Final Report for Publication

Concerted Action on FSEA
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Project Co-ordinator:	**Germanischer Lloyd on behalf of EEIG Unitas**
Partners:	**Det Norske Veritas**
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1 Partnership

The Concerted Action comprised a Consortium of representatives from 11 European countries and a Secretariat, coordinating and managing the project.

Participants came from Finland, France, Germany, Greece, Italy, The Netherlands, Norway, Portugal, Sweden, and the United Kingdom. They represented administrations, shipping industry, classification societies, research institutes and insurers. Observers from maritime associations were also invited to project meetings to share their views and comments on project results and discussions.

The project Secretariat represented four European classification societies. It consisted of the EEIG Unitas and Det Norske Veritas. The European Economic Interest Group UNITAS embodies the three classification societies Bureau Veritas, Germanischer Lloyd and Registro Italiano Navale. EEIG Unitas was presented in the Secretariat by Germanischer Lloyd.

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2 Executive Summary

The Concerted Action on Formal Safety and Environmental Assessment of Ship Operations, a project funded by the European Commission, intended to establish a common knowledge within European shipping about methods for assessment of the safety and environmental impact of ships. The project was also aiming at a common understanding of how those methods can be applied to shipping.

Project activities started in March 1997 with a network of experts from various fields in shipping. The experts, coming from 11 European countries were participating in the project and four observers were following the process and provided relevant input.

The project had several objectives, most of which were achieved. A common knowledge about the current state of the art of assessing risk and environmental impact of ships was established within the project. Contacts to relevant initiatives and project consortia investigating into formal risk assessment approaches were established and different viewpoints were collected. A review of the current practice of risk assessment and accepted methods in other industries was performed and discussed with respect to the applicability of these approaches and methods to shipping.

Aiming at finding a common approach for assessing safety and environmental impacts of ships, potential users of such approach and their possible needs with regard to safety and environmental assessment were identified. Requirements from existing and future mandatory regimes which would have to be reflected by a common assessment approach were also identified.

Special aspects related with the application of safety and environmental assessment methods in shipping were discussed, such as availability and applicability of data, requirements for data format and collection, the problem of implementing the human factor and the consideration of environmentally sensitive marine areas in safety and environmental assessments.

The evaluation of identified assessment methods in shipping showed that currently there is no methodology available, which could fully serve as a common assessment methodology, covering all relevant aspects and all needs of potential users. However, the project concluded that instead of developing a common methodology a common approach would be a more realistic aim for future development. This approach should be capable of being common to all major actors in shipping and should consist of several complementary and suitable methods applied according to the user needs.

The project activities concluded in suggesting and prioritising several further research and development tasks for implementation in present and future European research programmes. Project results are available on the CA-FSEA Web Site: http://www.germanlloyd.org/fsea

3 Objectives of the Project

The project had several general objectives:

- Bring together experts from all relevant parties involved in European shipping with the aim to:
- Establish a common knowledge about the assessment of safety and environmental impact of ships by this network of experts
- Create a common understanding in Europe of how approaches to risk and environmental impact assessment can be applied to shipping, e.g.: as adequate basis for future safety and antipollution regulations, as possible tools leading to more flexibility in ship safety design.
- Contribute to the harmonization of European activities in regulating shipping transport.

In order to serve the above general goals the project had the following specific objectives:

- Establish a common knowledge about the current state of the art of assessing risk and environmental impact of ships.
- Collect the different present viewpoints on assessing risk and environmental impact of ships.
- Identify all relevant aspects to be considered when assessing risk and environmental impacts from ships.
- Clarify objectives and requirements from potential future users of formal risk assessment approaches.
- Identify and specify necessary further developments on the way to a commonly understood and accepted approach in assessment of both risk and environmental impact of ships.

4 Means Used to Achieve the Objectives

The tasks of the project work programme were mainly dealt with by establishing working groups (WG) and workshops (WS). Specific tasks of the work programme were allocated to different WGs and WSs. TheWG/WSs consisted of a limited number of participants with special expertise and/or interest regarding the tasks to deal with.

During the first half of the project period the work programme tasks were elaborated mainly by correspondence. Following a mid-term project assessment the outstanding project tasks were re-assigned to smaller groups of participants. These groups each had a workshop which on average lasted for three days. The members of the WSs had to prepare for the WS and to discuss specific work programme tasks according to Terms of Reference given to the group by the project Consortium. The results and conclusions of a WS were summarised in a WS report.

The results were also presented and discussed in meetings with the entire Consortium. Observers were invited to join these meetings and share their views, comments and relevant input with the Consortium. Results were also disseminated on maritime conferences and via the project's own website (Annex A1 and A2).

5 Scientific and Technical Description of the Project

In the following chapter the results achieved within the project are presented. For easier reading the results are summarised first, and then described in more detail, providing additional information and further insights in methodologies described, in discussions during the project and reasons for the conclusions drawn.

Sub-chapters 5.1 and 5.2 provide a description of the state of the art in safety and environmental assesment in the maritime industry and in other industries. Detailed descriptions of methodologies have been provided by participants individually as a basis for discussion and further elaboration in the project. It should be noted that this information does not represent a consolidated view of the project Consortium.

5.1 State of the Art of Safety and Environmental Assessment Methodologies in Shipping

Introduction:

Safety assessments have been performed for many years in various industries. However the quantified approach to safety is much more recent, in particular the probabilistic approaches to safety assessments.

Especially in the nuclear, aviation and process industry probabilistic safety assessments have been performed for many years. These industries deal with equipment whose failures can have very serious consequences, and thus it is necessary that they operate with very high reliability levels. These conditions were certainly drivers for the development of quantified methods in these industries. Complex systems and operational situations, such as occurring in the nuclear industry, in which qualitative and global assessments are not able to cope with all the technical and operational details, have not only created the need for quantified safety assessments but also for systematic and transparent approaches.

The public pressure on one side and the pressure from the scientific community have raised the attention of the maritime industry to the need of probabilistic based, quantified and systematic risk assessment. To distinguish from the earlier safety assessments made in this industry for many years, Formal Safety Assessment is the term which is most often used today to describe this type of assessments.

Other industries use different terms, e.g. Safety Case approach in the offshore industry. However, the main features of any quantified risk assessment are the same, independently of the names adopted by the industries.

The risk assessment procedure consists of several different steps. Figure 5.1 shows how these steps are interrelated and also, how the steps are embedded in the life cycle of a system and its operation.

For later reference in this report, typical methods used in the different steps are listed also.

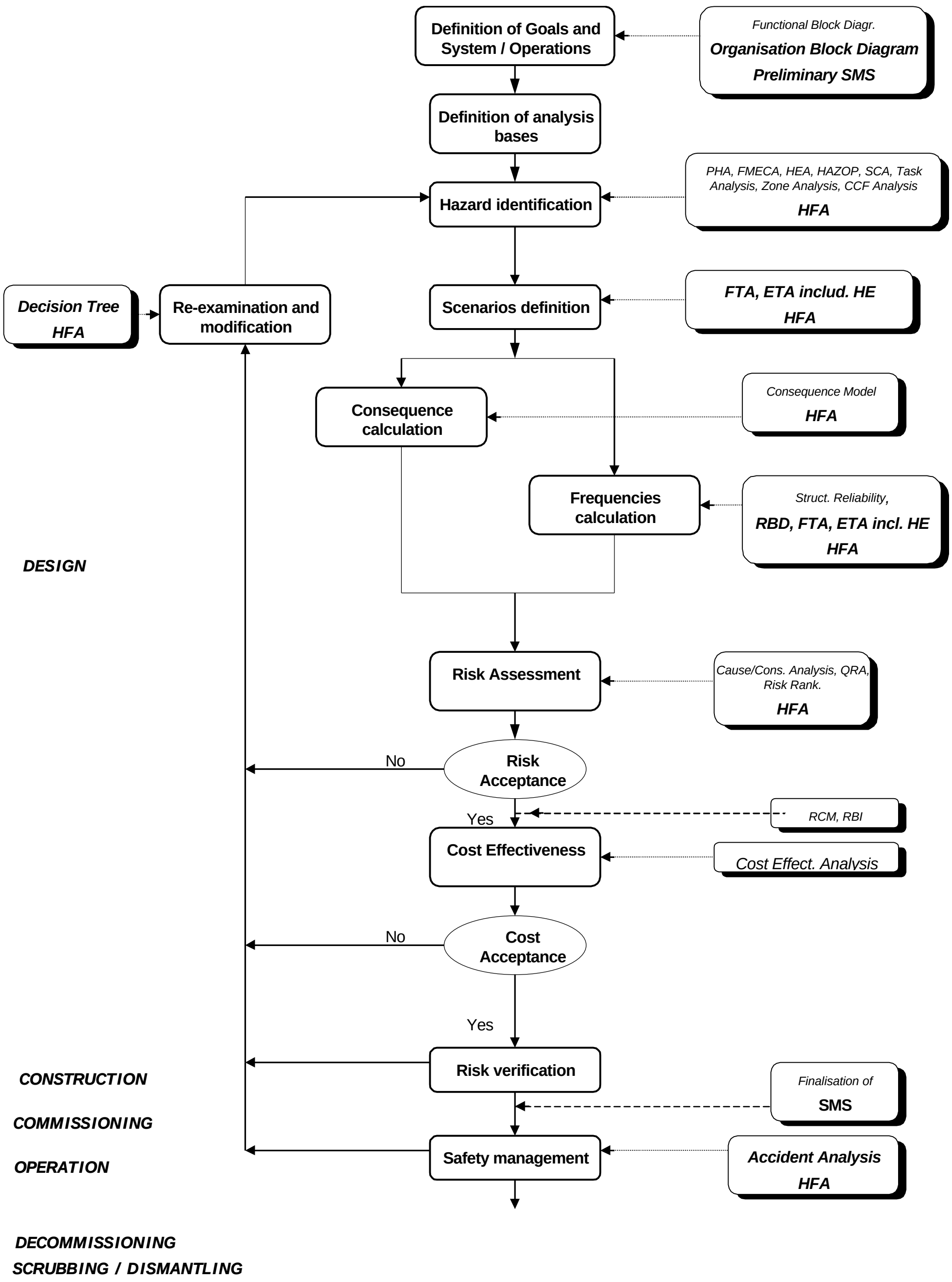

Figure 5.1: General structure of a risk based approach

In the project several methodologies and methods, which are currently in use or being developed for the assessment of safety and/or environmental impacts of ships were identified. The different approaches of these methodologies/methods and the elements they consist of have been described. General objectives, typical achievable results and its limitations as well as the status of the method/methodology have been identified. The methodologies/methods are listed in the following sections.

5.1.1 Formal Safety Assessment (FSA)

Summary:

The FSA methodology consists of the five steps: 1) identification of hazards, 2) risk assessment, 3) risk control options, 4) cost benefit assessment and 5) recommendations for decision making. FSA covers accidental events and their accompanied risk to people, to property and to the environment.

Currently two application areas are seen:

1) for rule making purposes, to establish a general overview of risks and risk control. This application area is currently discussed at IMO, as FSA is seen as a possible tool to support the IMO rule-making process. "Interim Guidelines for the Application of FSA to the IMO Rule-Making Process" have been drafted and approved by MSC 68 and MEPC 40. Administrations and Organisations have been invited to start trial applications according to the Guidelines in order to gain experiences with the FSA approach. At MSC 69 several trial applications and their results were already presented.

2) for particular activities, operations, installations, ships. Such application is normally called a "safety case".

   The current understanding in the Consortium is that a safety case application of FSA could be done on a voluntary basis but was not regarded practical to be performed for each individual ship.

5.1.1.1 Description of Formal Safety Assessment (FSA) - by Jim Peachey, United Kingdom

General Objectives and Potential Users

Formal Safety Assessment is a designation that has been used in a number of different contexts and industries to describe the systematic risk-based approach to safety.

In the maritime world the expression Formal Safety Assessment (FSA) has started to be used by the International Maritime Organisation (IMO) and its members, as part of the rule-making process for international shipping. FSA comprises a structured and systematic approach using risk and cost/benefit assessments, which is aimed at enhancing maritime safety. Its objectives include the protection of life, health, the marine environment and property. Being a tool designed to assist maritime regulators, FSA is not intended for application to individual ships, but for use in a generic way for shipping in general.

The FSA methodology has been developed with two potential users in mind:

- IMO committees, to help in the review of existing regulations or in the evaluation of proposed new regulations; and
- Individual maritime administrations, to support proposed amendments to IMO regulations.

It is anticipated that FSA would usually be relied upon where proposals may have far reaching implications in terms of safety, cost or legislative burden. In these circumstances, the use of FSA should facilitate the achievement of a balance, not only between the various technical, operational and human issues involved, but also between safety and cost.

Although described above in the context of the regulatory regime for shipping, the phrase Formal Safety Assessment has also been applied to specific analysis to individual ships. In this case, although the general methodology is the same, the specific aspects will be adjusted to the particulars of the ship in question.

Description of Approach and Elements of the Methodology

The approach comprises five inter-related steps:

1. Identification and ranking of hazards
2. Quantified assessment of the risks arising from the hazards identified in step 1
3. Identification of regulatory options for controlling the risks defined in step 2
4. Cost/benefit assessment of the risk control options identified in step 3

5. Recommendations for decision making, based upon the information derived in the preceding steps

Established techniques are employed at each step of the FSA process. These include, for example: structured group reviews (brainstorming), analysis of historical accident data, and task analysis for hazard identification in step 1; fault and event tree analyses for the determination of risk in step 2; and net present value calculations of costs and benefits in step 4. However, because the FSA process is intended to be used for shipping in general rather than for any particular ship, additional techniques are also used, including in particular:

- Development of a generic model to describe the functions and features which characterises the problem (eg. the ship type) under consideration; and
- Modelling of the regulator's influence over the underlying causes of accidents.

This latter is achieved by constructing diagrams (Influence, or Regulatory Impact Diagrams) which enable the principal underlying causal factors to be identified and evaluated. These factors include for example training, management, the human element, design, communication, maintenance, etc. They are assumed to comprise a network of influences, which link regulatory policy with the occurrence, and escalation of accidents. Their evaluation, using both historical data and expert judgement, allows the factors, which significantly influence risk to be systematically addressed.

The FSA methodology also recognises that there are typically several different stakeholders involved in a shipping venture (eg ship owner, cargo owner, passengers, crew, flag state, port state, etc), and that the attitudes and actions of these stakeholders are probably the greatest single influence over safety. The FSA methodology therefore includes the identification of stakeholders and consideration of the impact and equitability of potential regulatory options for each of the relevant stakeholders.

Status of Methodology

The FSA methodology has been developed by a joint Working Group of the IMO's Maritime Safety and Environmental Protection Committees, based upon research undertaken in the UK. The two committees approved guidelines setting out the details of the method during 1997.

Although many of the elements of the approach described above are well established in other contexts, their application to the shipping industry, and in an overview or generic way, are relatively new and unproven. Trial applications are presently being undertaken, with the intention of reporting the results and experience gained to the IMO.

Consideration is also being given, by a Correspondence Group of IMO members, to the development of suitable mechanisms and procedures by which the FSA process can be applied by the IMO committees in their future decision making.

Type of Results Achievable and Limitations

FSA is intended to be applied at an overview level (for example to all the hazards affecting a particular ship type), with a view to identifying and prioritising the principal risks and regulatory options. FSA results will comprise a summary of the key risks relevant to the scope of the study, and information regarding the relative costs and benefits of the regulatory options for addressing those risks. The conclusions of an FSA study should therefore facilitate a proactive approach by the IMO, by providing a justifiable basis for making decisions about the need for, and content of, maritime regulations.

It is not, however, the purpose of FSA to take account of the details of specific ships, or their arrangements, operations, etc, nor is the process designed to address the risks facing a particular owner or ship.

As with all risk assessments, the results obtained are dependent in part upon data (eg historical incident and accident information), and also upon judgement in interpreting that data and anticipating industry trends, the impact of changes in technology, the potential for future accidents, etc. The results of an FSA study are therefore dependent upon not only the availability of relevant data, but also suitably qualified and experienced people to undertake such judgements.

5.1.1.2 Safety Case - by Jim Peachey, United Kingdom

The Safety Case was introduced to the UK offshore industry by the UK Health & Safety Executive (HSE). For offshore activities a Safety Case has to be produced for submission to the HSE. This Safety Case regime is primarily a UK offshore approach.

General Objectives and Potential Users

The primary objective of a safety case is to ensure an adequate level of safety for a particular ship, based upon the management and control of the risks associated with that ship. A central feature of a safety case is that the shipowner takes responsibility for assessing the risks associated with his ship, and for documenting how his safety management system limits those risks to an acceptable level.

The document containing details of the risk assessment and the safety management system is called a safety case. The safety case constitutes a demonstration, to the vessel's owner, and to his employees, customers and society at large, that risks arising from the operation of the ship are adequately understood and controlled.

In some industries, for example the UK offshore oil & gas industry, the safety case regime is mandatory, i.e. operations cannot legally be commenced or continued until a safety case has been compiled by the owner and submitted to the official regulator for scrutiny and approval.

However, it is beginning to be recognised by responsible owners in the shipping industry that a safety case approach can be adopted voluntarily. Thus, in addition to complying with existing prescriptive regulatory requirements, an owner may choose voluntarily to compile a safety case and introduce a safety management system, for example to protect his business interests or reputation, or where he wants to achieve a higher level of safety than is implied by the regulations.

It should be noted that although described above in the context of a vessel's owner, a safety case can, where appropriate, be compiled and maintained by a vessel's operator.

Description of Approach and Elements of Methodology

A safety case will include a comprehensive description of the ship itself, and of its operation and the environment within which it operates. The risk assessment will be undertaken using a number of established techniques, such as FMEA and HAZOP studies for hazard identification, and fault and event tree analyses for the determination of risk. Risks will be quantified to the extent it is appropriate to do so. Risk criteria will be set, relevant to the vessel and its operational context, and usually in accordance with the ALARP principle.

Likewise, the safety management system will be developed from established good management principles, and will be an integral part of the company's overall management strategy. The safety management system will include elements firstly of setting policy, secondly of organising, planning and implementing actions to fulfill that policy, and finally of monitoring, review and feedback to assess performance against the policy.

Typically, for a new vessel, a design safety case would initially be compiled. This would subsequently be developed and expanded into an operational safety case as the vessel enters service. Thereafter, the safety case would normally be subject to regular review, with updating as necessary, to take account of changing conditions, ownership, activities, modifications, etc. A safety case will usually make reference to extensive back-up information recording details of the ship and its operation, the risk assessments, risk criteria, etc.

It is essential that the safety case is developed with the involvement of staff who have close familiarity with the vessel, its operation, company practice, procedures, etc. This approach also ensures „ownership" of, and commitment to, the safety targets and philosophy contained within the safety case. However, in compiling a safety case, an owner will often need to seek specialist assistance, particularly in respect of the quantified assessment of risks.

The effectiveness of the safety management system is usually monitored and verified by means of regular audits, and compliance with the requirements of the safety case checked by means of inspections.

Status of Methodology

The safety case methodology is well established in industries other than shipping, most notably in the offshore oil and gas sector. However, the approach can, in principle, be applied to ships, and in recent years there has been discussion of this possibility.

There are at present no known requirements by maritime regulators to impose a safety case regime on shipowners, although at least one national administration (Sweden) is considering introducing the approach for domestic shipping.

All known current examples of the application of the safety case approach for ships fall into the „voluntary“ category, in that the organisations involved have decided to develop safety cases without being required to do so by any regulatory authority. Most notably, the UK Ministry of Defence introduced a safety case regime for each of its new ships with effect from 1996. In the merchant shipping sector, two companies are known to have adopted the safety case approach, these being BP Tankers in respect of their new-build crude oil tankers for the Alaskan oil trade, and Stena Line in respect of their HSS1500 high speed catamaran ferries. In neither instance has official approval of the safety case yet been sought.

Type of Results Achievable and Limitations

The safety case approach is intended to be applied primarily to an individual ship. It provides a comprehensive and detailed evaluation of all the risks to which that ship is exposed, together with an explicit statement of the safety management system that the owner has established for controlling and reducing those risks to an acceptable level. The safety case document therefore provides the reference source, not only for checking the completeness and validity of the owner's risk assessment, but also as the basis for auditing the owner's management system and operations, and for inspecting the vessel, with the object of verifying compliance with the provisions of the case.

The principal limitation of a safety case regime is that it presumes a high degree of responsibility on the part of the vessel's owner to be accountable for the risks created by his vessel and its operation. Therefore, exclusive reliance upon a safety case regime as a mechanism for ship safety regulation would only be practical within a framework where the regulator has both the competence to assess the veracity of the safety case, and also the authority to exercise effective sanctions in the event of being dissatisfied with the case itself or the owner's compliance with its provisions.

A further limitation on the widespread introduction of the safety case approach for shipping is the burden of work required to undertake the complex analyses and compile extensive documentation for each and every vessel.

