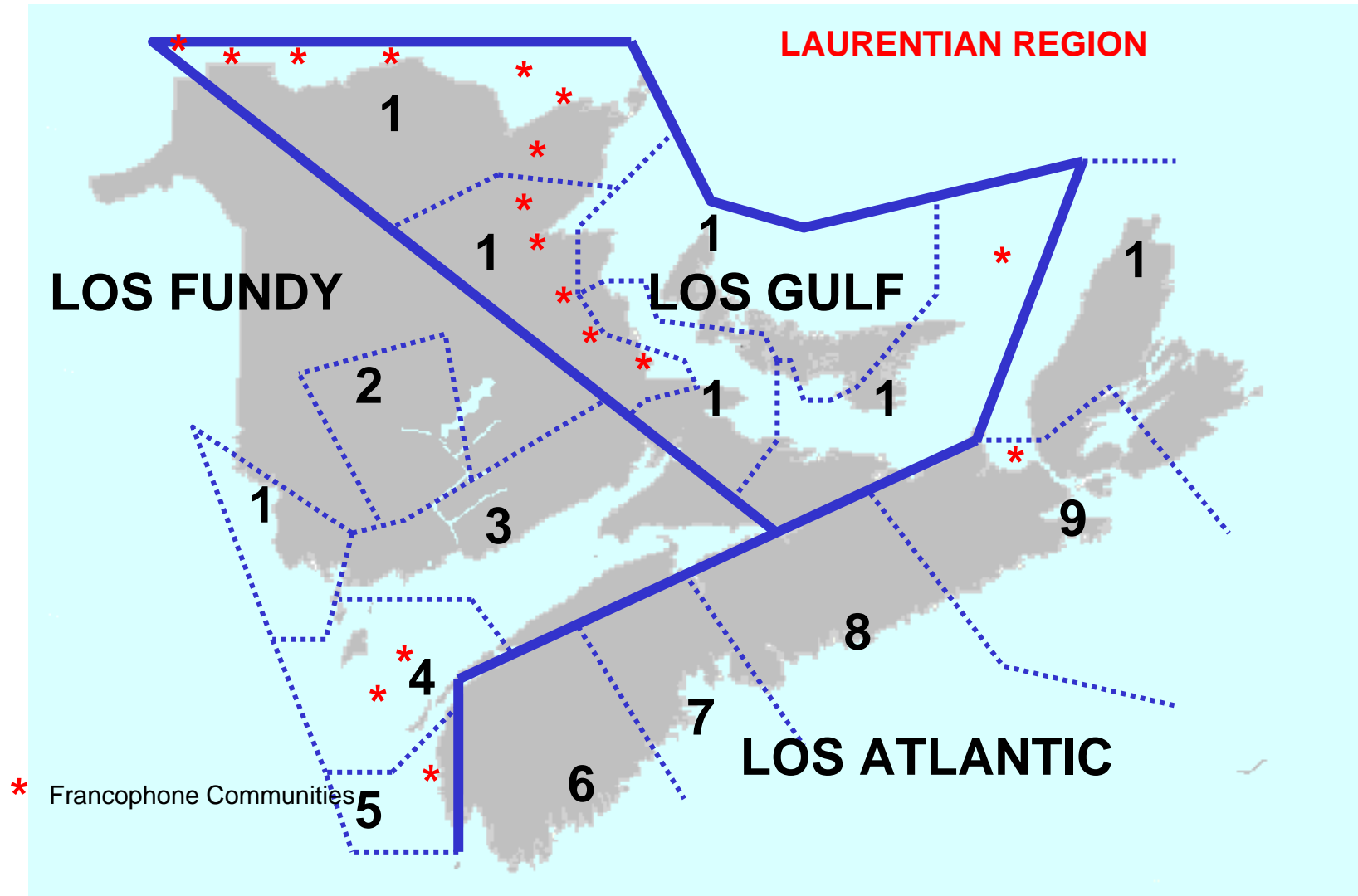


Figure 5 LOS AREAS - MARITIMES

While the 25-year accident history does not indicate any residual risk that should have been addressed by aids to navigation program, 25 years is still not a long period of time to observe some types of rare but potentially serious accidents – for example, a grounding involving a tanker with associated cargo loss. Thus, we reviewed the annual traffic statistics for LOS Area 3 (see Table 4).