5.1.2 Environmental Assessment Approaches

5.1.2.1 Description of Environmental Assessment Approaches – by Rolf Skjong, Norway

Introduction

A number of methodologies have been developed to measure environmental performances of products, processes, activities, and transportation means. Within the maritime sector methods as environmental indexing, environmental rating, environmental risk analysis and assessment, life cycle analysis and assessment, and environmental accounting have been used. The various methods may be characterised by intended use, systems boundaries, and information included in the model.

In describing the various methods it is important to distinguish between a few important concepts. The terminology from risk analysis and assessment is used in describing the various methods. Risk analysis is the activity to estimate the risk in qualitative or quantitative terms, while the assessment is the process of comparing the estimated risk with acceptance criteria in order to arrive at a recommendation to the decision-maker.

Environmental Accounting

The intended use of environmental accounting is comparable to any other accounting system. The idea is to keep records of the performance, to be able to identify development trends, compare one year to the other, one ship to the other etc. Environmental accounting does not contain an assessment. The system boundary is the ship, and the consequences to the environment are not analysed nor assessed. The accounting may include discharges and emissions as well as accidental releases and resource consumption. Only the operational phase is included. To make the system practically useful models are developed to quantify releases and emissions based on system parameters (e.g. NO_X is not actually measured but quantified based on a model with the relevant system parameters for the machinery). These models may later be used to quantify the effect of suggested improvements. Environmental Accounting may be useful to document performance to authorities, clients, harbour authorities etc. Some ship owners may publish the account in the annual report, where results are compared with previous years or with other ship owners. Environmental accounting may be part of a continuous improvement process within the company.

Life Cycle Analysis

Life Cycle Analysis or Life Cycle Assessment (LCA) is used to analyse the entire life cycle of a product e.g. from mining through production, operation, to demolishing or recycling of the materials. In LCA there are generally large problems with defining the systems boundaries. LCA could for example be done to compare marine transport with road transport, where all results are converted to the same unit (e.g. per ton-kilo-meter). A LCA include all recourses used through the entire lifecycle of the product, emissions and discharges are also included. Accidental releases should be included by its expectation value, but this is not necessarily done in practice. LCA base the information on identified use of recourses and on models. LCA is mostly used to demonstrate superior environmental performance compared to a competing product.

Methods for LCA have been standardised in Nordic Guidelines on Life Cycle Assessment' and a ISO standard is under development and currently circulates as the second draft of ISO 14040

Environmental Indexing

Environmental Indexing or Environmental Rating is an extension of environmental accounting to include the assessment part. This means that the consequences to environmental problems (e.g. global heating, acidification) of the various releases and discharges are quantified relative to each other. For example the weighing system decided at the Kyoto conference for the greenhouse-gases may be used as part of the indexing system.

The system boundary is the ship, and the consequences to the environment are analysed and assessed. The indexing may include discharges and emissions as well as accidental releases. Only the operational phase is included. To make the system practically useful models are developed to quantify releases and emissions based on system parameters. These models may later be used to quantify the effect of suggested improvements. Environmental indexing may be useful to document performance to authorities, clients, harbour authorities etc. Compliance to international agreements on environmental protection will normally result in additional costs to comply for each nation. Environmental indexing may be used to transfer these costs to the polluter by (green) taxes, tolls, and tariffs.

The assessment part of the environmental indexing is obviously difficult, since relatively little is known of actual consequences. The system will therefore have to include both information with little uncertainty (e.g. the emission) and information with large uncertainties (e.g. consequences of greenhouse effect). Within environmental protection the precautionary approach is used to account for these uncertainties, a principle which lacks a quantitative definition. To avoid the problem of quantification the indexing system may be based on comparison with other ships (relative instead of absolute index). This may be done by defining the performance based on Best Available Technology (BAT) or Best Available Technology Not Entailing Excessive Costs (BATNEEC), in addition to the performance of the average or normal ship,

$$E_R = \frac{E_A - E_B}{E_N}$$

E_R is the new Relative index, E_A is the initial Absolute index, E_B is the index for the BAT-ship or the BATNEEC-ship, while E_N is the index of the Normal or average ship. As technologies improve the rating will become poorer for a ship that is not upgraded. Continuous improvement will be a necessity to maintain the rating.

The Norwegian Research Council Green Ship project contributed to basic knowledge and models for regular emissions and discharges as well as accidental releases. The Norwegian Joint Industry project on Environmental Indexing developed an indexing system based on the relative index. Accidental releases were included, the system boundary was the ship, and only the operational phase was included. Norway proposed a similar system at IMO/MEPC (MEPC/40/16/2). The plenary discussion at MEPC revealed that similar systems exist in The Netherlands (Green Award) and Canada.

Environmental Risk Analysis

Environment risk analysis is carried out much the same way, and sometimes in parallel with a risk analysis addressing safety issues. When the term environmental risk analysis is used geographical areas or habitats usually define the system boundaries. The most important pollutants and environmental components are selected. The frequency of and the impact severity of releases and discharges, regular and accidental, to the area in question are the main result, together with the effect of suggested risk reduction measures.

5.1.3 The Green Award System

Summary:

The system emphasizes the environmental aspects in particular, more than safety aspects. Based on the compliance with (inter)national laws and regulations the additional technical and operational means on-board the individual ship as well as management on-shore are audited and scored. If an acceptable score is reached in the audit, a Green Award Certificate is issued for a period of three years. Based on this certificate a several percent reduction in the normal port fee is given by the Port of Rotterdam and many ports worldwide that have joined the scheme.

So far, the procedure has been established only for oil tankers, but will be extended to other types of ships.

5.1.3.1 Description of the Green Award System - by Kees Metselaar, The Netherlands

General Objectives

The Green Award certification scheme is an initiative developed by the Rotterdam Municipal Port Management to improve safety and environmental standards on board seagoing ships. This includes not only the actual visit to the dockside, but also all elements in sea transport between ports all across the globe. The scheme started in '94 and is carried out by a foundation (GA). It incorporates and accepts existing Quality Assessment and certification schemes (ISO 9002, ISM,etc.)

Its objective is to promote safe and environmental-friendly behaviour of ship and crew/management, mainly by achieving international acceptance, recognition, regulation and co-ordination of the "Green Award" certification, all in observance of (inter)national conventions, legislation and developments in the area of ship lay-out, equipment, crew, operations and management.

The Green Award procedure is carried out by the Bureau Green Award, the executive body of the independently validated Green Award Foundation.

Certification is applicable to product/oil tankers with deadweight of 20,000 tons and above.

Description of Approach, Elements, Achievable Results and Limitations

The certification procedure consists of audits of

- Crew;
- Management procedures; and
- Technical provisions.

The emphasis is on safe and environmentally friendly management and crew competence. A certificate will be valid for three years, unless the Bureau Green Award withdraws it. All cases in which certification can be withdrawn are mentioned in the workbook of Green Award, called 'Secure for Operations'.

Assessment for certification is carried out only on application of the shipowner. First a desk survey on the basic requirements will be held at the Bureau Green Award based on documents forwarded by the applicant. This desk survey of the basic requirements is to determine if the ship and its crew comply with (inter) national laws and regulations. If the basic requirements are not met the certification process will be concluded at this stage.

Next is an audit at the owner or manager's office. This audit usually is valid for more than one ship, unless there are reasons to believe the circumstances have changed. Finally an audit on board the ship is carried out to verify and assess the implementation of procedures and the technical requirements. This ship audit by the Bureau Green Award can, at the request of the ship owner, be carried out anywhere in the world.

Provided the basic requirements are met, the ship is eligible for certification. The Bureau Green Award will grant a specific score to each of the requirements that meet crew, management and technical provisions. Depending on the total score, the vessel is granted a certificate.

The owner/managers office audit is focussed on:

- ship/shore interface (control, maintenance, reporting feedback, consultation), management)
- verification and compliance with documented policies and instructions
- standard companies' crew/manning policy, qualifications and competence
- organisation

The on-board audit is focussed on:

- verification of compliance with items applicable to the ship involved
- implementation of company policies and instructions

The audits will be concluded in an audit/survey report. The certification department will carry out the rating.

Optional provisions might be allocated a score if proven and relevant to extra investment in safety precautionary measures and protection of the environment. All ships that passed the Green Award assessment will be mentioned on a list, published once a year by Green Award.

Status of Methodology

At the end of 1996, 33 tankers aggregating 7,1 million dwt had been Green Award certified. In Rotterdam ships with a Green Award Certificate are rewarded with a premium on port fees of 6%. Meanwhile also other ports have joint the scheme.

The certification is open for tankers but is intended to cover all types of sea-going vessels in due course. Bulk carrier extension is intended early 1999.

5.1.4 The International Marine Safety Rating System (IMSRS®)

Summary:

IMSRS® is an approach based on management system audits and physical condition checks. The primary focus is on best management practice for control of losses. Losses are related to accidental injury, illness, property damage, fire and explosion. IMSRS® also covers some environmental and quality management issues and occupational issues such as ship operation and crew involvement.

IMSRS® is used by several shipping companies, on a voluntary basis. This system is consistent with the ISM Code and can be used as a tool in implementing the Code requirements.

5.1.4.1 Description of the IMSRS® - by Sven Otto, Germany

General Objectives

Det Norske Veritas (DNV) developed their International Marine Safety Rating System (IMSRS®) for the marine industry. It was derived from the International Safety Rating System (ISRS®). It essentially provides an objective measurement of the status of a safety management system.

According to IACS procedural Guidelines, a safety management system is a structured and documented system enabling company personnel to effectively implement their company safety and environmental protection policy.

According to DNV, the basic concept of IMSRS® is that loss control is the direct responsibility of the line leadership in any company. Loss control is defined as all activities to reduce accidental losses, whether involving safety, quality or environment.

The IMSRS® primary focus is on best management practice, which can control losses and potential losses. Losses, the avoidable waste of any resource, are related to injury, illness, accidental property damage, fire and explosion. It also covers some environmental and quality management issues. The IMSRS® also deals with occupational issues such as ship operation and crew involvement.

Being a loss control management tool the IMSRS® can be used for auditing on the basis of ISM Code & DNV SEP Rules as well.

The objectives of the IMSRS® are:

- to provide a system which objectively measures and quantifies work being done to control loss,
- to provide a system which guides the development of an effective loss control system,
- to provide a systematic approach, rather than a segmental one, for loss control management,
- to identify the majority of exposures causing loss of people, property, products, environment, services or processes.

Description of the Methodology, Results achievable

The measurement method of IMSRS® is based on audits, which consist of interviews, documentation and record checks, and a physical condition tour. The audit results are presented in a detailed and comprehensive report. The auditor uses a number of questions dealing with 20 elements (table 5.1.4.1). These elements are subdivided into 126 sub-elements and more than 650 system requirements. The auditor rates the performance of each requirement with a number of points. The sum of all points yields the level of the safety management system. Those levels are called "Levels of Excellence" (Figure 5.1.4.1). The achievement of level 1 indicates that the system complies with the ISM Code requirements. Level 2 indicates that the System is in compliance with the DNV SEP Rules. A Safety Managing System can achieve level 1 to 10.

The IMSRS® contains 6 different scoring methods relating to the type of question.

The application of the IMSRS® is based on the use of the following tools.

- Internal Audit Tool
  A Company can confirm internal audits with their own corporate, operational or staff personnel. These internal audits provide information about the system progress and identify areas needing attention.
- External Audit Tool
  A Company can request an evaluation by experienced DNV auditors. Upon completion of the evaluation, DNV can issue a distinctive certificate, suitably identified with the appropriate recognition level.
- Implementation Tool
  In order to assist the implementation of the ISM Code with the IMSRS® the minimum system requirements can identified.
- Element Criteria
  Criteria were established for each of the elements, based on work being done by leading companies around the world. They represent the work, which could be done by the company to achieve a high level of loss control through the establishment of internal performance standards and procedures
- Element Weighting
  The number of points available in each element varies. Points were allocated to each audit element based upon opinion polls of companies actively using this system.

- Improvement Tool
  The IMSRS® can be used as an improvement tool. To improve the Safety Management System the present status will be established. This can be done by DNV auditors or by internal suitably trained company personnel.

Status of Methodolgy

The system is currently used by several shipping companies.

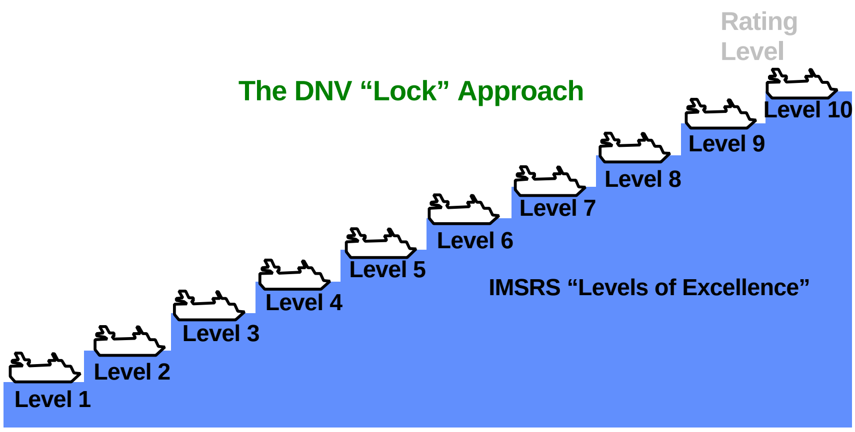

Figure 5.1.4.1: IMSRS® "Levels of Excellence"

Table 5.1.4.1: Program Elements of the International Marine Safety Rating System- IMSRS®

No.	Element	Rating Points
1	Leadership and administration	1310
2	Leadership training	700
3	Planned inspections and maintenance	690
4	Critical operations and task analysis	650
5	Accident/incident investigation	605
6	Observation of work performance	450
7	Emergency preparedness	700
8	Company safety rules and work permits	615
9	Accident/incident analysis	550
10	Knowledge and skill training	700
11	Personal protective equipment	380
12	Occupational health and hygiene control	700
13	System review and evaluation	700
14	Engineering and change management	670
15	Personal communications	490
16	Group communications	450
17	General promotions	380
18	Personal recruitment and orientation	405
19	Purchasing and contract management	615
20	Off-the-job safety	240

5.1.5 Port State Control

Summary:

This approach is focussing on the identification of deficiencies on ships and their follow-up, using a scoring system. The main purpose of this approach is to reduce the number of sub-standard ships.

5.1.5.1 Description of Priority Inspections in Port State Control - by Kees Metselaar, The Netherlands

General Objective

In Commission Directive 98/42/EC of 19 June 1998, amending Council Directive 95/21/EC concerning the enforcement , in respect of shipping using Community ports and sailing in the waters under the jurisdiction of the Member States, of international standards for ship safety, pollution prevention and shipboard living and working conditions (Port State Control) the procedure for determining the 'targeting factor' which is used in selecting ships for inspection is laid down.

In each Community Port 25% of the incoming ships are to be inspected by the 'competent authorities'. The targeting factor is used in determining which ships fall into this 25%.

Description of approach

In selecting ships for inspection the competent authority shall give overriding priority to the ships referred to under A) to E) below. In determining the order of priority for inspection of other ships, the competent authority shall use the ship's overall target factor referred to in table 5.1.5.1.

Overriding factors

Regardless the value of the target factors, the following ships shall be considered as an overriding priority for inspection.

Ships which have been reported by pilots or port authorities as having deficiencies which may prejudice their safe navigation.

A) Ships which have failed to comply with the obligations laid down in Directive 93/75/EEC.

B) Ships which have been the subject of a report or notification by another Member State.

C) Ships which have been the subject of a report or complaint by the master, a crew member, or any person or organisation with a legitimate interest in the safe operation of the ship, shipboard living and working conditions or the prevention of pollution, unless the Member State concerned deems the complaint or report to be manifestly unfounded; the identity of the person lodging the report or complaint must not be revealed to the master or the shipowner of the ship concerned.

D) Ships which have been:

- involved in a collision, grounding or stranding on their way to the port,
- accused of an alleged violation of the provisions of discharge of harmful substances or effluents,
- manoeuvred in an erratic or unsafe manner whereby routing measures, adopted by the IMO, or safe navigation practices and procedures have not been followed, or
- otherwise operated in such a manner as to pose a a danger to persons, property or the environment.

E) Ships which have been suspended from their class for safety reasons , property or the environment.

<u>Overall targeting factor</u>

The following ships shall be considered as priority for inspection

		Target factor value
1	Ships visiting a port of a Member State for the first time or after an absence of twelve months or more. In applying these criteria Member States shall also take into account those inspections which have been carried out by members of the MOU. In the absence of appropriate data for this purpose, Member States shall rely upon the available Sirenac data and inspect those ships which have not been registered in the Sirenac following the entry into force of that database on 1 January 1993.	+ 20
2	Ships not inspected by any Member State within the previous six months	+ 10
3	Ships whose statutory certificates on the ship's construction and equipment, issued in accordance with the Conventions, and the classification certificates, have been issued by an organisation which is nor recognised under the norms of Council Directive 94/57/EC of 22 November 1994 on common rules and standards for ship inspection and survey organisations and for the relevant activities of maritime administrations.	+ 5
4	Ships flying the flag of a State appearing in the three-year rolling average table of above-average detentions and delays published in the annual report of the MOU. • 0 - 3% above average • 3.1 – 6% above average • more than 6% above average	 + 3 + 4 + 5
5	Ships which have been permitted to leave the port of a Member State on certain conditions: • for each deficiency to be rectified before departure • for each deficiency to be rectified at the next port • for every two deficiencies to be rectified within 14 days • for every two deficiencies for which other conditions have been specified • if ship-related action has been taken and all deficiencies have been rectified	 + 1 + 1 + 1 + 1 - 2
6	Ships for which deficiencies have been recorded during a previous inspection, according to the number of deficiencies: • 0 • 1 – 5 • 6 – 10 • 11 – 20 • more than 20 deficiencies	 - 15 0 + 5 + 10 + 15
7	Ships which have been detained in a previous port	+ 15
8	Ships flying the flag of a country which has not ratified all relevant international Conventions referred to in Article 2 of this Directive	+ 1
9	Ships flying the flag of a country with a deficiency ratio above average	+ 1
10	Ships with class deficiency above average	+ 1
11	Ships which are in a category for which expanded inspection has been decided (pursuant to Article 7 of this Directive)	+ 5

		Target factor value
12	Other ships: • between 13 and 20 years old • between 21 and 24 years old • above 25 years old	 + 1 + 2 + 3

Table 5.1.5.1: Overall targeting factors

The target factor means the numerical value allocated to an individual ship in accordance with the provisions of this paragraph and displayed on the Sirenac information system.

In determining the order of priority of the ships listed above, the competent authority shall take into account the order indicated by the overall target factor. A higher target factor is indicative of a higher priority. The target factor is the sum of the applicable target factor values indicated above. Items 5, 6 and 7 shall only apply to inspections carried out in the last 12 months. The overall target factor shall not be less than the sum of items 4, 8, 9, 10, 11 and 12.

Further information on the scoring system

Concerning the question, if the elapsed period of time since the last Port State Control inspection was a factor taken into account it was clarified: it is indeed a factor, scoring 10 points for 6-months, and 20 points for 12 months without being inspected (compared with e.g. 5 points for a "disreputable" flag, 15 points for a detention, and up to 15 points for the number of deficiencies). The point system is set out in a recent EU Directive (98/42/EC).

There is no „criterion" score, as such, for determining whether or not a vessel will be inspected, but the higher the score, the greater the priority to inspect. Of course, lower-scoring vessels are also inspected if too few high-scoring vessels arrive, so as to maintain the 25th quota. There are also „overriding factors" such as reports from pilots or a collision, which indicate a high priority regardless of the value of the target factor.

Concerning the analytical background to the scoring system, no rigorous analysis has either been undertaken or published. However, the Port State Control Committee of the Paris MoU has reviewed and agreed the „formula". An analysis by an MoU Task Force led by the UK of detentions and deficiencies has revealed good correlation with the target factors derived prior to the inspections.

5.1.6 Probabilistic Approach in the Maritime Industry

Summary:

A probabilistic approach in the maritime industry is used for the assessment of the ship subdivision and damage stability. Collisions are common accidents among ships. They are random events and their structural consequences are uncertain. A decision about the location of watertight bulkheads is therefore based on a probabilistic formulation. The probabilistic approach enables to calculate a numerical value that can be related to the level of safety and to the residual risk of ship loss associated with a specific subdivision.

5.1.6.1 Description of the Probabilistic Approach in the Maritime Industry - by Kees Metselaar, The Netherlands

Note: The probabilistic approach is presented in the following for the aspects of subdivision and damage stability of cargo ships. A more detailed introduction of the concept is given by C. Guedes Soares and S. Ferreira in /4/.

General objective

The short description below is applicable to cargo ships over 100 m in length. The objective is to guarantee a certain safety level with respect to the stability of these ships in damaged condition.

Minimum safety level

The minimum safety level with respect to the stability in damaged condition is presented by an index, the so-called required subdivision index R.

R is expressed by a formula:

$$R = (0.002 + 0.0009L^3)^{1/3}$$

Achieved safety level

The achieved safety level is expressed by the attained subdivision index A.

A is expressed by a formula:

$$A = \Sigma\, p_i\, s_i$$

where:

i represents each compartment or group of compartments under consideration

p_i accounts for the probability that only the compartment or group of compartments under consideration may be flooded, disregarding any horizontal subdivision

s_i accounts for the probability of survival after flooding the compartment or group of compartments under consideration, including the effect of any horizontal subdivision.

For the exact calculation reference is made to SOLAS. It is only mentioned here that in the factor p_i the location of the compartment or group of compartments plays an important role. The maximum positive righting lever and the range of positive righting levers (both in damaged condition) play a role in determining s_i .

The attained subdivision index A can be obtained by different subdivision of the ship. This means this methodology gives the designer an opportunity to make a design that fits best to the wishes of the customer.

5.1.7 Quantitative Risk Assessment for Transportation of Hazardous Substances; the Approach Used in the Netherlands

Summary:

In the Netherlands a risk assessment approach has been developed for the application in road, train, pipelines and inland waterway transport. The risk is calculated for the people living along transport routes. Based on specific risk criteria, individual and societal risk is calculated, considering aspects such as volume of transport, substances transported, population data along transport routes, weather effects. Results are displayed as individual risk contours along the transport route and as societal risk curves per kilometer section.

5.1.7.1 Description of Quantitative Risk Assessment for transportation of hazardous substances; the approach used in the Netherlands - by Kees Metselaar, The Netherlands

Introduction

In the Netherlands a risk policy for the transportation of dangerous goods has been developed. This policy is applicable to the transportation by road, train, pipelines and inland waterways and is focused on the hazards that may arise for people living along routes which are used for the transportation of dangerous goods.

As a consequence of this policy a methodology for quick scans of risk levels has been developed.

The risk policy in general

The risk policy is based on two definitions of risk: Individual risk and Societal risk.

Individual risk: The IR represents the probability of a fatal situation occurring at a particular location with regard to the activity in question.

As the distance to the activity in question increases, the risk of (fatal) injury decreases. Locations with identical risk can be connected on a map by means of so-called risk contours (like contour lines on a topographical map). This makes the IR suitable for determining a safe zone between a route and vulnerable functions such as residential areas.

The IR is being used for decision procedures involving transport routes.

Societal risk: The SR gives an indication of the probability of a calamity with a certain number of fatalities occurring.

The number of persons present in the vicinity of a route is essential in determining the value of the SR. Accordingly, the SR indicates locations of importance with regard to possible 'disaster situations'. The aim of checking the SR against the (target) SR value (see below) is to reduce the probability and magnitude of a serious accident.

In the calculation of the SR value all kind of mitigation factors are taken into account as best as possible. SR can be used to get an idea of the seriousness of risks to society.

Risk criteria

Individual risk: limiting value of 10^{-6} per annum for new situations; for existing situations this is a target value. Intervention is necessary when the IR exceeds the value of 10^{-5} per annum.

Societal risk: target values: per km route 10^{-4} per annum for 10 fatalities and 10^{-6} per annum for 100 fatalities (see fig. 5.1.7.2).

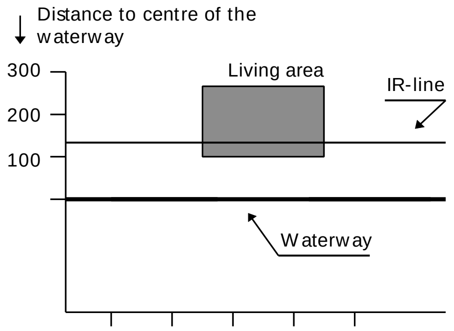

Figure 5.1.7.1: Individual Risk line drawn along a waterway

Part of the living area is inside the IR-line. If this line represents the IR-criterion the risk in that part of the living area is too high.

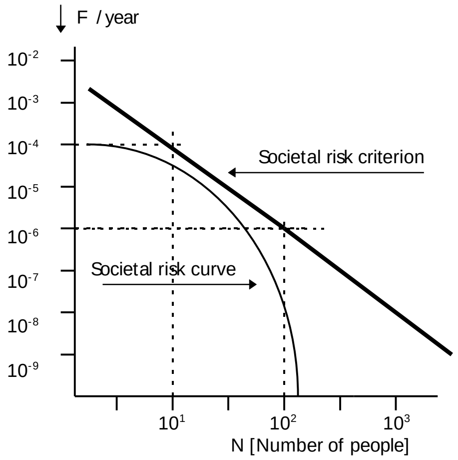

Figure 5.1.7.2: The Societal Risk criterion

General description of the methodology

Introduction:

The first input parameters needed for the calculations are the nature and volume of the transport, which for inland waterways are often obtained from registered lock passages. The substances transported are divided into categories based on their potential for causing fatalities using the UN classification. The calculations are carried out for those categories.

However, in specific individual cases very detailed calculations may be necessary.

Next to information on nature and volume, data on the population along the transport route has to be gathered in order to enable societal risk calculations.

The calculated risk will be compared with the risk criteria in order to determine locations where risk levels, resulting from the transportation of hazardous substances, are such that measures for risk reduction are necessary.

Overview:

The system is described by a certain type of waterway and the annual number of transports per substance category. Accident frequencies are defined per section of the waterway.

From this information the probability of an outflow of a certain magnitude is calculated.

Population density is indicated by rectangles along the waterway with a uniform population density per rectangle. Input parameters include the size of these rectangles, the distance to the waterway and the population density per rectangle.

For the weather that sets the dispersion after a release default values are introduced.

In case of flammable gaseous and liquid substances, an immediate and delayed ignition probability can be defined for minor and major outflows. For delayed ignition calculations one can define whether the ignition probability is dependant on the passage time or not.

The program uses agreed models for the calculation of physical effects and possible damage to people and objects resulting from releases of hazardous substances.

Results are displayed as individual risk contours along the total transport route and as societal risk curves per kilometre section.

5.1.8 Human and Organisational Factors Assessment

Summary:

With regard to the assessment of human and organizational factors several approaches have been identified.

A distinction could be made between:

1) analytical methods concentrating into human errors within a system and
2) methods emphasizing the importance of the management and the environment.

Some methods have already been used in shipping, e.g. for monitoring navigation bridge procedures.

5.1.8.1 Description of human and organisational factors assessment – by Harri Soininen, Finland

Introduction

The current view of safety and risk analysis techniques is that a system under consideration should be understood as a socio-technical entity that is formed of humans, machinery and environment. The focus solely into technology is not any more considered sufficient.

In practice the safety and risk analysis methods applied in navigation as well as in other fields are often quite technology-oriented. One reason for this may be that the study of technology is experienced easier. This, again, is a result of the fact that the focus on methodology development has traditionally been within methods that study technical details of systems. A typical example of a technology based analysis method is the FMEA (Failure Modes and Effects Analysis) presented in the IMO HSC-Code. Another typical example is the HAZOP-method (Hazard and operability study) that is used a lot in process industry for exceptional behaviour examination. Also, these methods can produce information on failures that human behaviour can cause. The human errors in the scenarios of HAZOP and FMEA appear typically as reasons for failures. The human being is considered as a part of the machinery. The technology based methods study the system according technical subsystems (for example a pipeline from the beginning of the process to the end). They are thus not very effective and systematic when the human behaviour is examined.

The Rasmussen model divides the human behaviour into three categories based on the requirements of the tasks to be performed:

- skill based level (routine tasks in a familiar environment)
- rule based level (control of frequent problem situations based on procedures that have been learnt)
- knowledge-based level (complicated actions in unexpected situations)

This categorising is useful in the analysis of complicated systems involving the human element.

Methods used in the Marine Community

Methods emphasising the importance of the management and environment

The Reason model:

Reason (1991) has presented an accident model where errors can be divided into passive and active. The following areas shall be considered:

- the actual human error
- the behaviour of a protection barrier
- the conditions of performance
- the practices and procedures of the organisation

The Reason model has been applied to a research task of the human errors in navigation bridge performance (The Finnish Maritime Administration, 1997):

- the accident is described as a simple chain of events
- each event in the chain is associated with an exceptional human or technical failure, that contributes the proceeding towards the accident
- active errors are the actual causes of an accident and are often easily found, but often not important for the prevention of accidents
- the reason for errors are searched from conditions during the accident (especially available information and the functioning of protection barriers)
- the pressures beyond the shipping company are considered

Accident investigation reports are analysed using this method. The human errors are identified, and the activity or task during which the error occurred are divided into three categories, that in the navigation bridge case are presented in Table 5.1.8.1 (Similar approach can be applied for example for engine and control rooms). Also latent failures are considered. Each cell represents a different type of human error with a different set of root causes and the corresponding set of preventive measures. The method does not produce a numerical index of risks due to human behaviour but clear findings of typical errors and their causes. The method can be extended to evaluation of a route/ship combination.

Table 5.1.8.1: Classification of human errors and the type of task

Task	**Type of human error**		
	Slips	Mistakes	Violations
Planning	Unintended omission of checking the stability of the cargo	Choice of wrong route in an unfamiliar area of sea	Neglection of regular lifeboat practices
Navigating	Failure to see approaching vessel	Collision in an overcrowded harbour	Use of overspeed to return to timetable
Steering	Mishearing of pilot´s instructions	Inappropriate choice of automatic devices	Leaving the bridge unattended

The Method of Performance Influencing Factors:

SINTEF[1] has applied the method of Performance Influencing Factors (PIF) for analysing maritime accident events. The method is used in a present joint Nordic study on safety of HSCs. The causes of accidents are categorised into human errors, hardware failure, payload and external impact. There are various PIFs that may affect the frequency and/or consequence of the accident event categories. The set of PIFs is organised in an hierarchical influence diagram and categorised into various levels:

- direct level
- operational level
- organisational level
- policy level

The relative effects of PIFs on risks are defined by expert judgements. Risk indicators for a specific route are defined for each PIF. The frequency of human error failures is affected by the status of personal performance, operational information and route operating conditions. On direct level, for example, the personal performance is affected by the status of operating procedures, working conditions, man-machine interface on bridge, competence and training etc. On next level, the operational level, the working conditions for example, are affected by working hours, workload, manning etc.

When the PIFs are defined and the numerical values of risk indicators obtained by expert judgements it is possible to calculate the frequency of an accident event due to human errors for a specified route. The human errors are handled in a rather mechanical way - defining the risk indicators includes the analysis of human behaviour.

TRIPOD-Method:

TRIPOD is a method that was developed by SHELL with Manchester and Leiden universities in the late '80s. It is in use at SHELL fleet and it is considered that the implementation of the method has decreased the accident rates significantly. The idea is to study the latent failures. They are categorised into eleven General Failure Types (GFT's):

- Hardware
- Design
- Maintenance management

[1] SINTEF Group, Trondheim, Norway: Activities in research and development for industry and public sector

- Procedures
- Error Enforcing Conditions
- Housekeeping
- Incompatible Goals
- Communications
- Organisation
- Training
- Defences

The safety environment of a ship is studied with a large set of indicator questions given to the target ship for staff onboard to answer. A randomly selected set of twenty questions within each GFT is used. Each question requires a simple yes/no answer. The answers are compared to the preferred answer and a „TRIPOD profile“ of the discrepancies created. The shipboard management team is then asked to consider the three worst GFT's and for each of these to produce three onboard actions that can be dealt with the ship's personnel. The improvement is checked later. The TRIPOD-method is supported by the TRIPOD-beta method that is intended as a tool for incident analysis. The method employs the following two basic models:

- Uncontrolled Hazard + Undefended Target = Incident
- Latent Failure + Precondition + Active Failure = Breached Control of Defence

The basic models are combined to form an „Incident Trajectory“.

Risk management during the operation

The dynamics of process operators´ decision making in a disturbance situation has been studied in a Finnish research programme on reactor safety. A method of analysis of the habit of action was created (AHA). The method comprises of three major phases:

- choice and modelling of the task situation
- observation of the operators´ performance
- evaluation of the dynamics of decision making

The central idea of the method is to define, with a rating tool, the operators´ habits of action which are supposed to regulate the operators´ ways of organising their task performances in dynamic process control simulations. The efficiency of different habits of action can be evaluated by comparing habits of action with adequacy of task performance. The latter is defined according to selected criteria indicating the maintenance of the safe state of the process on a global level. This method has also been used in a Finnish study of the human behaviour in piloting situations, the decision making of the team consisting the pilot and the bridge personnel.

Relevant Methods used in other Industries

Analytical methods concentrating into the human errors within the system

Both methods within this category are used in process industry.

Action Error Analysis:

The purpose of action error analysis is to identify operator errors and propagate their effects on a plant in a systematic manner. The method was developed in the late '70s in Risö. The object of the analysis is consequently a procedure to be carried out in interaction with a more or less complex technical system. Applications include:

- operating procedures
- sequential control
- maintenance and repair

The method consists of the following steps:

- a sequential listing of the individual actions to be carried out by operators
- for each action, the consequences of the action to the plant are noted
- for each action, information is supplemented regarding possible errors and their effects on the system
- for actions leading to serious consequences, possible causal factors and corrective actions are identified

The human errors are categorised in the method to a few categories, for example:

- forgetting the action
- performing the action too early, too late or too strongly

The method is in principle similar to HAZOP or FEMEA. The performance of the operator is studied instead of study of the performance of a technical system. This method is not good enough in analysing performance of the knowledge-based human behaviour.

THERP (Technique for Human Error Rate Prediction):

THERP is a method for human reliability analysis, developed at Sandia National Laboratories in the '70s and '80s. It is considered to be the first qualitative method to study human errors. The method has been employed extensively within the nuclear industry and the development of weapon systems. The human reliability analysis consists of the following steps:

1. Define the system failure of interest - a separate analysis is done for each such failure.
2. Identify and list human operations performed and their relationships to system tasks and functions related to item 1
3. Predict error rates for each relevant human operation in item 2.
4. Determine effect of human errors on system failure rate for item 1.
5. Recommend changes to reduce the system failure rate to an acceptable level and repeat steps 1 - 4.

Human operations and their relationships to tasks and functions of the system are represented by a binary event tree. The probability of following a particular route through the event tree is the product of the probabilities, i.e. the probabilities of human error on all of the tasks, which must be performed correctly to achieve some end result.

Methods emphasising the importance of the management and environment

Both methods in this category have also been used in process industry.

MIMIX (Method of Investigating Management Impact on Causes and Consequences of Specific Hazards):

The method was developed within the TOMHID-project in the early '90s to investigate the impact of human and management factors on plant safety. Selected incident scenarios are analysed, with the intention of identifying critical areas and deficiencies in plant safety management. The idea is to start with events constituting the scenarios, and assessing the task-related human factors and more general management factors that might contribute to the occurrence of these events. The steps of the method are:

- incident scenario selection
- operator interviews (output: list of error- and violating promoting conditions)
- management interviews (output: list of error- and violation-promoting characteristics of managerial activities)
- group working session (output: rated list of corrective acts)
- plans of implementation the proposed improvements

MORT (Management Oversight and Risk Tree):

MORT analysis was developed for the U.S. Energy Research and Development Administration in the late '70s as a safety analysis method that would be compatible with complex, goal-oriented management systems. MORT is a diagram which arranges safety program elements in an orderly manner. It presents a schematic representation of a dynamic, idealised safety system model using fault tree analysis methodology. The method considers an undesired event resulting from oversights and omissions or from assumed risks or both. The next hierarchy level divides the risks that occur through oversight and omission to accident specific factors and general management system factors. The next hierarchy level divides the accident specific factors in three areas: factors relating to the control of potential targets of accidents; factors relating to the control of hazards which initiate accidents; and factors relating to the control of procedural and physical barriers intended to prevent accidents. Management factors have also been developed in three areas. These include the establishment of policy, the implementation of established policy and risk assessment or evaluation.

Utilization of Human and Organisational Factor Methods within Risk Studies

In figure 5.1 the typical steps of a general approach to analyse, assess and manage risk were presented in a flow chart. The following list describes, in which of the steps the above described human and organisational factors methods can be applied.

It should be noted that all methods are listed, not only the ones applied in the maritime industry.

Hazard identification	Action Error Analysis THERP
Consequence calculation	Action Error Analysis THERP
Technical/Human Risk assessment	MIMIX MORT Reason model PIF-method TRIPOD
Risk management	Reason model AHA-method TRIPOD

5.1.9 Review of Current Assessment Practice in Shipping

A review of the current assessment practices in shipping found that safety and environmental impact is currently dealt with mostly by complying with prescriptive rules and regulations and that risk based assessment approaches are currently not playing a major role in this industry. However, it was also found that some actors in shipping also use assessment techniques to address safety and environmental risks in a more comprehensive way. The following table presents the review of the current assessment practices for major actors in shipping.

Potential users	Current assessment practice
Ship owners	The needs are taken care of by complying with existing regulations from flag states, port states, classification societies and other relevant regulatory bodies. Own and industry wide experience with suppliers and reliability of their components/services, systems and operations (historical data) is utilised when negotiating the ship's design with the yard.

Potential users	Current assessment practice
Ship yards, Suppliers	Assessment/design by complying with safety / environmental requirements from flag states, classification societies, and regional authorities. Dealing with many different requirements on a ship to ship case basis. Risk analyses, requested by the ship owner, are performed for LNG tankers and passenger ships on a case by case basis.
Charterers	Vetting schemes to assess the risk inherent with chartering a specific ship are being used by several charterers, such as oil companies. These include (ship/shore) auditing of the organization responsible for the vessel's management with respect to effective vessel management and adequate response in emergency situations.
Ship owner associations	Ship owner associations assess risk in different ways. They represent the owners towards the authorities and the public, and take a supportive role for their members, assisting them in dealing with rules and regulations. Associations would also assess risk through statistical analyses and overviews to identify and pinpoint problem areas or to check safety and environmental standard of ship transport in relation to other transport alternatives.
Insurance companies	Risk evaluation based on statistics and experience with respect to: Damage record of ship operator, management of ship operator, size of ship, type of cargo, quality of ship, etc. As in many cases inspection of the ship's quality is not possible when insurance coverage is needed (vessel on voyage), insurers rely on the quality assessment through inspections of the responsible classification society. Insurance fees are not only dependent on the estimated operational risk but are also significantly influenced by competition within the insurance market. The frequency and size of claims is used as a criteria for adjustment of the deductible (part of claim to be paid by the insured party)
Financial organisations	Financial organizations will normally assess risk [2] by documented compliance with rules and regulations. They are also likely to assess the quality of the ship owner/operator.
P&I Clubs	Statistical evaluation is assumed to be the main approach to risk. Many P&I-Clubs also evaluate the risk by a Condition Survey and a Ship Vetting. The latter is concentrating on the onboard management and communication, the ship to shore communication, surveillance intensity by the ship owner, quality of operation. The fee of a member is calculated by taking into account: Damage record of past years, ship type, age of ship, flying flag, crew structure and crew manning, type of cargo, sailing area, experience and quality of ship owner's/operator's management.

[2] Assessment performed with regard to economic risk, no safety assessment

Potential users	Current assessment practice
Port authorities	Ports normally assess risk by checking documented compliance with rules and regulations. Some ports also take into account other safety documentation, e.g. by reducing the port fee for ships holding the Green Award Certificate, which is based on an environmental assessment of the ship and its operation. In UK: environmental risk assessment performed by port authorities in order to develop emergency response plans.
Flag states	Flag states address risk through their development of own rules and regulations, and in contributing to development of international rules, e.g. the ISM Code. Flag states also address risk by checking documented compliance with the same rules and regulations. In the U.S.A.: New regulations should be based on risk analysis
Environmental authorities	Environmental authorities take part - in the development of rules and regulations by e.g. requesting environmental impact studies, - and the monitoring of ship traffic with respect to rules and regulations (presumption).
Regional (waterway) authorities	Coast guards and other waterway authorities address risk by monitoring traffic and by checking documented compliance with rules and regulations when relevant.
Classification societies	Risk assessment according to fulfilment of own rules. Rules developed and maintained through: Reacting on experienced safety design deficiencies, reliability performance of systems/components on classified ships, utilizing research results in rules, reacting on incidents/accidents, incorporating safety & environmental requirements from IMO-Conventions and EU-directives in their rules. IACS adjust different safety requirements from their member societies by development of IACS Unified Requirements. In the last years systematic risk assessment methods have been used more frequently for the rule development process.

5.2 Risk Assessment Approaches in Other Industries

5.2.1 Summary

Assessment approaches used in other industries were identified and described in order to utilize experience from these industries. Aviation, nuclear, offshore, process and railway industries were reviewed. It was found that all these industries use risk based assessment approaches, some of them for many years. Differences and similarities between these industries and shipping were discussed.

Possible reasons for the identified differences in the ways of dealing with safety and environmental issues between shipping and other industries were discussed, and it was suggested that major reasons may be that shipping is characterised by short design- and manufacturing time and international operations in different environmental conditions and social, economic and legal environments.