*Table 4 Estimated Annual Traffic for Fundy LOS Area 3\**

<b>Vessel Type</b>	<b>Saint John Harbour</b>	<b>Upper Bay of Fundy</b>
Barge & Cargo Vessels	1800	200
Cruise Vessels	10	0
Ferries	1500	0
Recreational Vessels	low	low
Fishing Vessels	low	low

\*As derived from ORCA

There are about 1800 barge, cargo, tanker, tug, research and other commercial vessel arrivals and departures each year at the port of Saint John (supertankers are included in this estimate). There are an additional 1500 ferry arrivals and departures for this port. The rest of LOS Area 3 records only about 200 transits per year related to commercial traffic. Recreational activity is low in the LOS area and fishing activity is only moderate when compared to many other LOS areas in the country.

While no grounding during the last 25 years appears to have been caused by a “down” aid to navigation, the traffic statistics shown in Table 4 do not preclude the possibility of one occurring over the longer term. Thus, we will continue with this review and look at the benefits and costs associated with some option or options that would address historical service levels in Fundy LOS Area 3.

### **2.3 Estimating Addressable Risk**

Risk is defined as the probability of an unwanted event times its consequences. Groundings are the most likely unwanted events that could be prevented by an aids to navigation program. From our discussion above, it is most difficult to estimate the probable frequency of groundings by vessel type that would be caused by the current level of service if it continued into the future. It is easier to estimate the expected consequences of grounding, given that it did occur, although even this task is problematic. For example, Canadian Coast Guard studies undertaken in the past have estimated the mean impact of tanker grounding with loss of cargo at nearly \$30 million Canadian dollars.<sup>4</sup> The Exxon Valdez was assessed damages amounting to nearly US\$ 1 billion. However, most fishing vessel groundings with no loss of life often exhibit damages in the hundreds or thousands Canadian dollars, at most. Thus, we will not attempt to produce an estimate of the expected losses (i.e. risk) that could be caused by the current level of aid outages, but proceed with estimating the cost of an option to improve service levels, and then use “threshold” analysis to draw conclusions about the possible risk-benefit of the proposed option.

<sup>4</sup> For an example application, see *Confederation Bridge VTS Benefit-Cost Analysis*, Prepared by Consulting & Audit Canada for the Canadian Coast Guard, Project 570-1224, May, 1997.

## **2.4 Step 3 Specify Risk Control Options**

### **2.4.1 Risk Control Options**

There are a number of methods that one could use to improve the availability of aids to navigation in Fundy LOS Area 3. For example, one could increase response time in order to reduce the mean number of “down” days by half. Such a solution would likely require an additional “1100” series maintenance vessel, costing about \$70 million, with attendant increases in personnel costs and other operating and maintenance expenditures. Consequently, this option was not pursued further.

Improved aid to navigation availability could also be achieved by a reduction in the number of “down” occurrences. Most outages associated with floating aids to navigation are related to inadequate anchoring while most outages associated with fixed aids to navigation are related to equipment failures. Thus, it is proposed to improve anchoring and increase equipment reliability.

### **2.4.2 Control Option Costs**

Costs for improving anchoring and equipment reliability were first estimated for each aid to navigation type in the LOS Area (see Table 5). For example, three tonne anchors for large floating buoys would be replaced by five tonne anchors at a cost of \$9,000 per replacement. These unit improvement estimates were then applied to the number of aids to navigation in each type category to arrive at a one-time cost for this option (again see Table 5). Using this method, it is estimated that \$1 million dollars would be required to bring aid to navigation reliability to targeted service levels (i.e., future “down” occurrences would likely be reduced by one-half). It could be noted that operation and maintenance expenditures for LOS Area 3’s 127 aids to navigation are estimated at about \$1.4 million per year (the total O&M budget for the Maritimes Region’s 5,000+ aids to navigation is around \$19 million).