5.2.2 Offshore Regulations and Risk Assessment - by R. Skjong, Norway

Within the offshore industry in Norway risk analysis has been used since the early 1980s, and is required by regulations since 1986. Risk analyses are to be carried out in order to identify risks, implement risk reducing measures, and to alert operators to the risks connected with their activities. This legislation requires that the authorities be allowed insight into the decision-making processes of the individual enterprise, including policies and target safety levels, and that they have access to all safety relevant documentation. The authorities then act on situations that are considered not acceptable, but do not approve the documentation or the safety targets - this is the responsibility of the owner. The approach is called „self-regulatory".

The Norwegian offshore regulations are designed to reflect that the licensees have full responsibility for the activity.

The initial legislation from the seventies was technically oriented, and rather detailed and prescriptive. The development has been in a direction of functional and goal oriented regulations. Most of the current regulations were developed in the early nineties. They are split into Regulations and Guidelines. The Regulations contain the mandatory requirements and the guidelines represent one method to fulfil the requirements of the regulations.

Quantitative Risk Analysis (QRA) techniques were first applied in the early eighties, where the Concept Safety Evaluations (CSE) studies played an important role, since they were integrated in the early project evaluation. The guidelines introduced a cut-off criterion to the impairment frequency for nine different accident categories. The cut-off was set at an annual probability of 0.001, indicating a system cut-off of less than 0.0001.

At the time this quantitative safety target was introduced this was quite revolutionary. Now, there is a general consensus that although the criteria was not 'well thought of' the criteria contributed to a focus on using formalised techniques. It is believed that the implementation of risk assessment would be much slower without explicit criteria. The negative effect was that the criteria lead to much number crunching, which was of little relevance to safety. The new regulation of 1990 is more process focused. The As Low As Reasonably a Practicable (ALARP) criterion is adopted and there is focus on continuous improvement over time.

The UK Safety Case regulations (1992), which came into force as a response to the *Piper Alpha* disaster, are similar to the Norwegian industrial self-regulation regime. The primary difference is that the Safety Case is subject to review and approval by the Health and Safety Executive.

It is required that all operators of offshore installations prepare a Safety Case and submit this to the Health and Safety Executive (HSE). The first 200 safety cases were completed in October 1993. The content of the safety case is two basic elements.

- The safety case must demonstrate that all major hazards have been identified, and that measures have been taken to reduce the risk to persons from these hazards to As Low As Reasonably Practicable. Risks are quantified as 'intolerable', 'broadly acceptable'. In between is the ALARP region where cost effectiveness criteria applies. Unless the costs of reducing the risk are in gross disproportion to the expenses, the operator is expected to implement the safety measure.
- An effective system for the management of health and safety, controlling risk through the lifetime.

The updated Safety Case regulation of 1995 include the 'Prevention of Fire and Explosion, and Emergency Response (the PEEFER Regulations).

Prior to 1995 the regulations stated that 'HSE will look for a demonstration that the frequency with which accidental events will result in loss of the integrity of temporary refuge, within the minimum endurance time stated in the Safety Case, does not exceed the order of 1 in 1000 per year'. Similar to first version of the Norwegian regulations this served as a focal point of most QRA.

In UK, as in Norway, QRA was used some years prior to the actual implementation in the regulations. The widespread attention was gained when the HSE Safety Case Regulation of 1992 was issued. In practice the use of QRA is very similar in the UK and Norwegian offshore regimes. However, there are a few noticeable differences relating to:

- The approval process

- Some differences in the acceptance criteria (The three risk regions approach is most common in UK, specific targets in Norway)
- The focus in terms of risk categories be somewhat different (UK: personnel Risk, Norway: Personnel, assets, and Environmental risk)

5.2.3 Aviation Industry - by J. Peachey, United Kingdom

Note: *The following information is based on a paper titled "Risk Assessment in Civil Aviation" by Adran G. Sayce, Head, Safety Analysis, Safety Regulation Group (SRG), Civil Aviation Authority, UK. (The views expressed in this Paper are those of the author and not necessarily those of Civil Aviation Industry, UK.)*

Introduction

This following text describes how a regulator has promoted the use of risk assessment techniques over the years and proposes a basic risk assessment process. It finally describes how it assesses risks when analysing Mandatory Occurrence Reports (MORs) and Global Fatal Accidents.

Background

The UK aviation industry has been at the forefront of the application of probabilistic safety assessment techniques for many years. This did not happen by chance but resulted from dramatic aviation events that occurred in the 1950's (eg. catastrophic structural failures of early Comet jets, severe engine icing problems on the Britannia). These and similar events had a profound effect on the UK aircraft industry and it was recognised in the early 1960's that if future projects, such as the Concorde, had similar in-service problems to the Comet and Britannia, the UK aircraft industry would not survive. To avoid this, the regulator and industry actively promoted the principles of reliability and redundancy for civil aircraft systems and structures.

Over the past 30 years, aviation safety has benefited from the application of risk assessment techniques. Not only are today's transport aircraft some 300% more productive in terms of their revenue passenger and cargo-carrying performance, but they are now some 10 times safer in terms of the fatal accidents per flight. Aviation has transformed from an adventurous activity enjoyed by a select few to a stable mass-market service industry which is largely taken for granted, until things go wrong. When they do, the level of media attention can be exceptional and the public often demands higher safety standards. The management of aviation safety can then become dominated by issues of social amplification and public perception of risk.

With the pressures of growth on the air transport system combined with the increased public expectation for higher safety and fewer technological solutions, the emphasis is now more on the monitoring of the air transport system to identify and address problem areas before they become disasters. This is a truly proactive approach and is, probably, the greatest challenge for aviation safety faced by regulators and the regulated throughout the world.

Risk Assessment Techniques in Aviation

A common measure of aviation safety is the number of fatal accidents per million flights. In the late 1950s, the fatal accident rate for western-built passenger jet aircraft was more than 5 per million flights (ie. $5x10^{-6}$). This reduced to $1x10^{-6}$ in 1980 and is currently just below $0.5x10^{-6}$. In terms of the fatal accident rate *per flight hour* the rate has reduced from about $4x10^{-6}$ in 1960 to $0.3x10^{-6}$ in 1995.

In the late 1950s a fatal accident rate of $1x10^{-6}$ was judged to be a reasonable target for the overall air transport system and safety assessments were initially used to assess auto-land systems. For aircraft today, all systems and equipment are required to show compliance with the safety standards shown in Table 5.2.3.1. This safety assessment framework is contained in the European Joint Aviation Requirement (JAR) design code Part 25 [3] under section JAR 25.1309, as promulgated by the European Joint Aviation Authorities (JAA). This standard was

[3] Joint Aviation Authorities. *Joint Aviation Requirements JAR-25 Large Aeroplanes*

originally developed in the 1970s and has now been adopted in some other aviation fields such as for ground landing aids, and for some aerodrome standards.

The table 5.2.3.1. presents the probability requirements in both quantitative and qualitative forms so that they can be applied to a range of subjects. This is the fundamental aviation safety assessment framework and without it the significant improvements in aviation reliability, performance and safety over the past 30 years would not have been made.

Table 5.2.3.1: - Relationship between Probability and Severity of Failure Condition.

Probability (Quantitative)	**1**	**$1x10^{-3}$**	**$1x10^{-5}$**	**$1x10^{-7}$**	**$1x10^{-9}$**
Probability (Descriptive)	***Frequent***	***Reasonably Probable***	***Remote***	***Extremely Remote***	***Extremely Improbable***
Failure Condition Severity Classification		Minor	Major	Hazardous	Catastrophic
Failure Condition Effect (Qualitative)	-Normal	-Nuisance -Slight reduction in safety margins -Slight increase in crew workload -Some inconven-ience to occupants -Operating limitations -Emergency proce-dures	-Significant reduction in safety margins or functional capabilities -Significant increase in crew workload or in conditions impairing crew efficiency -Some discomfort to occupants	-Large reduction in safety margins of functional capabilities -Higher workload or physical distress such that the crew could not be relied upon to perform tasks accurately or completely -Adverse effects on occupants	-All failure conditions which prevent continued safe flight and landing

The application of this statistical safety assessment method requires the definition of an overall ‘risk budget’ for the air transport system. It assumes that 1 in 10 fatal accidents are the result of a catastrophic system or equipment failure and that all such failures must not combine to give a failure rate of $1x10^{-7}$. In addition, it assumes that a typical aircraft has 100 potentially catastrophic failure conditions and each with a failure rate of better than $1x10^{-9}$.

The JAR 25.1309 safety assessment framework has served the industry well, but as the original goal of $1x10^{-6}$ was achieved some time ago it may be necessary in the future to review the numerical targets used in the framework. A greater challenge for the industry would be to quantify more accurately the human element in the overall ‘system’ risk. This would enable a more systematic approach to minimising failures resulting from human error.

A Basis Risk Assessment Process

Where risk assessments are required in areas other than aircraft design, such as airline operations, aerodromes, ATC facilities, it is important that a consistent and simple risk assessment methodology is adopted. Without such an approach it is likely that a risk assessment will become unduly complex and costly and the whole process may be discredited by the costs and resources being disproportionate to the risks being addressed. A basic risk assessment process is being promoted by the Safety Regulation Group (SRG) for wider use, particularly as the UK operating industry is now encouraged to adopt formal Safety Management Systems as part of there normal day-to-day business processes. For further details reference is made to /4/.

Aviation Safety Monitoring in UK

In most many major accidents there have been precursors, which, if acted upon, would have prevented the accident. To address this in the UK, there has been a Mandatory Occurrence Reporting Scheme in operation for the past 20 years (an 'occurrence' is defined as any hazardous or potentially hazardous event and embraces both incidents and accidents). All UK public transport aircraft operators, aircraft/equipment manufacturers, maintenance and air traffic control organisations are legally required to report occurrences to the SRG within 96 hours. These reports are recorded on a database in both text and coded forms which permits routine investigations and detailed analyses to be carried out by other specialist staff. Each year, over 5000 occurrences are recorded.

About two years ago, SRG examined how it could improve business effectiveness by making better use of occurrence reports and it has now developed an Occurrence Grading Process to enable SRG to:

- quantify aviation hazards more objectively,
- identify significant safety hazards,
- provide a basis for new SRG safety performance measures,
- provide direction for the SRG safety research programme, and
- provide better management information on aviation safety.

The Process employs a matrix in which the two elements of risk are formally assessed - the *Severity* and the *Probability* of the event recurring as shown in table 5.2.3.2. Criteria for both Severity and Probability are based on JAR 25.1309 definitions and the process has been applied to occurrence reports received by SRG since 1st April 1996.

Table 5.2.3.2: - Coding System used in Occurrence Grading Process

SEVERITY	SEVERE A	A1	A2	A3
	HIGH B	B1	B2	B3
	MEDIUM C	C1	C2	C3
	LOW D	D1	D2	D3
		1 HIGH	2 MEDIUM	3 LOW
		PROBABILITY		

The results of the grading process are now being used by SRG to monitor various trends in the UK air transport system.

<u>Review of Global Fatal Accidents</u>

It is important that a regulator can influences others and makes policy decisions from an informed position. Over the past 2 years, SRG has developed a methodology to systematically review world-wide fatal accidents since 1980 involving large passenger aircraft. The aim of this review has been to systematically extract safety related information from past accidents so that lessons can be learnt and safety strategies developed to reduce the worldwide fatal accident rate.

The conclusions of the review are of greatest value and are being used by SRG to develop safety improvement strategies as part of its annual business planning process.

5.2.4 Railway Industry - by J. Peachey, United Kingdom

Note: The following sections describe the approach used in the UK railway industry as an example for risk based approach in a European railway industry.

The Context in which risk assessment tools and techniques are used within the railways is set by the legislation of the country. Many of the actual tools and techniques are developments of those used in the nuclear and process industries and include those from the field of reliability.

There are a number of levels of risk assessment ranging from simple 5x5 risk ranking tools used in occupational health and safety assessments to sophisticated predictive mathematical models. The main challenge of undertaking a risk assessment is to ensure it is ‘suitable and sufficient’ for the specific circumstances in which it is applied and for which decisions it is used.

<u>Legislation</u>

The significant pieces of legislation, which affect the application of risk assessment, are;

- Health and Safety at Work etc. Act 1974
- Management of Health and Safety Regulations 1992
- Railways (Safety Case) Regulations 1994

The H&SAW Act require that risks due to undertaking an activity be reduced, to employees and those affected by the undertaking, 'so far as is reasonably practicable'. The MH&SAW Reg. requires that risk assessments be undertaken. The Railway (Safety Case) Regulations set the frame work under which the Infrastructure Controller (e.g. Railtrack) produces a Railway Safety Case in which they describe the activity and its scope that they undertake, the hazards and risks that may result and most importantly how they will control this risk. The significant part of the safety case is the explanation of the hazards and risks and the management system for ensuring they are controlled.

Safety Cases

Railtrack in its Railway Safety Case has identified the hazards due to its operations under the headings; train accidents, movement accidents and non-movement accidents. Within the policy section it describes how it tolerates risks and how it determines what is 'reasonably practicable' in risk reduction. Train Operating Companies (TOC's) are required to produce Railway Safety Cases which explain their activities, risks, hazards and risk control processes. These map onto that of the Infrastructure Controller on whose network they operate and have to be accepted by them. The Infrastructure Controller Railway Safety Case describes how it accepts the Railway Safety Case (RSC) of a TOC. RSC's are the backbone of Safety Management on the railways and other safety activities derive from them.

Railway Group Standards

Under the RSC the Infrastructure Controller and TOC's are required by law to comply with Railway Group Standards (RGS's). These are managed by the Safety & Standards Directorate of Railtrack. These set out the framework and minimum levels of safety to be attained. As part of the determination of what level these standards should be set, Safety Justifications are developed which are specific risk assessments of the situation and issue and determine what is 'reasonably practicable' control to reduce risk. These use a wide variety of risk assessment tools and techniques, from qualitative discussion of the hazards, risks and control measures to detailed modelling and cost benefit analysis calculations. However they do not necessarily demonstrate that a specific risk has been reduced 'so far as is reasonably practicable' but just rather that the specific control is 'reasonably practicable'. A recent exercise undertaken to understand better the controls provided by the historically developed RGS's was the production of a Risk Control Matrix, mapping the hazards and risks of Railtrack RSC on to RGS's control of them. This was done in a judgmental and qualitative manner by the managers who understand and maintain the standards and provided a useful oversight of the control regime and whether there maybe; over control in some areas, a lack of control or even scope for combining controls. This work, with that of producing Safety Justifications is ongoing.

Risk Assessment Tools

Many different risk assessment tools and techniques have been applied in the railways. For day to day occupational health and safety task risk assessments the common 5x5 severity vs. likelihood is applied. However this approach has been applied for system risk assessments on occasions for which it is less appropriate. The 5x5 approach is ideal for 'rough and ready' risk a ranking exercises when only one person is exposed to the hazard or the exact numbers exposed is not so important.

A number of risk models have been developed to assess risk of specific issues, these have included;

- level crossings
- track safety
- bridge bashes
- Layout Risk Method
- Line of Route

Each of these has used the principles of fault and event trees (sometimes called cause - consequence) and analysis of historical data to determine the risk. For further details on these models reference is made to /4/.

5.2.5 Probabilistic Safety Assessment (PSA) for Nuclear Power Plants - by C. Vivalda, France

Scope

Scope of the current chapter is to present the approach followed by the Nuclear Industry for safety evaluation of Nuclear Power Plants. According to the common terminology, this approach is named Probabilistic Safety Assessment (PSA) and its first comprehensive application dates back to 1975 to the United States Nuclear Regulatory Commission's Reactor Safety Study (WASH 1400).

Probabilistic Safety Assessment

Probabilistic Safety Assessment techniques have become a standard tool in safety evaluation of nuclear power plants since 1975. The main benefit of PSA is to provide insights into plant design, performance and environmental impacts, including the identification of *dominant risk contributors* and the comparison of *options for reducing risk*. PSA provides a consistent and integrated model of nuclear power plant safety. Consequently, PSA offers a consistent and integrated framework for safety related to *decision making*. Changes or alternatives in different design and engineering areas in the nuclear power plant can be compared on a common basis, namely the quantitative estimate of risk provided by PSAs. Furthermore, PSA is a conceptual and mathematical tool for deriving numerical estimates of risk for nuclear plants and industrial installations in general. PSA can also estimate the uncertainties of these estimates. PSA methods continue to develop and improvements will reduce uncertainties; however, present PSA methods are quite capable of providing meaningful numerical results.

PSA differs from traditional deterministic safety analysis in that it provides a methodological approach to identifying accident sequences that can follow from a broad range of initiating events and it includes the systematic and realistic determination of accident frequencies and consequences. A major advantage of PSA is that it allows for the *quantification of uncertainties in safety assessment* together with *the quantification of expert opinion and/or judgement*. Finally, PSA has been shown to provide important safety insights in addition to those provided by deterministic analysis.

In international practice three levels of PSA have involved:

Level 1: The assessment of plant failures leading to the determination of core damage frequency.

Level 2: The assessment of containment response leading, together Level 1 results, to the determination of containment release frequencies.

Level 3: The assessment of off-site consequences leading, together with the results of Level 2 analysis, to estimate the public risks.

A **Level 1** PSA provides insights into the design weakness and into ways of preventing *core damage*, which in most cases is the precursor to accidents leading to major radioactive releases with potential health and environmental consequences.

A **Level 2** PSA provides additional insights into the relative importance of accident sequences leading to core damage in term of severity of the *radioactive releases* they might cause, and insight into weaknesses in and ways of improving the mitigation and management of core damage accidents.

Finally, a **Level 3** PSA provides insights into the relative importance of prevention and mitigation measures expresses in terms of the *adverse consequences* of the *health of both plant workers and the public*, and the *contamination of land, air, water, and foodstuffs*. In addition, a Level 3 PSA provides insights into the relative effectiveness of accident management related to emergency response planning.

PSA can provide useful insights and inputs to decision on:

1. design and back-fitting ;
2. plant operations ;
3. safety analysis and research ;

4. regulatory issues.

<u>Objectives of PSA</u>

The general objectives of a PSA, which is considered as one of the most efficient and effective tools to assist decision making for safety and risk management in nuclear power plants, can be summarised as follows.

Objective 1: to assess the level of safety of the plant and to identify the **most effective areas for improvement.**
The specific objectives are the following:

- identification of dominant accident sequence;
- identification of systems, components, and human actions important for safety;
- assessment of important dependencies(system and man-machines) ;
- identification and evaluation of new safety issues;
- analysis of severe accidents ;
- decision on back-fitting of generic and plant specific items ;
- design modifications ;
- prioritisation of regulations and safety research.

Objective 2: to assess the level of safety and compare it with **explicit** or **implicit standards**.
The specific objectives are the following:

- comparison with target values;
- comparison with accepted design;
- comparison of alternative design.

Objective 3: to assess the level of safety to assist **plant operation**.
The specific objectives are the following:

- evaluation of plant technical specifications and limiting conditions of operations;
- prioritisation of inspection/testing activities;
- evaluation of operation experiences;
- accident management.

<u>Stages of the plant life-cycle</u>

A PSA can be performed at any stage of plant life cycle, namely:

- the plant at *conceptually/early design stage*;
- the plant at the *final design stage*;
- the *operating plant*.

It is generally considered desirable to start the PSA process as early in the plant life-cycle as possible. Design and procedural weaknesses that are recognised early can be corrected or improved less expensively than those that remain until the plant is in operation. It is also recommended that the PSA models and documentation be maintained and updated throughout the operating life of the plant to provide continued benefit.

A PSA study is normally commissioned by one of the following:

- the plant designer;
- the utility;
- the regulatory body.

5.2.6 Risk Assessment Approaches in the Process Industry - by H. Soininen

Development of risk assessment techniques

The requirements set for safety analysis in the chemical industry differ to some extent from those defined e.g. in the nuclear branch. The fact that process plants are more versatile in many respects implies that more emphasis must be allocated to the identification of accident contributors and to the modelling of accidents. Methodological development in the new field of application was needed, and it began in the early 1960s when the Mond Division of ICI, a private company, developed the first version of a method called Hazard and Operability Study (HAZOP). HAZOP is now one of the best known and most widely used safety analysis methods within the chemical industries.

The early applications of safety analysis outside the nuclear industry were mainly voluntary, and were based on the motivation of and benefits perceived by the industrial enterprises themselves. Critical examinations of plants even as early as at the design stage began to be practised. While this was the state of affairs, two serious accidents occurred in the chemical industry, those at Flixborough in June 1974 and at Seveso in July 1976. They led the Commission of the European Communities (EC) to prepare the Council Directive on the Major Accident Hazards of Certain Industrial Activities, which is generally known as the Seveso Directive.