Table 5 Reliability Improvement Cost Estimates by Aid Type

Category	Capital Cost per Navaid (\$)	Number of Nav aids	Total Cost (\$)
01-Radiobeacon / DGPS Sites	0	1	0
03b-Major Shore Lights - Unstaffed	30,000	9	270,000
04a-Minor Shore Lights - Small	5,000	8	40,000
04b-Minor Shore Lights - Standard	5,000	9	45,000
04c-Minor Shore Lights - Large	5,000	10	50,000
07b-Radar Reflector*	750	2	1,500
08c-Ranges Lighted - Large	35,000	6	210,000
09c-Sector Light - Large	35,000	1	35,000
10b-Stakes and Bushes*	250	2	500
11-2.9m Long Leg Buoy (9 ½')	9,000	1	9,000
12-2.9m Short Leg Buoy (9 ½')	9,000	27	243,000
14a-Buoys Lighted - 500 to 1000 kg	3,000	1	3,000
14b-Buoys Unlighted - 500 to 1000 kg	1,500	11	16,500
16b-Buoys Unlighted - 175 to 500 kg	1,500	15	22,500
17b-Buoys Unlighted < 175 kg	1,000	23	23,000
N/A*	250	1	250
<b>Total</b>	<b>141,250</b>	<b>127</b>	<b>969,250</b>

\*Yearly costs over five years have been applied here

## 2.5 Step 4 Make a Decision

### 2.5.1 Option Benefits

As already stated, it is very difficult to estimate the risk-reduction benefit of spending \$1 million to reduce “down” time for 127 aids to navigation by approximately one-half. While no groundings appear to have been caused by a non-functioning aid to navigation over the last 25 years, a grounding could be caused by such an occurrence in the future. A grounded tanker would likely produce impacts exceeding \$1 million, especially if loss of cargo or bunker fuel were involved; and even the loss of one life would exceed the estimated improvement cost given the value normally placed on a statistical life in these types of analysis. However, the probability of such unwanted events caused by a non-functioning aid to navigation must be very small—no such impacts even resulted from the 45 non-aid related groundings that did occur over the last 25 years in the LOS Area.

Most marine stakeholders would likely conclude that the safety benefits of this option would not exceed its \$1 million cost; and perhaps there is a good reason for such a conclusion. When an aid to navigation is “down”, a NOTSHIP is issued and mariners then take special care and operate at a heightened degree of awareness for the

duration of the outage period. This reaction likely explains why we did not observe any groundings that were caused by “down” aids to navigation over the last 25 years in this LOS area.

### 2.5.2 Comparing Costs and Benefits

As discussed above, we do not need to further compare an estimated \$1 million cost for service improvements to an estimated safety benefit which would likely be significantly less than this amount.

### 2.5.3 Making a Decision

While the direct safety benefits of reducing aid to navigation outages do not appear cost-beneficial, there are two other issues that could be pursued:

- 1 Would the long-term reduced maintenance costs resulting from an estimated 50% reduction in aid to navigation outages compensate for the one-time capital investment of \$1 million?
- 2 Should the current level of service goals be revised to conform more to the actual service being delivered in light of the apparent absence of groundings caused by “down” aids to navigation in this LOS area? Perhaps a lower level of service can be tolerated without increased risk as long as only a “reasonable” number of NOTSHIPS are issued at any one time for a given area? If one cries wolf too many times, all warnings tend to be ignored. Of course, a review of service level standards would require the involvement of all stakeholders from the very beginning.

## 2.6 Step 5 Take Action

No implementation of the proposed option for risk-reduction purposes is recommended. However, it is recommended that two additional reviews be conducted as outlined in step 4 above (see section 2.5).

## **ANNEX IV CONTEXT AND EXPANSION OF THE RISK MANAGEMENT PROCESS**

### **1 THE IMPORTANCE OF USING A RISK MANAGEMENT PROCESS**

Organizations should evolve on an ongoing basis in order to remain relevant and to meet their mandate and objective as changes occur. Managing risk is becoming essential as part of the current evolutionary context.

Risk is about something that may happen in the future. Factors such as technological innovation and complexity and growing social and cultural awareness are making it increasingly difficult to anticipate what may occur in the future. Risk management involves the analysis of scenarios about future events, their likelihood, impact and acceptability to stakeholders. This information is critical to issues such as the balancing of “program integrity” and “limited resources.” Simply put, limitations on resources can adversely affect program integrity that involves the ability of organizations to ensure the continued achievement of results consistent with priorities. Organizations need modern management approaches including risk management to make judgments about maintaining program integrity. Competency in conducting intuitive and systematic analyses of the level of risk involved in organizational transition and new opportunities will support timely decision making and demonstrate due diligence across and down the organization.

Individuals and organizations manage risk every day consciously and unconsciously. The need to do so more systematically and explicitly is also a matter of transparency, accountability and credibility. Transparency gains are occurring as a matter of public sector reform and technology advances. Transparency leads to accountability and potential effects on credibility. Integrating risk management into management and operational practices provides a basis for anticipating transparency issues, managing accountability expectations and maintaining credibility. Credibility is maintained when stakeholders gain assurance that the organization is “in control.” Such assurance is gained in part when it is transparent in plans, reports and stakeholder interfaces that the organization systematically and continually identifies, assesses and manages its risks. In effect, an organization must incorporate risk management into its own management system.

### **2 TEMPORAL NATURE OF RISK MANAGEMENT**

Risk also has a temporal nature and it should be recognized that the process is iterative, and that a return to a previous step can be made at any time.

### **3 FLEXIBILITY IN A RISK MANAGEMENT PROCESS**

Risk management involves estimation, assumptions and implementation of strategies and procedures carried out by people. In many cases it is necessary to take a decision where all these elements have degrees of uncertainty. Most risk management approaches will examine these uncertainties and devise strategies to monitor events in order to be timely in adjusting a decision as a result of an uncertainty unfolding in a manner other than expected.

Risk management includes the objectives of sensible risk taking in order to support the achievement of results. Because zero risk situations are by and large not affordable in today’s resource environment, some level of risk taking will always be a part of decisions. However, the climate for promoting timely decisions involving risk

will be undermined if there is not an attitude of allowing for adjustments after a decision has been made. Allowing for adjustment should be built into the risk management process. Allowing for adjustment should involve learning from the adjustment so that it will be avoided in the future. Managers can be taken to task for not avoiding a known problem but they need to feel supported in terms of there being an allowance for adjustment on areas of new uncertainty.

Monitoring the estimations, assumptions and actions by the people implementing strategies and procedures will ensure adjustments are identified and implemented in a timely manner.

## **4 CONSULTATION AND COMMUNICATION**

Reforms aimed at becoming more fiscally sound have increased the need for trade-offs in the options and services provided by most organizations. Risk is generally a factor in these trade-offs. Over and above trade-offs, however, there are three compelling rationales for continued consultation and communication among stakeholders in the development of policies for managing risk.

First is the principle that program managers should consult with stakeholders, with a related agreement that stakeholders have the right to participate meaningfully in decision-making and be informed about the basis of decisions. It should be acknowledged that, notwithstanding the benefits of broad consultations, the program manager usually has the final decision. Virtually all public involvement processes have to address the question of the stakeholders role in the decision process regardless of whether participants are empowered to set policy or not.

Second is the belief that relevant wisdom is not limited to scientific specialists and officials of the organization and stakeholders often contribute relevant information that might otherwise not be available to decision-makers.

Third is the rationale that broad consultations may decrease the conflict and increase the acceptance of, or trust in decisions by marine aids to navigation authorities. Related to this is the growing recognition of the importance of trust as a factor affecting how all stakeholders perceive risk.

Effective communications and consultations with stakeholders can provide the decision-makers with improved insight into risk problems since stakeholders often have a unique perspective or relevant information not otherwise available to decision-makers. This leads to better, more informed decisions. Just as important effective communications provide a unique opportunity for decision-makers to improve their credibility with stakeholders. Improved credibility increases safety as a result of increased acceptance of and compliance with a safety program. Conversely, inappropriate or poorly conducted communications can reduce credibility and seriously inhibit the achievement of objectives.