Major industrial accident hazards related to chemical substances (Seveso Directive)

The Seveso Directive does not say anything about how the hazards should be identified and assessed. Implementation of the Directive in the Netherlands has meant that the provision of a complete quantitative safety analysis has become an obligatory part of licensing procedures for the industrial activities falling under the Directive. The rest of the EC Member States, however, have adopted less stringent requirements with respect to quantification in their safety analyses. Also in the USA, federal, state and local legislation is increasingly obliging the owners of chemical facilities to undertake a variety of activities with respect to risk management including e.g. assessment of the risks, in some cases by using qualitative methods such as HAZOP, and in other instances by applying quantitative methods.

In Finland a hierarchical approach is suggested (site level analysis, plant level analysis, detailed analyses of selected parts and units of the process) when preparing safety reports on large and complex sites. The site and plant level analyses are carried out by applying a coarse hazard identification method and a coarse hierarchical description of the site and its plants for that purpose. The detailed analyses of selected parts and units of the process (the selection is based on the results of the site and plant level analyses) are carried out using traditional safety analysis methods. Such methods include e.g.:

- Reaction Matrix
- Hazard and Operability Study (HAZOP)
- Failure Mode and Effects Analysis (FMEA)
- Action Error Analysis (AEA)
- Work Safety Analysis (WSA)
- Management Oversight and Risk Tree (MORT)
- Fault Tree Analysis
- Event Tree Analysis
- Consequence Analysis (consequences of chemical releases)

Other hazards

The legislation referred to above applies to major accidents typically involving multiple fatalities, and it covers only certain industrial activities provided that certain amounts of certain dangerous substances are used. However, it has been argued that major accidents are not a very significant factor in the overall picture of accidents. About 80% of all fatalities even within the chemical and petroleum industries occur singly. Recent developments in European legislation seem to appreciate the importance of preventing accidents of a more common nature, too.

Extensive development of safety legislation and safety standards relating to machinery manufacturing and design is in progress in Europe, within the EC. One of the basic thrusts to this development is to remove the trade barriers caused by disparities in the legislative systems of the Member States regarding accident prevention. A so-called "new approach" has been applied during the process of developing safety regulations; it includes introducing a generally worded Machinery Safety Directive, defining only the essential health and safety requirements of general application, as a binding document and an umbrella for standards of three different levels of detail. The role of the related standardisation then is, in a non-binding manner, to codify the "state of the art" as regards the means to be applied to satisfy the obligations laid down by the essential requirements presented in the Directive.

The Machinery Safety Directive was published in 1989 and has been amended in 1991. In the Member States, the national laws and regulations to comply with the Directive came into force at the end of 1992. The field of application of the Directive covers a very broad area, from individual machines of very simple design to complex installations. The Directive and the extensive amount of related standards, many of which are currently under development, are specially concerned with the role of designers. The Directive and the related standards also emphasise the importance of product documentation and the need for adequate instructions. The risk assessment standard EN1050 (1996) includes an explicit reference to e.g. such safety analysis methods as Preliminary Hazard Analysis (PHA), Failure Mode and Effects Analysis (FMEA), Hazard and Operability Study (HAZOP) and Fault Tree Analysis (FTA).

Methods for risk assessment

Detailed descriptions of various analysis methods as well as advice on their selection and use in the process industries can be found e.g. in Guidelines... (1992). The methods included are:

- Checklist Analysis
- Relative Ranking
- Preliminary Hazard Analysis
- What-If Analysis
- What-If/Checklist Analysis
- Hazard and Operability Analysis
- Failure Modes and Effects Analysis
- Fault Tree Analysis
- Event Tree Analysis
- Cause-Consequence Analysis
- Human Reliability Analysis

Most of the methods are technology oriented and consider the human being as one part of a machinery. The modern view is to consider the whole sociotechnical system. The most common quantitative methods are perhaps the fault and event tree analysis.

5.3 Evaluation of Assessment Methods

5.3.1 Summary

The identified assessment methods in chapter 5.1 were evaluated regarding their suitability to cover the assessment needs of potential users in the shipping community. It was found that there exist many different users with different needs and decision problems regarding safety and environmental assessments. They are listed in chapter 5.3.2.

Due to this fact it was concluded from the evaluation exercise that no single method is capable of covering all the essential safety and environmental problems and needs in shipping. Therefore, the original expectation in the project that a single common methodology, able to serve all the needs, could be developed was considered to be unrealistic.

However, it was concluded that instead of a single common "methodology" - a common European "approach" could be established. This approach should be based on an optimal combination of methods. Before such a combination can be identified and defined it was found necessary to investigate the current and future needs of the potential users in more detail.

5.3.2 Potential Users of Assessment Approaches and Their Needs

The safety and environmental assessment approaches identified in the poject and described in chapter 5.1. have been developed to serve particular needs of actors within the maritime Community. Some of these approaches are still under development, others are already in use.

Trying to find a common approach it was useful to evaluate, how suitable each approach is with regard to covering existing needs of users/actors in the shipping field.

Therefore, in a first step, potential users of the approaches were identified. In a second step users' needs with regard to assess safety and environmental impacts of ship operations and corresponding decision making were specified.

The result of this analysis is presented in the table below.

Potential users	Needs/decision/problems
Ship owners	1. Selection of ship design options 2. Safety design optimisation 3. Seeking exemptions or equivalencies to prescriptive regulations 4. Negotiation with yards 5. Negotiations with insurance companies 6. Safety system investments 7. Support for safety management investigations/ decisions 8. ISM compliance 9. Pollution avoidance 10. Crew training 11. Training in routine operations and emergency preparedness 12. Accident and incident investigation 13. Database structuring and incident/accident information collection and archiving
Ship owner associations	1. Evaluation of fleets 2. Developing codes of good practice 3. Advisory actions 4. Persuasive activities
Charterers	1. Acceptance/refusal of ships 2. Targeting Port State Control inspections and other surveys
Ship managers	1. ISM compliance 2. Pollution avoidance 3. Crew training 4. Training in routine operations and emergency preparedness
Ship yards	1. Design development 2. Design optimisation
Classification societies	1. Proactive approach to assess ship design safety 2. Tool for (safety) equivalency evaluations 3. Acceptance/Refusal of ships' safety design 4. Tool for rule development/adjustment 5. Accident and incident investigation

Potential users	Needs/decision/problems
	6. Targeting Port State Control inspections and other surveys
Financial organisations	1. Information on a ship's risks 2. Acceptance/refusal of financing 3. Interest estimation/ adjustments
P&I Clubs	1. Information on/assessment of (ship type specific) risks 2. Acceptance/refusal of shipping companies 3. Evaluation of fleets 4. Developing codes of good practice 5. Loss reduction campaigns 6. Targeting Port State Control inspections and other surveys
Insurance companies	1. Information on/assessment of ship's risks 2. Acceptance/refusal of ships 3. Premium estimation/ adjustments 4. Developing codes of good practice 5. Loss reduction campaigns 6. Advisory activities
Ship sale and purchase brokers	1. Support for acceptance/refusal of ships 2. Advisory activities 3. Marketing
Port authorities	1. Assessment of (ship type specific) risks (e.g. to optimize checklists for port state control surveys) 2. Acceptance/refusal of ships 3. Fee estimation/adjustments 4. Pollution avoidance 5. Fulfilling national/local requirements for contingency planning, and provision of emergency services 6. Targeting Port State Control inspections and other surveys 7. Policy setting
Flag states	1. Information on/assessment of risks 2. Decision on safety regulations (through IMO) 3. Database structuring and incident/accident information collection and archiving
Environmental authorities	1. Information on/assessment of risks in certain areas (e.g. coastal) 2. Acceptance/refusal of ships 3. Accident and incident investigation
National governments,	1. Policy setting
Regional governments	1. Policy setting
Regional (waterway) authorities	1. Information on/assessment of risks in certain areas (e.g. coastal) 2. Acceptance/refusal of ships 3. Pollution avoidance 4. Fulfilling national/local requirements for contingency planning, and provision of emergency services

Potential users	Needs/decision/problems
	5. Policy setting
EU	1. Policy setting
IMO	1. Policy setting 2. Database structuring and incident/accident information collection and archiving
Maritime research organisations	1. Support for ship design and operation development/improvement
Seafarer training and other maritime educational establishments (including universities)	1. Crew training 2. Training in routine operations and emergency preparedness
Accident/incident database managers	1. Database structuring and incident/accident information collection and archiving
Search and rescue (SAR) organisations	1. Training in routine operations and emergency preparedness 2. Fulfilling national/local requirements for contingency planning, and provision of emergency services
Consumer and environmental pressure groups	1. Persuasive activities
Political advisors (e.g. members of EU parliament)	1. Policy setting

Table 5.3.2.1 Potential users of assessment approaches and their needs

5.3.3 Evaluation Process and Results

Having identified the specific needs and decision problems of potential users the assessment approaches listed in chapter 5.1 were evaluated with the aim to find out to what extent the particular needs of potential users would be covered by each approach.

There are several results achievable from such evaluation:

1. Clarification which needs/decision problems are served best by each approach, i.e. which approach is most suitable for a particular user
2. Clarification which approach covers the most needs/decision problems
3. Clarification which needs/decision problems are not or insufficiently covered

The evaluation was performed by assessing the coverage of needs/decision problems using the following five terms: No use, low, medium, high coverage, not known. The last term was used whenever it was not clear, what coverage of a particular need/decision problem was possible with the approach under evaluation.

It should be noted that the evaluations were performed each by an individual expert. The results of that evaluation process mainly represent the view of this individual expert, not necessarily of all participants.

In order to highlight which of the evaluated approaches covers the needs best, a summary table has been prepared, including the results of each particular evaluation. This is presented in table 5.3.3.1. The evaluation results for each individual approach are given in /4/.

Table 5.3.3.1 Summary of Evaluation

Note:

1. For FSA and Safety Case the evaluation was restricted to high coverage of user needs only.
2. Human and organisation factors methods are indicated generally as HF. The specification of which of the several HF-methods is meant, is given in the column "remarks".

Needs/Decision problems	Potent. users	No use	Low	Medi um	High	Not known	Further explanations
Acceptance/Refusal of ships' safety design	CS	GA, HF		IM	SC		
Seeking exemptions or equivalencies to prescriptive regulations	SO	HF, ERA	GA	EI	EA, LCA, FSA, SC	IM	
Tool for (safety) equivalency evaluations	SO,CS		GA	HF	IM, FSA, SC		AEA, THERP
Support for design negotiations with yards	SO	HF		GA, IM	SC		
Supportive tool for (safety) design development, optimisation and selection of design options	SO,SY			GA, IM, HF	FSA. SC		AEA, THERP

87Abbreviations:

AHA	analysis of the habit of action method	AEA	action error analysis	EA	Environmental Accounting
EI	Enviornmental Indexing	ERA	Environmental Risk Analysis	FSA	Formal Safety Assessment
HF	human/organisation. factors methods as specified	IM	IMSRS	LCA	Life Cycle Analysis
MIMIX	method of investigating management impact on causes and consequences of spec. hazards			MORT	management oversight and risk tree
PIF	method of performance influencing factors	THERP	technique for human error prediction rate	SC	Safety Case
Brok	ship sale &purchase brokers	IGB	intergovernmental bodies	RWA	regional waterway authorities
Ch	charterers	MRO	maritime research organis.	SAR	SAR organisations
CS	classification societies	NG	national governments	SM	ship managers
DAT	database managers	PAd	political advisors	SO	ship owners
EA	environmental authories	PG	consumer & environmental pressure groups	SOA	ship owner association
FO	financial organisations	P&I	P&I clubs	STE	seafarer training&educational establishments
FS	flag states	PO	port authorities	SY	ship yards
IC	insurance companies	RG	regional governments		

Needs/Decision problems	Potent. users	No use	Low	Medium	High	Not known	Further explanations
Proactive approach to assess ship safety design	CS	GA	IM	HF	FSA, SC		AEA, THERP, PIF
Evaluation of safety system investments	SO		HF		GA, IM, FSA, SC		AEA, THERP, PIF, TRIPOD
Support for activities concerning crew training	SO,SM,STE	GA, LCA, EI, ERA			IM, HF, EA, SC		Reason, AHA, PIF, TRIPOD
Training in routine operations and emergency preparedness	SO,SM,STE,SAR	GA, LCA, EI, ERA			IM, HF, EA, SC		Reason, AHA, PIF, TRIPOD
Support in fulfilling national/local requirements for contingency planning, and provision of emergency services	PO,RWA, SAR	GA. EA, EI	HF	IM	ERA, LCA, SC		Reason, PIF, MIMIX
Support for ISM compliance	SO,SM	ERA, LCA	GA		IM, HF, EI,		Reason, AHA, PIF, MIMIX, TRIPOD

87Abbreviations:

AHA	analysis of the habit of action method	AEA	action error analysis	EA	Environmental Accounting
EI	Enviornmental Indexing	ERA	Environmental Risk Analysis	FSA	Formal Safety Assessment
HF	human/organisation. factors methods as specified	IM	IMSRS	LCA	Life Cycle Analysis
MIMIX	method of investigating management impact on causes and consequences of spec. hazards			MORT	management oversight and risk tree
PIF	method of performance influencing factors	THERP	technique for human error prediction rate	SC	Safety Case
Brok	ship sale &purchase brokers	IGB	intergovernmental bodies	RWA	regional waterway authorities
Ch	charterers	MRO	maritime research organis.	SAR	SAR organisations
CS	classification societies	NG	national governments	SM	ship managers
DAT	database managers	PAd	political advisors	SO	ship owners
EA	environmental authories	PG	consumer & environmental pressure groups	SOA	ship owner association
FO	financial organisations	P&I	P&I clubs	STE	seafarer training&educational establishments
FS	flag states	PO	port authorities	SY	ship yards
IC	insurance companies	RG	regional governments		

Needs/Decision problems	Potent. users	No use	Low	Medi um	High	Not known	Further explanations
					EA, SC		
Support for safety management investigations / decisions	SO			GA	IM, HF, SC		Reason, AHA, PIF, MIMIX, TRIPOD
Developing codes of good practice	SOA,P&I,IC	ERA, LCA	GA		HF, EA, EI, SC	IM	Reason, PIF, AHA, MIMIX, TRIPOD
Support for persuasive activities	SOA,PG		HF, EI, EA		IM, ERA, LCA, FSA, SC	GA	AHA, MIMIX
Support for advisory actions (activities)	SOA,IC	EA	HF	IM	ERA, LCA, EI, FSA	GA	AHA, MIMIX
Acceptance/refusal of shipping companies	P&I	HF, ERA, LCA	GA		IM, EI, EA, SC		

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AHA	analysis of the habit of action method	AEA	action error analysis	EA	Environmental Accounting
EI	Enviornmental Indexing	ERA	Environmental Risk Analysis	FSA	Formal Safety Assessment
HF	human/organisation. factors methods as specified	IM	IMSRS	LCA	Life Cycle Analysis
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Brok	ship sale &purchase brokers	IGB	intergovernmental bodies	RWA	regional waterway authorities
Ch	charterers	MRO	maritime research organis.	SAR	SAR organisations
CS	classification societies	NG	national governments	SM	ship managers
DAT	database managers	PAd	political advisors	SO	ship owners
EA	environmental authories	PG	consumer & environmental pressure groups	SOA	ship owner association
FO	financial organisations	P&I	P&I clubs	STE	seafarer training&educational establishments
FS	flag states	PO	port authorities	SY	ship yards
IC	insurance companies	RG	regional governments		

Needs/Decision problems	Potent. users	No use	Low	Medi um	High	Not known	Further explanations
Evaluation of fleets	SOA,P&I	HF, ERA	IM	GA	LCA, EA, EI		
Acceptance/refusal of ships	Ch,CS,IC,PO,EA,RWA	HF, LCA	GA, ERA	IM	EI, EA		
Acceptance/refusal with regard to financing activities	FO	IM, HF, ERA	GA, EI, EA, LCA				
Estimation / adjustments of – interest rates – fees – premiums	FO,IC,PO	HF, ERA			GA, EA, LCA, EI	IM	
Support for negotiations with insurance companies	SO	HF, ERA	LCA	IM	GA, EI, EA		
Information on/assessment of risks: - of a specific ship – of ship types – in specific maritime areas – to target Port State Control inspections and other	FO,P&I,IC, PO,FS,EA, RWA	IM, EA		HF	GA, ERA, EI, LCA, FSA, SC		PIF, TRIPOD

87Abbreviations:

AHA	analysis of the habit of action method	AEA	action error analysis	EA	Environmental Accounting
EI	Enviornmental Indexing	ERA	Environmental Risk Analysis	FSA	Formal Safety Assessment
HF	human/organisation. factors methods as specified	IM	IMSRS	LCA	Life Cycle Analysis
MIMIX	method of investigating management impact on causes and consequences of spec. hazards			MORT	management oversight and risk tree
PIF	method of performance influencing factors	THERP	technique for human error prediction rate	SC	Safety Case
Brok	ship sale &purchase brokers	IGB	intergovernmental bodies	RWA	regional waterway authorities
Ch	charterers	MRO	maritime research organis.	SAR	SAR organisations
CS	classification societies	NG	national governments	SM	ship managers
DAT	database managers	PAd	political advisors	SO	ship owners
EA	environmental authories	PG	consumer & environmental pressure groups	SOA	ship owner association
FO	financial organisations	P&I	P&I clubs	STE	seafarer training&educational establishments
FS	flag states	PO	port authorities	SY	ship yards
IC	insurance companies	RG	regional governments		

Needs/Decision problems	Potent. users	No use	Low	Medium	High	Not known	Further explanations
surveys							
Business risk management, and resource deployment (virtually any organisation)		IM, HF, LCA, ERA		EI, EA		GA	
Seeking commercial competitive advantage, marketing, introducing new working methods, (any commercial organisation)		HF, ERA	IM	GA	EI, EA, LCA, SC		
Support in development of loss reduction campaigns and relevant persuasive activities	P&I,IC	HF, ERA			IM, EA, EI, LCA, FSA, SC	GA	
Support for pollution avoidance	SO,SM,PO,RWA		HF	IM, LCA	GA, EI, EA, LCA, SC		PIF
Tool for rule development/adjustment and relevant	CS,FS		IM	GA,	EA,		Reason, PIF, MIMIX

87Abbreviations:

AHA	analysis of the habit of action method	AEA	action error analysis	EA	Environmental Accounting
EI	Enviornmental Indexing	ERA	Environmental Risk Analysis	FSA	Formal Safety Assessment
HF	human/organisation. factors methods as specified	IM	IMSRS	LCA	Life Cycle Analysis
MIMIX	method of investigating management impact on causes and consequences of spec. hazards			MORT	management oversight and risk tree
PIF	method of performance influencing factors	THERP	technique for human error prediction rate	SC	Safety Case
Brok	ship sale &purchase brokers	IGB	intergovernmental bodies	RWA	regional waterway authorities
Ch	charterers	MRO	maritime research organis.	SAR	SAR organisations
CS	classification societies	NG	national governments	SM	ship managers
DAT	database managers	PAd	political advisors	SO	ship owners
EA	environmental authories	PG	consumer & environmental pressure groups	SOA	ship owner association
FO	financial organisations	P&I	P&I clubs	STE	seafarer training&educational establishments
FS	flag states	PO	port authorities	SY	ship yards
IC	insurance companies	RG	regional governments		

Needs/Decision problems	Potent. users	No use	Low	Medium	High	Not known	Further explanations
decision making				HF, ERA	EI, LCA. FSA, SC		
Support for international, national, regional policy setting	PO,NG,RG,RWA,EU, IMO,PA			HF, ERA	GA, EI, EA, LCA, FSA	IM	Reason, PIF, MIMIX
Support for accident and incident investigations	CS,SO,FG, EA,IMO	GA, IM, ERA, LCA	EI, EA		HF		Reason, AEA, MIMIX, TRIPOD-BETA
Support for database structuring and incident/accident information collection and archiving	DAT	IM		HF, LCA	ERA, EI, EA		Reason, AEA, MIMIX, TRIPOD-BETA

87Abbreviations:

AHA	analysis of the habit of action method	AEA	action error analysis	EA	Environmental Accounting
EI	Enviornmental Indexing	ERA	Environmental Risk Analysis	FSA	Formal Safety Assessment
HF	human/organisation. factors methods as specified	IM	IMSRS	LCA	Life Cycle Analysis
MIMIX	method of investigating management impact on causes and consequences of spec. hazards			MORT	management oversight and risk tree
PIF	method of performance influencing factors	THERP	technique for human error prediction rate	SC	Safety Case
Brok	ship sale &purchase brokers	IGB	intergovernmental bodies	RWA	regional waterway authorities
Ch	charterers	MRO	maritime research organis.	SAR	SAR organisations
CS	classification societies	NG	national governments	SM	ship managers
DAT	database managers	PAd	political advisors	SO	ship owners
EA	environmental authories	PG	consumer & environmental pressure groups	SOA	ship owner association
FO	financial organisations	P&I	P&I clubs	STE	seafarer training&educational establishments
FS	flag states	PO	port authorities	SY	ship yards
IC	insurance companies	RG	regional governments		

5.3.4 Conclusion

In order to be common to a large number of users an approach must be able to deal with a significant range of decision problems and needs.