## **5 INFORMATION AND DATA**

Suitable data is necessary for each step of the risk management process. When data is not available, expert judgment, physical models, simulations and analytical models may be used to achieve valuable results.

Data concerning incident reports, near misses and operational failures may be very important for the purposes of making more balanced, proactive and cost-effective decision. A judgment on the value of data that are to be used should be carried out in order to identify uncertainties and limitations, and to assess the degree of reliance that should be placed on the available data.

A more detailed list of data and information that should be considered in evaluating risk specific to marine aids to navigation is attached in Annex II.

## **6 DOCUMENTATION REQUIREMENTS**

There is a requirement for extensive documentation throughout the risk management process, especially if risk to life, property or the environment is being evaluated. If the issues under review are relatively inconsequential, documentation requirements may be modest, but still necessary.

6.1.1 Documentation provides:

- 1 Help in explaining decisions;
- 2 Help in defending decisions after they have been made;
- 3 A reference for future risk management processes, so as to facilitate continuous improvement;
- 4 For the monitoring function;
- 5 The basis of all decisions, in that all decisions are based on information;
- 6 A record of proceedings; and
- 7 A means of communicating reasons for decisions to stakeholders.

It may be critical that documentation is detailed and comprehensive, as in cases of possible litigation. However, the need for documentation should reflect the importance to stakeholders of the risk decisions to be taken, the level of concern regarding these issues and/or the resources available to the decision-maker. Reasonable efforts should be made to document the process without generating excessive paperwork.

Documentation may be an important resource for future decisions, just as a lack of documentation may generate serious problems. The amount of documentation to be provided should be a matter of serious consideration. While it is cautioned against being secretive, some information may need to remain confidential.

## ANNEX V BIBLIOGRAPHY

- 1 Bea, R.: "The Role of Human Error in Design, Construction, and Reliability of Marine Structures". Technical report, Ship Structure Committee, 1994. SSC-378.
- 2 Comstock, J.P. and Robertson, J.B.: "Survival of Collision Damage Versus the 1960 Convention of Safety of Life at Sea", SNAME, pp. 461-522. 1961.
- 3 Froese, J, Hartung, R. and Schack, C.: "Risk Assessment for Solo Watchkeeping at Night under Defined Conditions". ISSUS, Germany. March, 1996.
- 4 Fujii, Y. Yamanouchi, H and Mizuki, N.: "Some Factors Affecting the Frequency of Accidents in Marine Traffic. II: The probability of Stranding, III: The Effect of Darkness on the Probability of Stranding". Journal of Navigation, Vol. 27, 1974.
- 5 Fujii, Y. and Yamanouchi, H.: "Visual range and the Degree of Risk", Journal Of Navigation Vol. 27, No. 2, pp 248- 252, 1974.
- 6 Fujii, Y.: "Integrated Study on Marine Traffic Accidents", IABSE Colloquium on Ship Collision with Bridges and Offshore Structures, Copenhagen, Vol. 42, pp. 91-98. 1983.
- 7 Fujii, Y., Yamanouchi, H. & Matui, T.: "Survey on Vessel Traffic Management Systems and Brief Introduction to Marine Traffic Studies", Electronic Navigation Research Institute Papers No. 45. 1984.
- 8 Fujii, Y. and Mizuki, N.: "Design of VTS systems for water with bridges". Proc. of the International Symposium on Advances in Ship Collision Analysis. Gluver & Olsen eds. Copenhagen, Denmark, 10-13 May, 1998. pp. 177-190.
- 9 Friis Hansen, P and Pedersen, P.T.: "Risk Analysis of Conventional and Solo Watch Keeping" Submitted to Int. Maritime Organisation (IMO) Maritime Safety Committee by Denmark at the 69<sup>th</sup> Session. 1998.
- 10 Friis-Hansen, P and Cerup Simonsen, B.: "Dogden Feasibility Studie 2001, Aktivitet 3.9, Søuheld", December 2001, HLD Joint Venture"
- 11 Gluver, H. and Olsen, D.: "Current practice in risk analysis of ship collisions to bridges". Proc. of the International Symposium on Advances in Ship Collision Analysis. Gluver & Olsen eds. Copenhagen, Denmark, 10-13 May, 1998. pp. 85-96.
- 12 Grech Michelle, Horberry Tim and Koester Thomas: "Human Factors in the Maritime Domain". ISBN 9781420043419, CBS Press, 2008.
- 13 Haugen, S.: "Probabilistic Evaluation of Frequency of Collision Between Ships and Offshore Platforms". Ph.D. thesis, Marine Structures, University of Trondheim. Aug. 1991.
- 14 Hollnagel, E.: "A Cognitive Task Analysis of the STGR Scenario". Nordic nuclear safety research (NKS). NKS/RAK-1(96)R3. April 1996.
- 15 IMO: "Resolution and Other Decisions", Resolution 680-732, London. 1992.
- 16 Inoue, K.: "On the Separation of Traffic at Straight Waterway by Distribution Model of Ship Paters", J. Nautical Society of Japan, No. 5. 1972.
- 17 ISESO: "Information Technology for Enhanced Safety and Efficiency in Ship Design and Operation", Danish Maritime Authority.  
<http://www.sofartsstyrelsen.dk/sw1161.asp>

- 18 Jensen, F.V.: "An Introduction to Bayesian Networks". UCL Press. 1996.
- 19 Karlson, M. Rasmussen, F. and Frisk, L.: "Verification of ship collision frequency model". Proc. of the International Symposium on Advances in Ship Collision Analysis. Gluwer & Olsen eds. Copenhagen, Denmark, 10-13 May, 1998. pp. 117-121.
- 20 Larsen, O. Damgaard: "Ship Collisions with Bridges – The interaction between Vessel Traffic and Bridge Structures". Structural Engineering Documents 4. International Association for Bridge and Structural Engineering. 1993.
- 21 MacDuff, T.: "The Probability of Vessel Collisions". Ocean Industry, September 1974. pp. 144-148.
- 22 Olsen, D. Gotfredsen, H.H. and Fujii, Y.: "Risk Reducing Effects of the Great Belt VTS System". 7<sup>th</sup> International VTS Symposium, Vancouver, Canada, June 1992.
- 23 Pearl, J.: "Probabilistic Reasoning in Intelligent Systems: Networks of Plausible Inference". Morgan Kaufmann Publishers, Inc. 1988.
- 24 Pedersen, P. Terndrup, Hansen, P. Friis, and Nielsen, L.: "Probabilistic Analysis of Collision Damages With Application to Passenger Ro-Ro Vessels". Safety of Passenger Ro-Ro Vessels. Dept. of Naval Architecture and Ocean Eng. Doc. pac-001. 1995.
- 25 Pedersen, P. Terndrup: "Collision and Grounding Mechanics". Proc. WEMT 1995, Copenhagen, Volume 1, pp.125-157. 1995.
- 26 Rasmussen, B. and Whetton, C.: "Hazard Identification Based on Plant Functional Modelling". Risø National Laboratory, Roskilde, Denmark. October 1993.
- 27 Rothblum, A. M. and Carvalhais, A.B.: "Maritime Applications of Human Factors Test and Evaluation". Chapter 15 in the book, *Handbook of Human Factors Testing and Evaluation*, edited by T. G. O'Brien and S. G. Charlton, Mahwah, NJ: Lawrence Erlbaum Assoc., 1996.
- 28 Schraagen, J.M.C, van Breda, L., and Rasker, P.C.: "Sole look-out during periods of darkness". TNO Human Factors Rresearch Institute. August 22, 1997.
- 29 Thau, J. Personal communication. Danish Maritime Institute, Denmark. 1999.
- 30 U.S. Coast Guard: Homepage of Research and Development Center. <http://www.rdc.uscg.mil>