From the evaluations performed it could be concluded that no single method is capable of serving the majority of decision problems and needs within shipping, meaning that there is a definite need for a toolbox consisting of several methods. The question is rather - will all the methods together be able to cover all needs, or will there be gaps or uncovered needs requiring new methods or development of existing ones?

In the following table 5.3.4.1 the results above have been combined with the original list of decision problems as presented in table 5.3.2.1 to establish:

- The potential of each method to form part of a common approach. Methods found able to cover a large fraction of the decision problems and needs might be seen as a potential “spinal cord” in a common approach
- Which minimum of combined methods would have the greatest potential of covering a majority of the decision problems and needs. A common approach should probably be based on a few strong methods, rather than a wide range of methods.
- Which decision problems and needs are poorly covered or not covered at all. A common method should at least be able to cover the essential decision problems and needs of all the parties.

Summarising the result represented in table 5.3.4.1:

- Each of the potential users and methods are presented in the table below.
- It can be seen that each of the needs is covered by at least one method.

Regarding the applicability of each of the methods to each need it is largely dependent on the problem to be analysed and the experience of the individuals undertaking the analysis. One method could be used for different purposes as well as two different methods for one problem depending on the analysts.

Table 5.3.4.1: Coverage of Decision Problems and Needs – all methods

Note:

- EAM (Environmental Assessment Methods), comprises Environmental Indexing, Environmental Accounting, Life Cycle Analysis and Environmental Risk Analysis.
- For abbreviations reference is made to the key of table 5.3.3.1.

Id.	Potential users	Needs/decisions	EAM	GAS	IMSRS	HF	FSA	SC
SO	Ship owners	Selection of ship design options	X				X	X
		Safety design optimisation	X				X	X
		Seeking exemptions or equivalencies to prescriptive regulations	X		X		X	X
		Negotiation with yards						X
		Negotiations with insurance companies	X	X				
		Safety system investments		X	X		X	X
		Support for safety management investigations/ decisions			X	X		X
		ISM compliance	X		X	X		X
		Pollution avoidance	X					X
		Crew training	X		X	X		X
		Training in routine operations and emergency preparedness	X		X	X		X
		Accident and incident investigation			X	X		
		Database structuring and incident/accident information collection and archiving			X	X		
SOA	Ship owner associations	Evaluation of fleets	X				X	
		Developing codes of good practice	X		X	X		X
		Advisory actions	X	X				
		Persuasive activities	X	X				X
Ch	Charterers	Acceptance/refusal of ships	X					X
		Port State Control inspections and other surveys						
SM	Ship managers	ISM compliance	X		X	X		X
		Pollution avoidance	X	X				
		Crew training	X		X	X		X
		Training in routine operations and emergency preparedness	X		X	X		
SY	Ship yards	Design development					X	X
		Design optimisation					X	
CS	Classification societies	Proactive approach to assess ship design safety					X	X
		Tool for (safety) equivalency evaluations	X		X		X	X
		Acceptance/Refusal of ships' safety design	X					X

Id.	Potential users	Needs/decisions	EAM	GAS	IMSRS	HF	FSA	SC
		Tool for rule development/adjustment	X				X	X
		Accident and incident investigation	X			X		
		Port State Control inspections and other surveys						
FO	Financial organisations	Information on a ship's risks	X	X				X
		Acceptance/refusal of financing		X			X	X
		Interest estimation/ adjustments	X	X				
P&I	P&I Clubs	Information on/assessment of (ship type specific) risks	X	X				
		Acceptance/refusal of shipping companies	X		X			
		Evaluation of fleets	X					
		Developing codes of good practice	X			X		
		Loss reduction campaigns	X	X	X		X	
		Port State Control inspections and other surveys		X				
IC	Insurance companies	Information on/assessment of ship's risks	X		X			X
		Acceptance/refusal of ships	X	X				X
		Premium estimation/ adjustments	X	X				
		Developing codes of good practice	X			X		
		Loss reduction campaigns	X	X	X		X	
		Advisory activities	X	X				
Brok	Ship sale and purchase brokers	Support for acceptance / refusal of ships						
		Advisory activities						
		Marketing						
PO	Port authorities	Assessment of (ship type specific) risks (e.g. to optimise checklists for port state control surveys)	X	X			X	
		Acceptance/refusal of ships	X	X				
		Fee estimation/adjustments	X	X				
		Pollution avoidance	X	X				X
		Fulfilling national/local requirements for contingency planning, and provision of emergency services	X					X
		Port State Control inspections and other surveys		X				
		Policy setting	X	X	X			
FS	Flag states	Information on/assessment of risks	X	X				
		Decision on safety regulations (through IMO)	X					X
		Database structuring and incident/accident information collection and archiving				X		
EA	Environmental authorities	Information on/assessment of risks in certain areas (e.g. coastal)	X		X			
		Acceptance/refusal of ships	X					
		Accident and incident investigation				X		

Id.	Potential users	Needs/decisions	EAM	GAS	IMSRS	HF	FSA	SC
NG	National governments,	Policy setting	X	X	X		X	X
RG	Regional governments	Policy setting	X	X	X		X	X
RWA	Regional (waterway) authorities	Information on/assessment of risks in certain areas (e.g. coastal)	X	X				
		Acceptance/refusal of ships	X					
		Pollution avoidance	X	X				
		Fulfilling national/local requirements for contingency planning, and provision of emergency services	X					
		Policy setting	X	X	X		X	X
IGB	Intergovernmental bodies	Support for policy setting	X	X	X		X	
EU	EU	Policy setting	X	X	X		X	X
IMO	IMO	Policy setting	X	X	X	X	X	X
		Database structuring and incident/accident information collection and archiving				X		
MRO	Maritime research organisations	Support for ship design and operation development/improvement					X	X
STE	Seafarer training and other maritime educational establishments (including universities)	Crew training	X		X	X		X
		Training in routine operations and emergency preparedness	X			X		
DAT	Accident/incident database managers	Database structuring and incident/accident information collection and archiving	X			X		
SAR	Search and rescue (SAR) organisations	Training in routine operations and emergency preparedness Fulfilling national/local requirements for contingency planning, and provision of emergency services	X		X	X		X
PG	Consumer and environmental pressure groups	Persuasive activities	X	X	X			
PAd	Political advisors (e.g. members of EU parliam.)	Policy setting	X	X	X			

5.4 Data Availability/Applicability, and Suggestions for Accident/Incident Reporting

5.4.1 Summary

A study of the current state of the art of databases, relevant to Formal Safety and Environmental Assessment approaches, was performed. Special attention was given to accident and incident reporting. The requirements for databases to be used within the process of Formal Safety and Environmental Assessments were discussed. Suggestions for necessary future data and data collection are given in this chapter of the report.

There are several databases available at international, national and company level. The widely available international ones were found to contain a very limited amount of information applicable in risk analysis. The national ones were found to contain some more information, but the population addressed is smaller and this will bias the data. Company level databases were found to have more useful information but in general are not accessible by the public.

For risk analysis it was found necessary to have data of the events included in accident chains. Such data also needs to include human and organizational factors contributing to the casualties. This type of data should be made widely available by an international body. Although the access to the database, and collection of data, can be decentralized to national bodies. However, special attention should be paid to the quality of the collection procedures.

An incident database, independent from the accident database, would be very useful for safety management since the population of incidents is naturally much larger than that of accidents. The collection of data could be further decentralized to the operator, although there may be problems guaranteeing confidentiality of the data and the anonymity of the reporters.

International, or at least European, reliability databases on machinery should be encouraged.

The technical problems involved in designing an accident database need to be defined in research projects at a European level. Their applicability to risk analysis and the formulation of data collection procedures should be considered. The same applies to the formulation of an incident database and an incident reporting system, which is expected to be more complicated than in the case of accidents.

5.4.2 Accident/Incident Databases

The databases which could be identified in the project differ in several aspects, such as the level of detail in recording incident and/or accident data, the level of confidentiality and availability of the recorded data and the number of users.

A detailed description of the accident and incident databases identified is given in /5/. The following international databases were found: Lloyd's Maritime Information Services (LMIS) database, IMO's database ("Reports on Marine Casualties and Incidents") and Marine Accident Reporting Scheme (MARS). National databases are: Marine Accident Investigation Branch (MAIB) of UK, Marine Incident Investigation Unit (MIIU) of Australia, MINMOD of USA and DAMA of Scandinavia. Company level databases are: Safety and Improvement Reporting System (SAFIR) and SYNERGI.

A comparison of the mentioned databases is given in the table below. Characteristics which are significant regarding the availability and applicability of data and the usefulness of the database for the purpose of supporting risk analysis have been used for this comparison.

Database	Availability	Type of Data	Level of Detail 1: low 5: high	Accident (a) or Incident (i) Data	Event Chain Description	Human Factors included	Usefulness for Risk Analysis 1: low 5: high
DAMA	Public	narrative, partial statistical	2	accident	no	no	2

Database	Availability	Type of Data	Level of Detail 1: low 5: high	Accident (a) or Incident (i) Data	Event Chain Description	Human Factors included	Usefulness for Risk Analysis 1: low 5: high
IMO database	Public	statistical	1	accident	no	no	1
LR database	Public	statistical	1	accident	no	no	1
MAIB	Public	narrative, partial statistical	increases with severity of casualty 2-5	accident	depends on severity of casualty	partial	depends on provided level of detail: 3-5
MARS	Public	narrative	increases with severity of casualty 2-5	accident, incident	depends on severity of casualty	partial	depends on provided level of detail: 3-5
MIIU	Public	narrative	increases with severity of casualty 2-5	accident, incident	depends on severity of casualty	partial	depends on provided level of detail: 3-5
MINMOD	not public	narrative, statistical	3	accident, incident	yes	limited	3
SAFIR	Private	statistical, narrative (?)	5	accident, incident	partial	yes	4
SYNERGI	Private	statistical, narrative	5	accident, incident	yes	yes	4

Table 5.4.2.1: Characterisation of accident and incident databases

5.4.3 Reliability Databases

Collecting reliability data for ships is different from reliability data collection in other industries. Some of the reasons are listed in the following:

- There are 80,000 ships in the world, all of which vary in design, trading pattern, normal geographical location, operating & maintenance philosophy and manning.
- The vessels are continuously moving from one port to another, therefore communication and the practical aspects of data collection are more complicated.
- It is an international industry – personnel, that may not share a common first language or that come from widely varying cultural backgrounds, may man vessels. Perception of risk and understanding of the term „failure“ may also vary widely.
- The design of vessels depends on a number of factors such as the intended trade, age, classification society and builder and owners' particular requirements. Even within one ship type there are many differences.
- The same types of ships can be operated in different geographical areas and by different ship operators with a different mission profile. This will have a large impact on ship performance as the components' quality are strongly affected by maintenance and management policies.
- Personnel training changes according to ship operator and operating country.
- In addition, ship builders and operators are generally reluctant to share failure data.

There are two main areas where data collection and analysis of failure data is required. One is the reliability assessment of new designs and the other is analysis of in-service reliability performance.

The four main problems traditionally associated with collecting data are lack of motivation, verification, cost and the recording of "non-failures" (failures which did not lead to major or more severe consequences).

The operators or engineers have to see the benefit of collecting data. Otherwise it is likely that recordings will be omitted or incorrect. Unrealistic time standards, poor working conditions and inadequate instructions are conditions that will have a negative impact on the collection programme.

The costs of data collection are high in terms of both the time to fill in the failure characteristics and the time to interpret and analyse the data. This means that it could be difficult to persuade companies, suppliers or manufacturers to take part in a major data collection program.

The accuracy of data has to be ensured. Data quality must not be sacrificed for the sake of data quantity.

Reliability databases have a different nature than the accident and incident databases that have been discussed before. While the latter are concerned with describing the chain of events that led to an undesired event, the reliability databases aim at quantifying the statistics of different equipment failure modes.

The reliability databases can be used to provide some information on the probability of failure of different equipment. This information could then be used to describe the initiating events for some types of accidents, such as machinery failure. They can also characterise the probability of failure of equipment on demand, i.e. stand by equipment that is called to function in a sequence of accidental events.

For this type of databases there is no international widely available system that has been collecting data, as for example the LMIS database for accidents. There are in fact recent research efforts to define the structure of such databases and to start data collection, which is a clear indication of the lack of such data operationally.

An interesting project is the RAMS SHIPNET initiative.

A few reliability databases exist that are concentrating on the reliability of the machinery and its components. The databanks are usually collected by a consortium of shipping companies and are generally not open to outsiders. The nature of the collected data easily gives an opportunity for statistical analysis. One problem is that historical data is not necessarily very applicable, for example, to new engine versions.

The following reliability databases are identified:

- Database Association by Swedish Shipowners
- Japanese SRIC (Ship Reliability Investigation Committee)
- Users-Diesel-Engines-Database by CIMAC

For further details reference is made to /5/.

5.4.4 Data Needed to Perform Risk Analysis

The basic steps of a risk analysis are to start from an hazard identification phase and then to pass to the modelling of the event chains that are associated with each of the identified hazards. The quantitative aspects are dealt with afterwards by attributing the relevant probabilities to the basic events in the model.

The identification of hazards has to be based very much on experience used in the analysis of a given engineering solution. Altough this is often achieved with brainstorming sessions in HAZOP teams, the existance of a good database with information on the frequent failures for the system under consideration will certainly be very useful.

However, the information that is required for hazard identification are the initiating events but in the most widespread databases the main information they contain is the final event which characterises the casualty.

Since hazard identification concentrates on the initiating event of an accident, the information provided by incidents is very helpful, because although they have not generated into an accident they will indicate the potential for such initiation. Therefore it would be very helpful to have an extensive database of incidents.

For quantitative risk analysis it is necessary to have statistics of failures of the different components that belong to the failure model. The information from reliability databases serves this purpose. Often fault-tree analysis is adopted for these calculations but other approaches are possible and they also require failure data.

In order to have data on failure rates of components it is necessary to have databases that include the various contributors in the event chain leading to the final failure. This implies that the database needs to include the whole chain of events leading to the final outcome as well as the causes of those events. While the general accident/incident databases such as LMIS and IMO's database do not contain that information, others like MINMOD model the chain of events and store that information. This basic data could then be used to produce statistics at component level, in particular the causes of failure of components.

Another important matter concerns the treatment of human and organisational factors in risk analysis. An important difference between the safety of structures and of vehicles is that in the latter case the failure is very much dependent on the operation, which is a smaller contribution in the first case. Therefore the risk analysis must take into account the human and organisational contribution to the failures (and their avoidance). This requires that accident investigation study properly the human and organisational contribution to failure and that the failure databases include this component also.

Therefore it can be concluded that in the case of ships it is necessary to have databases that record the chain of events in the casualty as well as their causes and contributing factors and these should include the technical as well as the human and organisational failures. If there is data on human failures it will be possible to develop risk analysis models that include that type of contribution. These models would then be able to differentiate the effect of crews with different level of skills, training and safety culture.

More recent databases, such as SAFIR and SYNERGY already contain some elements of human factors although this aspect of those databases has not been studied in detail.

For the complete description of an accident it is not enough to calculate the probability of its occurrance. It is also necessary to quantify its consequences, both in terms of damaged property and damage to the environment. With regard to environmental assessments data about costs implied with clean-up and recovery activities is helpful. Data on the costs of consequences is needed for the cost-benefit analysis of introducing risk reducing measures.

5.4.5 Data Provided by Current Databases for Risk Analysis

As mentioned above, the current databases can be divided into the following groups: International databases, national databases and company databases.

International databases like LMIS and IMO's database basically include the final event in the casualty chain and in some occasions the initial event. However it is expected that in the future the IMO database will also include the causes of accidents.

National databases, in general, only cover worldwide casualties of their own fleet and casualties of all vessels in their own waters. They are often more interested in the casualty descriptions and analyses of causes, leading to the lessons learned. Generally, they do not publish statistics systematically of the events in the accident chain, although this may possibly be done once the database can be accessed.

Company databases are sometimes developed for a group of companies and they may have detailed information about the causes of casualties, including human factors. The drawback of these databases is that data is only collected from a group of ship owners. This means that for general purposes, including regulatory purposes, this is too limited and possibly biased information.

The data in these databases should be used with care, because it should be considered that changes in design and operation patterns are likely induce changes in failure rates. Thus, limiting the usefulness of old data.

5.4.6 Suggestions with Regard to Necessary Future Data and Data Collection

5.4.6.1 Responsibilities for Data Collection

It is important that failure data is made available to all parties involved with the maritime industries, such as maritime administration, ship yards, ship designers, operators, classification societies, research institutions, etc.

There should be one database, which contains all data worldwide. It seems logical that the responsibility for such a database lies with an international agency. However, the responsibility of making the data available could either be done by an international agency or decentralized to national bodies. With evolution of information technology it should be feasible to make access easy through the use of electronic means.

Data collection could be done by this agency, but it would probably be more practical to decentralize it to the national bodies. If data collection would be decentralized it would be important to make sure that minimum quality standards were met by all the data that would be included in the global database.

5.4.6.2 Collection of Incident Data

Incident data is very useful in hazard identification and in safety management in general. This type of data which is often an order of magnitude larger than accident data has to be treated confidentially, otherwise it may not be supplied.

In aviation there are already confidential reporting systems in existence, like CHIRP (Confidential Hazardous Incident Reporting Programme) in UK.

Discussion has been raised within EU´s Concerted Action on Casualty Analysis (BERTRANC) whether a similar system should be established within EU as a means of improving safety at sea. The name CHIRP is used in this context as a working name. Besides the proposal, to establish an EU-wide system, similar initiatives are going on in some of the member countries. It remains to be seen if the best option is a wide, common system or a co-operation of national systems that share the information. The aim of this kind of system is to establish a forum whereby mariners can report any event, touching on safety, without fear of prosecution or disciplinary action being taken against them. The CHIRP will receive, collate and distribute incident reports from all sectors of the marine community.

An organisation taking care of CHIRP must be seen to be absolutely confidential and independent. There should not be any formal association with any Maritime Administration. The CHIRP should be a self-standing unit, perhaps having charitable status, as in the case with the UK aviation CHIRP. An absolute guarantee would have to be given that anyone submitting a report to CHIRP would never have his identity revealed. The CHIRP will need to be headed by a marine specialist capable of understanding and commenting on reports sent by individuals from all areas of the marine community. The CHIRP must be more than a posting box, as informed editorial comment, will form a valuable part of the regular bulletins. All means of identifying the reporter would be removed before publication.

Data collection in the case of incident data could be more decentralized than in the case of accident data, e.g. by shipping companies. However, the responsibility of keeping the incident databases and making data available should rest with public bodies.

Reliability databases could be seen as similar to incident databases because the type of information that they provide for safety assessment is similar. Both types of data just point to potential problematic areas. There are very few international initiatives concerning reliability databases for machinery.

5.4.6.3 Collection of Accident Data

The existing data collection systems have evolved from manual records of accident investigations to software systems. The initial systems recorded the accidental events. Only more recently has it become clear that a complete picture of an accident can only be established through the sequence of events that led to it. Furthermore, the awareness of the importance of human factors in an accident has led to the inclusion of some human factor parameters in the data collection system.

The evolution of the understanding of the problem is reflected in the existing databases. The older ones contain limited data on events whereas more recent ones record event chains. The most recent ones also record human factors, consequence costs and, often, incident details too.

Recently, at IMO, documents (IMO 1997) have been produced with recommendations on data collection and reporting procedures as well as with the taxonomy for classification of accident event and causes. It is expected that in time some of these recommendations will be adopted in different countries and in the future available data will reflect those recommendations.

The CASMET project started about a year ago, following the work of the Concerted Action on Casualty Analysis Methodology (BERTRANC). In that concerted action, the state of the art was summarised on how accident investigation is being conducted in the various European countries.

The objective of the CASMET project was to propose a methodology, in view of the different approaches in practice, that could be adopted by several countries and which would also address human and organisational factors specifically.

Although the project is not finished yet and the methodology not yet fully developed, there are some critical features of the approach, which have already been identified.

- The information in the database must distinguish between the reporting of facts and their interpretation. The basic reporting will be mainly narrative in style. The first step in the analysis of the accident is to extract from that narrative description a list of events in the accident chain and to identify their causal and temporal relationships. A second step in the analysis will be to identify the causes of the events, which can be found in failures of technical systems or human malperformances.
- Having obtained the causes of the events in the accident chain, a special study of the human malperformances may identify common features that point towards potential organisational problems or mismanagement.
- The type of information to be kept in databases is the one produced by the above method of accident investigation. This points to one type of information of narrative character and another one, which is codified and available for statistical analysis.
- The codified information should include the event chain and the causes of each event, both from a technical system and from human performance.

A database with this type of information will be useful for risk assessment because the data is described at an event level, as is used in risk analysis.

Further recommendations about the necessity of future data and its collection will be produced by the CASMET project. Therefore the final report of this project should be consulted whenever it becomes available.

5.5 Integration of Human and Organisational Factors

5.5.1 Summary

Methods to integrate human and organisational factors in risk based approaches are available, today.

However, there is currently no structure for a complete integration of human and organisational factors in any of the quantitative assessment methods. This is partly because the assessments traditionally have focussed on quantitative data, and partly because human and organisational factors traditionally has been dealt with in a qualitative way with very little data acquisition and statistical analysis, i.e. the two traditions have not so far found a common “language”. However, quantitative assessment methods are very seldom purely quantitative. Engineering judgement, approximations and adjustments to data is quite frequently used also in “quantitative” assessments. The lack of human and organisational factors in such assessments may therefore prove to be a result of “lacking awareness and knowledge” of such factors rather than “differences between methods”.

An approach for a qualitative integration of human and organisational factors in quantitative assessment is suggested in /6/. In the long run, however, it is not seen as fully satisfactory to leave human and organisational factors to qualitative evaluation only. The aim should be to develop the knowledge of these factors through modelling of the causation mechanisms of accidents, database developments and statistical analyses, and to integrate these factors in the assessment algorithms.

5.5.2 Human and Organisational Factors in Risk Analysis

The current view of safety and risk analysis techniques is that a system under consideration should be understood as a socio-technical entity that is formed of humans, machinery and environment. The focus solely into technology is not any more considered sufficient.

In practice the safety and risk analysis methods applied in navigation as well as in other fields are often quite technology-oriented. One reason for this may be that the study of technology is experienced easier. This, again, is a result of the fact that the focus on methodology development has traditionally been within methods that study technical details of systems. The human being is considered as a part of the machinery. The technology-based methods study the system according technical subsystems (for example a pipeline from the beginning of the process to the end). They are thus not very effective and systematic when the human behaviour is examined and in addition the organisation cannot be directly addressed.

Methods for human factor evaluation/analysis

At the end of chapter 5.1.8.1 a list of methods for Human Factor evaluation/analysis applied in marine and other industries was provided. The list is not exhaustive but it gives a good picture of the current state of the art. For more detailed information reference is made to /4/.

In addition to the methods in this list, it should be noted that the rating methods mentioned in chapters 5.1.3 – 5.1.5 represent attempts to provide qualitative assessments including technical, human and organisational factors. The rating systems emphasise human and organisational factors. Technical factors are included in the form of “physical conditions checks”. The rating systems are not aiming at calculating risk, but are rather a systematic judgement of the efforts and systems in place to reduce and control risk.

Process to integrate human and organisational factors

At this stage, a three-step approach is suggested to initiate the process to integrate the human and organisational factors in risk analysis:

1. Create a general awareness of human factors in risk analysis;
2. Establish a data base on these factors to increase the knowledge on cause distribution, including all the causes;
3. Use statistical bases for prioritising human factors and increase the accuracy when integrated in risk analysis.

It may be considered that a general awareness of the importance of the inclusion and consideration of human factors in risk analysis and incident/accident investigation is already acquired. The human factor issue has assumed increasing importance within IMO over the last few years. The various IMO Committees and their subsidiary bodies, as a standard practice, take the human element into account when preparing new instruments.

Nevertheless, as a consequence of the difficulties with the human factor, these factors are very often nearly disregarded or treated in a deficient way. It is recognised that a much more stringent attention should be devoted to human factors and that they must be considered from the very beginning of any project.

The percentages of accidents or incidents that are believed caused by “human error”, “the human element” or “the human factor" varies a lot but they are as high as 80% or even higher. With these figures in mind it will be easy to understand how important it is to have a good understanding of and control on the human element.

Aware of the importance of human factors and also of its complexity it is necessary to search for a more systematic, methodical and comprehensive way of dealing with human factors. The Joint ILO/IMO working group on investigation of human factors in maritime casualties produced a “Guidelines on investigation of human factors in marine casualties and incidents”. The purpose of those guidelines is to provide practical advice for the systematic investigation of human factors in marine casualties and incidents and to allow the development of effective analysis and preventive action with the long-term intent to prevent similar casualties and incidents in the future. It is expected that these guidelines should result in an increased awareness by all involved in the entire marine industry of the role human factors play in marine casualties and incidents. This awareness should lead to proactive measures by the maritime community.

Human and organisational factors Database

There is a general feeling that a database of human factors that lead to accident or incidents will be very helpful to prevent recurrence of similar occurrences in the future by identifying and recommending remedial action.

Attempts to develop a good database that categorises human behaviour so far have not been very successful. Human behaviour is much more difficult to classify than to describe and categorise technical "behaviour" (mechanical, electrical or other).

A major positive aspect of a standard classification scheme is that it provides a structure to data collection and may provide some consistency across investigation. However, it also creates the problem of collecting data for the purpose of only filling out the form, potentially inhibiting a full investigation of all aspects of the accident. Therefore, a careful determination of what data are needed is critical when developing the classification scheme of an accident database.

Four important factors are considered to be relevant to the accuracy, reliability and completeness of data within any accident database;

- An understanding of the purpose of the database
- The expertise needed to identify data of interest
- The taxonomy used to represent those data within the database
- Computer interface of the data entry program.

The IMO casualty database is one more proposal for such a kind of database including, in a very prominent position, human factor.

The IMO database and IMO report format should be the references for any new work on this subject. Any attempt to produce a better database will be advisable to be assumed as an improving process on those references.

The guidelines consider a certain number of factors that have a direct or indirect impact on human behaviour grouped under the following headings;

- People factors
- Organisation on board
- Working and living conditions
- Ship factors
- Shore side management
- External influences and environment

It is not the intention to transcribe in every case all the factors indicated on the reference. It would be sufficient to enumerate some of them to have an idea of the multitude of factors and the difficulties to evaluate how they may influence the situation and human behaviour. More detail on the above mentioned factors is given in /5/.

Human failure categories

Four categories of "human failures" may be considered - slip, lapse, mistake and violation:

- A slip is an unintentional action motivated by attention failure.
- A lapse is an unintentional action motivated by memory failure.
- A mistake is an intentional action motivated by a wrong application of a rule or plan due to misinterpretation or similar fault. There is no deliberate decision to act against a rule, procedure or plan.

- A violation, the failure that is only conceivable to the human being, is a planning failure where deliberate decisions to act against a rule or plan have been made. In normal conditions the violation is committed to get the job done with no blameworthy intention.

Some suggestions for how to deal with the human and organisational factors are given in table 5.5.2.1 below.

Risk Analysis Steps	**Traditional approach**	**Integration of human factor**
Definition of goals and system/ Operations	Description of the objectives of the system under study and its mode of operation. Functional block diagrams may help to organise the descriptions	Definition of tasks/responsibilities. On mode of operation working and living conditions are to be considered.
Definition of analysis bases	Definition of analysis boundaries and objectives.	
Hazard identification	Identification of the hazards related to the system operation. There are a series of techniques available to reach that goal, some more based on generating a brainstorm activity among people familiar with the installations being studied, others having a more systematic nature trying to help the analyst in considering all possible origins of accidents.	Identification of hazards related to human behaviour, adopting specific methods such as Action Error Analysis and THERP.
Scenarios definition	Study all possible sequence of events that can develop from that hazard and check if they originate an accident	When studying all possible sequence of events, hazards related to human behaviour are to be considered.
Consequences calculation	Evaluation of consequences seriousness	As above
Frequencies calculation	Evaluation of accident frequency	As above
Risk assessment	Evaluation of risk by combining accident frequency and consequences seriousness. A non-satisfactory solution will lead to system and/or operational modifications	Besides human life, property and environment protection, human wellbeing must be considered.
Cost effectiveness	Assess if the costs for preventive/protective measures (including maintenance costs) are balanced with the benefits, i.e. reduction in hazards and economic loss. A non-satisfactory solution will lead to system and/or operational modifications	Human investment is one of the highest costs, including training, living conditions healthcare. On cost effectiveness analysis, personnel costs and benefits shall be carefully considered.
Risk verification	Verification that a satisfactory solution has been found	A satisfactory solution implies human safety and wellbeing.
Safety management	Development of a Safety Management programme / System with the purpose it to ensure that during the operation of the system, the probabilities of failure and the consequences are always such that the risk is kept acceptable. A non-satisfactory solution will lead to system and/or operational modifications	The Safety Management Programme/ System must consider the human element.

Table 5.5.2.1: Integration of Human and Organisational Factors in Risk Analysis

5.6 Regulatory Requirements and Assessment Techniques for Rule Making

5.6.1 Summary

A review of current regulations was done to identify demands for risk analysis, and it was found that there is a number of regulations containing risk connotations. However, these connotations were typically found to be hidden out in annexes or not being explicit. The current regulatory regime for shipping is defined by a set of IMO regulations, classification rules, regional agreements and national requirements and other technical standards.

The regulatory system was generally found to lack clear statements of safety objectives. Functional requirements with respect to safety were rarely found. The impression was that regulators would rather resort to continuous amendments of existing prescriptive regulations than discuss and agree upon fundamental safety principles. This makes the regulations gradually more and more fragmented, and it was suggested that an introduction of risk based approaches could help structure the fundamental principles and thereby the regulations.

In this respect the principle of equivalence was seen fundamental for the introduction of risk analysis. There was a principle of technical equivalency observed for current regulations, and it was the opinion that a change to a safety equivalency principle is required. And this again would require clearer safety objectives. Currently it is left to risk analysts to interpret the implicit safety objectives of the regulations.

Regarding the use of safety and environmental assessment techniques for rule making it was agreed that the general purpose of developing maritime rules and regulations is to manage risk, and that a key element in risk management is the proper use of risk assessment techniques. It was found that Formal Safety Assessment (FSA) contains most of the necessary steps of a risk management and that FSA is as applicable to environmental consequences as for safety issues. The already existing “Interim Guidelines on the Application of Formal Safety Assessment for the IMO rule-making process” were reviewed. A number of suggestions were provided for improving the contents with the aim of facilitating the application of FSA for rule making.

5.6.2 Identification of Regulatory Requirements

A modern regulatory framework for safety and environmental protection consists of the following elements:

- the objectives and the underlying philosophy of the regulations are clearly stated;
- high-level principles and policies are formulated;
- functional requirements are described;
- the associated guidelines contain standard solutions to meet these functional requirements, but other alternative means for achieving the same objectives are permitted
- the guidelines are not mandatory.

This is illustrated by the triangle in figure 5.6.2.1.

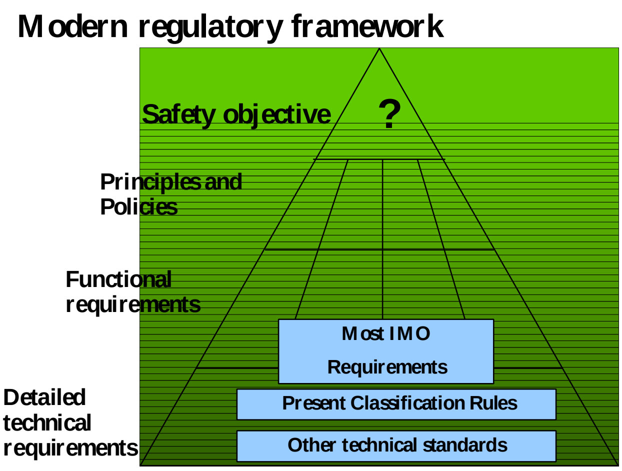

Figure 5.6.2.1: Modern Regulatory framework

The current regulatory regime for shipping is defined by a set of IMO regulations, classification rules, regional agreements, national requirements and other technical standards. As compared to a modern regime, this regime is to a considerable extent lacking safety objectives and statements of functional requirements. Most of the regulations are prescriptive and to some extent very detailed. The development is based on a very broad experience, a gradual development, re-use of proven solutions and technologies and only occasional introduction of new equipment and solutions. For conventional ships this type of regulations is cost-effective, easy to use and predictable.

In the situation of the introduction of innovative equipment, approval may be obtained by using Regulation 5 of SOLAS, which is stated below:

International Convention for the Safety of Life at Sea, 1974.

CHAPTER	I	GENERAL PROVISIONS
PART	A	APPLICATION, DEFINITIONS, ETC.
Regulation	5	Equivalents

(a) Where the present Regulations require that a particular fitting, material, appliance or apparatus, or type thereof, shall be fitted or carried in a ship, or that any particular provision shall be made, the Administration may allow any other fitting, material, appliance or apparatus, or type thereof, to be fitted or carried, or any other provision to be made in that ship, if it is satisfied by trial thereof or otherwise that such fitting, material, appliance or apparatus, or type thereof, or provision, is at least as effective as that required by the present Regulations.

(b) Any Administration which so allows, in substitution, a fitting, material, appliance or apparatus, or type thereof, or provision, shall communicate to the Organization particulars thereof together with a report on any trials made and the Organization shall circulate such particulars to other Contracting Governments for the information of their officers.

Guide:

For certain types of ships IMO has issued own safety codes which are intended to give safety levels equivalent to this Convention for those certain ships. Attention is drawn to:

- Code for dynamically supported craft: Resolution A.373(X),
- Code for offshore supply vessels: Resolution A.469(XII) (OSV Code)
- Code for special purpose ships: Resolution A.534(13) (SPS Code)

Regulation 5 contains a “technical equivalence” concept and does not relate to the objective of the regulations. In periods of rapid technology developments the pace of regulatory developments is too slow to cope with industrial needs. For innovative design, e.g. high speed craft and next generation cruise ships, it is hardly possible to use this technical equivalence. In such cases, specific safety objectives or functional requirements are needed.

Therefore, there is a urgent need for formulating these safety objectives and functional requirements. This would allow for the introduction of a “safety equivalence principle” that may be found in most modern regulations.

This is illustrated in the figure below.

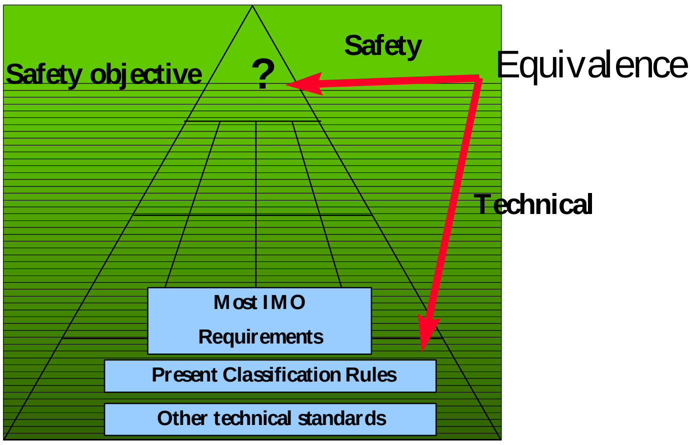

Figure 5.6.2.2: Illustration of the difference between “technical equivalency” and “safety equivalency”.

5.6.3 Examples of New Regulations and the Use of Risk Analysis

A number of existing and future regulations that contain a risk connotation were identified. It was found that these connotations have a tendency to be hidden out in annexes or not being explicit at all. In the following the identified regulations and the parts which contain a risk connotation are presented and discussed. For more detailed information reference is made to /7/.

<u>Revision of chapter II-2 of SOLAS</u>

The revision of chapter II-2 of SOLAS is currently undertaken by the IMO Correspondence Group on Comprehensive Review of SOLAS Chapter II-2. As base documents for this example IMO documents FP 43/3/2 and FP 43/3/5 have been used.

In the current status of the review it appears that the main text of the proposed SOLAS chapter will include a part of a design guidance (Currently drafted in FP 43/3/5). It specifies:

- the preliminary hazard identification
- qualification of the fire risk analysis team
- specification of involvement of the flag administration
- description of the system
- principles for identifying elements for equivalency
- principle of identifying decision parameters in SOLAS
- identification of fire scenarios
- quantitative analysis
- specification of design fires
- estimation of consequences of fire scenarios
- design evaluation and documentation

This can be regarded as a step forward in moving from the technical equivalence to the safety equivalence principle. Safety equivalence is referenced to in regulation 17 of FP/43/3/2, paragraph 1.2:

> The designer, when deviating from the prescriptive requirements, shall proof that the alternative design or arrangements have the equivalent safety level of that in accordance with the prescriptive requirements. For proving the safety level, engineering analyis shall be carried out in accordance with paragraph 2 of this regulation. The engineering analysis shall be presented to the Administration for evaluation and be to the satisfaction of Administration.

Some observations made are listed below:

- The observed current version of SOLAS chapter II-2 is still missing the safety objectives and functional requirements (but there is a clear intention of filling these gaps in the final version)
- For a certain regulation seen in isolation, proving equivalence may seem trivial especially when it is related to performance of passive fire protection means. The complication is to understand the intricacy of the inter-relationship between the various regulatory requirements.

The questionable part of this new development is that it will require another level of competence also in the flag state administrations. In the traditional system with prescriptive requirements the inspection process is based on clear requirements that are easy to verify. This will now be substituted by documents in containing risk analysis, advanced CFD calculations etc. that have been approved by a flag state. It may be questioned how many flag states administrations have the necessary qualification to verify this type of analysis. This situation is probably better but in principle similar when delegated to classification societies.

In cases of change of flag this may raise a lot of questions. For example within the European Economic Area, the Council Regulation (EEC) No. 613/91 of 4 March 1991, requires a flag state to accept ships approved by any other flag state. To avoid the unpredictability that could jeopardize safety a more detailed and accepted procedure would be required within Europe (or globally). This may include the agreed acceptance of certain software, in particular CFD software and associated procedures.

Enhanced Programme of Inspections

IMO Assembly Resolution A744(18) contains two annexes:

> Annex A - Guidelines on the Enhanced Programme of Inspections during surveys of bulk-carriers
>
> Annex B - Guidelines on the Enhanced Programme of Inspections during surveys of oil-tankers

A risk connotation is contained in paragraph 5 and annex 4 of annes A and B:

> '5. Preparations for Survey
>
> 5.1.4 Alternatively the close-up survey in this survey programme may be based on a planning document, approved by the Administration, as described in annex 4. The planning document should comply with a procedure for the application of risk assessment developed by the Organization.'
>
> Annex 4 - Principles for planning documents
>
> 3. The basis for nomination of spaces and areas referred to in 1 is a risk assessment in consideration of possible deteriorations where the following elements on the particular ship are taken into account:
>
> .1 design features such as extent of high tensile steel and local details;
>
> .2 former history available at owner's and Administration offices with respect to corrosion, cracking, buckling, indents and repairs for the particular ship as well as similar ships;
>
> .3 information from same offices with respect to type of cargo, use of different tanks/holds, corrosion prevention system and condition of coating, if any.

For the risk assessment mentioned in par. 5.1.4 above the following methods may be used: structural reliability analysis combined with risk based inspections (RBI), FMEA, RCM.

MEPC RES 66(37)3

par.1.7 states:

> 'In principle, and as far as applicable, the requirements of paragraphs (3)(d)-(f), (6) and (8) of regulation 13F apply also to alternative designs. The requirements of paragraph (9) of regulation 13F also apply to alternative designs. In addition, it should be demonstrated by means of a risk analysis that the new design under consideration provides an adequate safety level. Such analysis should address any specific risks associated with the alternative design, and if there are any, it should be demonstrated that safe solutions exist to cope with them.'

This paragraph defines equivalence acceptance by the use of risk analysis for the following systems:

- (3d) Capacity of ballast-tanks
- (3e) suction wells in cargo tanks
- (3f) ballast and cargo piping
- (6) assumptions on the extent on bottom raking damage
- (8) position of collision bulkhead

It is observed that an adequate safety level is not specified and it is up to the user to find out the implicit level of safety in the prescriptive requirements. In paragraph 3.1 of the Resolution it is mentioned that these exemptions should be approved by MEPC. This procedure is probably so cumbersome and time consuming with unpredictable outcome that it is not likely it will ever be applied.

<u>MSC Circ. 645</u>

par. 2.1 states:

> ‘ A DP-system consists of components and systems acting together to achieve sufficiently reliable position keeping capability. The necessary reliability is determined by the consequence of a loss of position keeping capability. The larger the consequence, the more reliable the DP-system should be.
> To achieve this philosophy the requirements have been grouped into three equipment classes. For each equipment class the associated worst case failure should be defined as in 2.2 below.
> The equipment class of the vessel required for a particular operation should be agreed between the owner of the vessel and the customer based on a risk analysis of the consequence of a loss of position. Else, the Administration or coastal State may decide the equipment class for the particular operation.’

A suggested method for performing the risk analysis mentioned above may be any method that can handle multiple failure and common cause failures, e.g. FTA, ETA Reliability Block Diagrams, Monte Carlo simulation and Markov models.

<u>High Speed Craft Code</u>

The High Speed Craft Code requires FMEA for machinery, electrical, stabilisation systems and directional control systems. Annex 3 (Use of probability concept) of the Code effectively defines a risk matrix containing risk acceptance criteria for single failures in those functions.

Some observations related to the use of FMEA:

- it is inadequate for common cause failures
- it is not effective to handle the human element
- FMEA is only a single risk analysis tool. It is not consistent with a comprehensive FSA approach. (FMEA is one hazard identification method, step 1 of FSA and applicable to technical sub systems.)

<u>Probabilistic approach for damage stability calculation for dry cargo ships > 100 meters</u>

The following observations were made:

- the probability of occurrence of scenarios is not taken into account
- consequences are only addressed implicitly and partly (will the ship sink or not)
- the acceptance criterion, which is the standard of compartmentation, could benefit from being based on the FSA approach for the relevant ship types and accident scenarios.

<u>ISM-Code Safety Management System</u>

Reference is made to paragraph 1.4 and 10.3 of the ISM-Code which are stated below.

1.4 Functional requirements for a Safety Management System (SMS)

Every company should develop, implement and maintain a Safety Management System (SMS) which includes the following functional requirements:

.1 a safety and environmental protection policy;

.2 instructions and procedures to ensure safe operation of ships and protection of the environment in compliance with relevant international and flag State legislation;

.3 defined levels of authority and lines of communication between, and amongst, shore and shipboard personnel;

.4 procedures for reporting accidents and non-conformities with the provisions of this Code;

.5 procedures to prepare for and respond to emergency situations; and

.6 procedures for internal audits and management reviews.

10.3 The Company should establish procedures in SMS to identify equipment and technical systems the sudden operational failure of which may result in hazardous situations. The SMS should provide for specific measures aimed at promoting the reliability of such equipment or systems. These measures should include the regular testing of stand-by arrangements and equipment or technical systems that are not in continuous use.

Par. 4 of 1.4 will generate a lot of data collection activity that are of interest in risk analysis. The requirement is limited to reporting within one company. The learning from experience is therefore limited to one company and the operational phase of the ship-life. It would be of great benefit if this information could be shared with others in the industry such that the experience could be used in the design of new ships. The use of FSA could benefit from such data.

This ISM requirement has been in force for only about one year, and it is unclear to which extent this requirement will lead to more extensive use of risk analysis to identify hazards and manage relevant risks. In principle SMS could develop into an 'operational safety case'.

5.6.4 How to Use Risk Assessment in Rule Making

5.6.4.1 General

The purpose of developing maritime rules and regulations is to manage risk. A key element in risk management is the proper use of risk assessment techniques. To put the various risk management concepts into context the term is defined as follows:

Risk Management [4] is a formal process for managing risks. The process consists of system definition, hazard identification, identification of accident scenarios, quantification of probabilities and consequences, assessment of risk, identification of risk control options, decision on implementation, identification and management of residual risk.

Defined in a stepwise process Risk Management may be defined to comprise the following steps:

1. System definition, clearly identified system boundaries and scope
2. Hazard identification and crude prioritization of hazards
3. Qualitative estimation or characterization of important accidental scenarios based on 2
4. Quantification of probabilities or frequencies of events. (Step 4 is not relevant for chronic conditions or regular releases) (May be done qualitatively - Risk Matrix)
5. Quantification of consequences of events (May be done qualitatively - Risk Matrix)

[4] Risk management normally would consist of other elements, e.g. financial risk management (the use of various financial instruments to reduce risks). The option for transferring risks by financial instruments and insurance is not discussed here.

6. Risk assessment (Assessing if the decision represent risks that is tolerable/acceptable, ALARP etc.) (May be done qualitatively - Risk Matrix)
7. Identification of risk reduction/control options
8. Decision on implementation of risk control
9. Identification of residual risks
10. Management of residual risks

The FSA process contains steps 1 to 8, while 9 and 10 can be regarded as being part of the Safety Management System as required by the ISM-code.

Different types of risks can be distinguished:

- individual risk to crew, passengers and third parties;
- societal risk to crew, passengers and third parties; and
- environmental risk.
- economical risk (commercial availability, off hire, damage to property, loss of revenue etc.)

In using this risk terminology IMO is committed to reduce:

- individual risk to crew, passengers and third parties (risk to third parties only implicitly and partially);
- societal risk to crew, passengers and third parties (risk to third parties only implicitly and partially); and
- environmental risk (as far as that can be regulated by requirements to the ship).

Economical risk should not be normally regulated and be left to commercial laws of the market place.

5.6.4.2 Aspects Related to the Application of FSA

FSA was developed for the purpose of supporting the IMO rule-making process by introducing risk analysis/assessment methods. Some aspects, which are often mentioned in connection with the applicability of risk analysis/assessment to shipping, such as applicability of FSA to environmental risk, inclusion of the human factor, necessity of reliability data, have been evaluated in order to find out if FSA is addressing and/or covering those aspects. The following text presents the main items, a full description of all items evaluated is given in /7/.

FSA applied to environmental risk

The IMO FSA Interim Guidelines have been developed by a joint IMO MSC/MEPC working group. However, the guidelines seem to be focused on maritime safety and not to a very great extent to environmental issues. Environmental issues in the guidelines are addressed only in general terms as possible consequences of an accident.

Damage to the environment may be due to:

1 accidental releases;

2 regular releases; or

3 intentional releases

The FSA guidelines are generally applicable to accidental releases.

The analysis of the probabilities of an event involving environmental risk can be done in the same way as for those involving societal and individual risk. The environmental consequences must be analyzed and presented similar to societal risk (e.g. an FN-diagram for each pollutant).

The FSA guidelines are missing a taxonomy for comparing the environmental consequences of different pollutants and acceptance criteria based on this taxonomy (the guidelines are missing acceptance criteria in general).

Decision parameters and corresponding acceptance criteria need to be developed by IMO. Decision parameters should be included in the guidelines, whilst acceptance criteria could be included in the guidelines but should preferably be part of the regulations.

Regular releases do not require any kind of probabilistic analysis as the probability per definition is 1. Risk analysis in general requires clearly defined system boundaries (step 1).

In the FSA guidelines the system boundary is the ship. To use risk analysis techniques for regular releases would require that the system boundaries are redefined to e.g. a habitat, a geographical area (environmental sensitive areas), or the entire ecosystem.

The assessment part of the consequences of regular releases is obviously difficult, since relatively little is known of long-term effects. The method will therefore have to include both information with little uncertainty (e.g. the regular releases) and information with large uncertainties (e.g. consequences of greenhouse effect). Within environmental protection the precautionary approach is used to account for such uncertainties, a principle which lacks a quantitative definition (like a quantile in the distribution). To avoid the problem of quantification the decision parameter may be based on comparison with other ships (relative instead of absolute parameter) as is done in the Environmental Indexing method (ref. to chapter 5.1.2.1).

<u>FSA including human factor</u>

The FSA guidelines in paragraph 4.3 require the human element to be specifically addressed and incorporated.

An explicit qualification statement for the hazard identification team is made in paragraph 4.2.1 of the guidelines requiring specialist competence in human element.

Specific techniques are described in /6/ and in the submission to MSC71 (MSC 71/14/1) from IACS. These documents contain a description of the relevant methods that may be applied.

<u>FSA and reliability data</u>

The FSA guidelines mention accident data and failure data in paragraph 5.1.3. Failure data contain the same information as reliability data, since they are complementary. Specific elements of reliability data are addressed in /5/ and in chapter 5.4.3.

As demonstrated there, it is easy to identify possibilities for improving the data collection. Lack of data is also the most common reason given for not carrying out an FSA.

5.6.4.3 Aspects which are critical to the application of FSA

In order to identify areas of improvement for the application of FSA to the rule-making process, problem areas have been identified. The following sections list the problems encountered when FSA is applied. In the last section a list of conclusions drawn is presented.

<u>Lack of data/ models</u>

It was mentioned above that lack of data is the most common reason given for not performing an FSA. When a decision needs to be made it should be based on the best available knowledge. In reality lack of data should never hinder the execution of an FSA. In most cases data do exist. The problem is that it may be very costly to retrieve and treat it. FSA is a new methodology in the maritime industry and will have to overcome the problems already tackled in the other industries (e.g. nuclear, offshore, process and aviation). Competence in retrieving data from various sources and processing them has to be built up and is part of the expertise required of a risk analyst.

<u>Treatment of uncertainty</u>

Treatment of uncertainty is being dealt with at different places in the FSA guidelines (reference is made to paragraphs 5.3.2, 6.2.1, appendix 3 paragraph 4 of the guidelines). In general all risk models contain uncertainty, and a base case representing the best estimate/ judgment should be presented first. Thereafter a sensitivity study should be carried out assuming optimistic and conservative estimates of the probabilities or consequences.

Limitation of scope

The FSA guidelines in paragraph 1.3 state the following:

> ‘1.3.1 The FSA methodology can be applied by an individual Administration or an organization having a consultative status with IMO when proposing amendments to safety and pollution prevention and response-related IMO instruments in order to analyze the implications of such proposals; or by the Committee, or an instructed subsidiary body, to review the overall framework of safety and environmental regulations, for instance for a particular ship type or hazard, aiming at identifying priorities or areas of concern of the current regulations.
>
> 1.3.2 It is not intended that FSA should be applied in all circumstances, but its application would be particularly relevant to proposals which may have far-reaching implications in terms of either costs (to society or the maritime industry), or the legislative and administrative burdens which may result. In these circumstances, FSA will enable the benefits of proposed changes to be properly established, so as to give Member Governments a clearer perception of the scope of the proposals and an improved basis on which to take decisions.‘

The FSA applications so far submitted to IMO fall into one of the following categories:

1. with a broad and open-ended scope
2. focused on one well defined risk control option (RCO)
3. various trial applications

From the experience gained until now with those ‘types’ of FSA it is clear that a well defined scope focused on a limited set of scenarios or risk control options is necessary to provide a clear basis on which a decision can be made.

In general the scope should be discussed and agreed with the decision maker prior to start of the project. Possibilities for limiting the scope are e.g.:

1. by screening the scenarios;
2. by focusing on specific risk control options, the RCO’s must include all relevant scenarios;
3. by hazard including relevant scenarios;

Communication in multi-disciplinary teams

Multi-disciplinary teams are addressed in the guidelines in paragraph 4.2.1 relating to the qualification of the members of the hazard identification team.

The guidelines specifically state:

> ‘The group carrying out such structured reviews should include experts in the various appropriate aspects, such as shipping, design and operations and specialists to assist in the hazard identification process and incorporation of the human element.’

The tradition in the marine industry is to organize departments, working groups, committees, etc. into competence area (e.g. strength, stability, loadlines, environmental loads).

Safety and environmental regulation requires an integral approach. This is reflected in the FSA approach. As a side-effect of FSA this work in multi-disciplinary teams will contribute positively to safety by improving the communication. For the team leader this will be a challenging task.

Inclusion of human factor

As mentioned above, specific techniques are described in /6/ and in the submission to MSC71 (MSC 71/14/1) from IACS. Within this field there is a lack of data which are applicable to the marine industry. Human reliability data may have to be taken from handbooks originating from other industries and a judgment of the applicability must be made. Such human reliability analysis will contain uncertainty that should be treated as described above.

There is a lack of data originating from operational experience and/ or experimental research of human behavior under conditions simulating the reality of a ship.

Lack of agreed decision parameters and acceptance criteria

Currently the FSA guidelines is not explicit in defining any decision parameters. They are only mentioned in general terms in chapter 7 of the guidelines.

Decision parameters and acceptance criteria would be required for defining the ALARP (As low as reasonable practical) region for:

- individual risk to crew, passengers and third parties;
- societal risk to crew, passengers and third parties; and
- environmental risk.

Within the ALARP region decision parameters and acceptance criteria based on cost effectiveness would need to be developed. This would define 'Reasonable' within the ALARP region.

The use of Regulatory Impact Diagrams

The concept of Regulatory Impact Diagram has caused much confusion since it was introduced in the Guidelines. Its aim is to identify and quantify the different influences from underlying factors on an accident, such as organisational and regulatory policy influences. However, its use seems to introduce an element of arbitrariness and subjectivity in the FSA. There were the opinions in the project that the use of RID is not necessary in an FSA and that the current version requires further research, and that reference to RID should be removed from the FSA Guidelines.

5.7 Aspects Linked with the Environmental Sensitivity of Marine Areas

5.7.1 Summary

The range of environmental aspects and sensitivities related to shipping was discussed in terms of types of pollution, including oil, chemicals, garbage, sewage, ballast water, Tributyltin (in anti-fouling systems), COx, SOx, NOx and noise, and types of areas likely to be sensitive to these pollutants.

A method to identify sensitive areas and to perform environmental risk assessment based on FSA was suggested. However, it was noted that a detailed analysis of components of the ecosystem within a geographical area may not require in most cases to adress the level of risk and the cost and benefits of risk control options. Instead, more aggregated techniques which consider the ecosystem and pollution consequences in general may be applied.

It was the opinion that the application of "sensitive areas" will most probably be part of studies which are related to specific ports, contingency plans, traffic control and special measures in special areas due to high traffic density. A review of various initiatives to define and prioritise areas from an environmental point of view was performed in order to clarify the meaning of different terminology currently used for environmental sensitive areas.

With regard to a common safety and environmental impact assessment approach it was concluded that such approach should cover pollution caused by operational handling as well as pollution caused by accidents, since operational pollution may be critical to the environment in cases of high traffic density and/or high environmental sensitivity.

As shipping is one actor in the transport market, in constant competition with other transport modes, such as rail and road transport for inland and coastal transportation, the issue of fair competition was discussed. The background for this discussion was the concern that environmental risk assessments limited to shipping alone would create an unbalanced picture of shipping related pollution, and possibly in some cases create an unbalanced focus on shipping. Based on this it was suggested that environmental risk assessments should always be performed and utilised with due attention to the total pollution picture, including the contributions from other transport modes and other sources of pollution, to enhance "fair competition" between the different transport modes. The objective should be to secure holistic assessments and to create a basis for sustainable combinations of transport modes.

5.7.2 Problem Description

Ship transportation may result in pollution through accidental and operational discharges and emissions. Operational pollution per ship year is typically found in the high frequency/low consequences part of the risk diagram, while accidental pollution per ship year is found in the low frequency/high consequences part of the diagram (Figure 5.7.2.1). However, when assessing the ship population, the consequences may be significant for operational pollution as well.

Formal Safety Assessment for the rule making process, as defined by the IMO may be applied to assess risk control options for both operational and accidental pollution. The assessment would include a cost/benefit analysis and the benefits could be expressed by reduced environmental consequences.

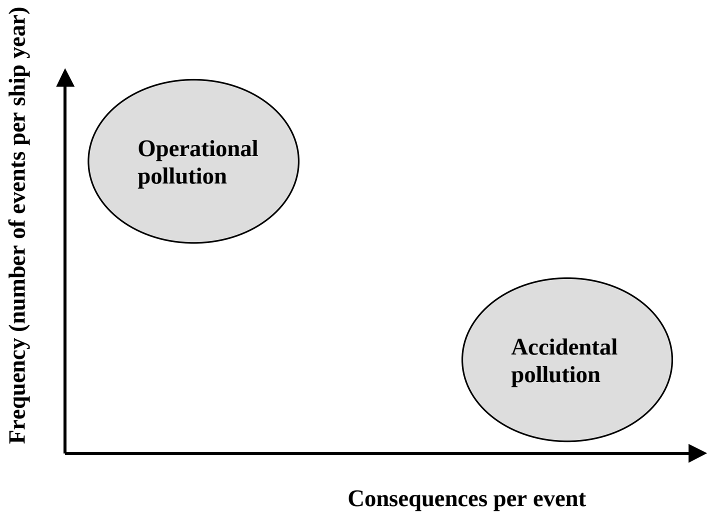

Figure 5.7.2.1: Operational pollution versus accidental pollution in the risk diagram

5.7.3 Significance of Sensitive Areas

The society have an obligation to protect the ecosystem from deterioration by human activities in line with the sustainable development principle (UN, 1987). This means that risk involved in human activities have to be analysed and risk control options have to be evaluated and implemented if the costs are fairly well balanced with the benefits obtained.

The ecological consequences referred to above are the most important in this perspective. That is, a significant reduction of a specie population that is numerous and for which other populations exist is not very important in an ecological perspective compared with a corresponding reduction in a rare and limited specie population. The economic, human health and aesthetic consequences may be considered significantly higher in the former case because of existing markets and public perception. However, the latter case may have a significant impact on the ecosystem and the bio-diversity, and should be considered most important within a context of sustainable development.

The ecosystem is too complex to allow reliable simplified modelling of consequences for the ecosystem as a result of pollution. Moreover, it is difficult to define appropriate parameters to for measurement of ecosystem impact. We are forced to focus on the most “important” ecosystem components. The most “important” components will respond differently to pollutants, depending on both the type of pollutant and the type of component. In order to have consistent and comparable analysis, the prioritisation and selection of “important” components in the ecosystem should be based on common criteria.

Dealing with the topic Sensitive Areas, this project focussed on ecological consequences. An outline of a method to be applied to identify sensitive areas which are considered to give the expected most severe impacts to the ecosystem for the given type and amount of pollution is given in chapter 5.7.6 of this report. The degree of pollution exposure is not taken into account in this definition of sensitive area. By combining measures for the sensitivity of areas and measures for the exposure risk of areas, the degree of risk may be defined related to an area.

The methodology outlined is developed and applied to assess ecological risk from offshore oil production and exploration drilling in Norway. Although the framework focuses on ecological risk, a corresponding framework may be applied to assess aesthetic, economic and human health risk as well.

The following sections provide extracts from /8/.

5.7.4 Prioritised Area

Various initiatives have been made to define and prioritise areas from an environmental point of view.

MARPOL

In MARPOL (International Convention for the Prevention of Pollution from Ships, 1973 and the Protocol of 1978 Relating to the International Convention for the Prevention of Pollution from Ships, 1973.) prioritised areas are called ‘Special Areas’.

Definitions for Special Areas can be found in Annex I (oil), Annex II (chemicals), Annex V (garbage) and Annex VI (air). The definition given in Annex I is presented below. Definitions for Annex II and V are similar.

Definition of Special Area in ANNEX 1:

"Special area" means a sea area where for recognised technical reasons in relation to its oceanographical and ecological condition and to the particular character of its traffic the adoption of special mandatory methods for the prevention of sea pollution by oil is required. Special areas shall include those listed in Regulation 10 of this Annex.

This definition of special area differs from the other definition by the fact that the traffic situation plays a role in this definition. The particular character of the traffic situation can make an area defined as a special area or not.

In Annex VI of MARPOL (air) the prioritised area is defined as a "SOx Emission Control Area", which is presented below.

“SOx Emission Control Area” means an area where the adoption of special mandatory measures for SOx emissions from ships is required to prevent, reduce and control air pollution from SOx and its attendant adverse impacts on land and sea areas. SOx Emission Control Areas shall include those listed in Regulation 14 of this Annex.

Protected Areas

There are many definitions of the term "protected areas". IMO defined protected areas in their Guidelines for the Designation of Special Areas and the Identification of Particularly Sensitive Sea Areas, Resolution A.720 (17), November 1991 as:

Areas of inter-tidal or sub-tidal terrain together with their overlying waters and associated flora, fauna, historical and cultural features, which have been reserved to protect part or all of the enclosed environment.“

This general definition covers a wide variety of marine protected areas. The number of terms used for marine protected areas, such as marine sanctuary, marine reserve, marine park, protected seascape or wildlife sanctuary, is an indication of this variety.

Red List

An overview of national and international red-lists can be found on the Internet site http://www.mnhn.fr/ctn

Special Areas of Conservation

In the UK some areas are called Special Areas of Conservation (SAC). These areas were proposed for designation under the EC Habitats Directive (Council Directive 92/43 EEC Conservation of Natural Habitats and Wild Fauna and Flora) for their marine features of conservation interests. A research project called Marine SACs provides criteria to establish those SAC. One task developed good practise guidelines for ports and harbours operating within or new UK Marine SACs (UK Marine SACs Project, 1998).

These guidelines focus on port and harbour operations managed under the Marine SAC Scheme of Management include:

- shipping and boating operation
- cargo handling
- port and harbour maintenance
- maintenance dredging
- management of ship and boat generated waste

Comparison between prioritised areas

The preferred definitions of MARPOL (MP), Protected Areas (PA), Red List (RL) and Special Areas of Conservation (SAC) show some differences in the criteria used to identify those areas.

The MP definition is specially addressed to areas where the provided regulation in the MARPOL ANNEX can be applied. The criteria are pollution by oil, chemicals, garbage and SO_x. Special attention is given to traffic characteristic.

The definition of PA is of general nature. All effects that change the environmental conditions are considered in this approach.

The definition of SAC is focused on special habitats and species that shell be protected.

5.7.5 Sensitive Areas in Relation to Consequences and Pollution Types

Main Types of Pollution

Two different polluting mechanisms can be distinguished:

- pollution caused by accidents; and
- pollution caused by operational handling

The purpose of the regulations related to pollution caused by accidents is to reduce the probability of an accident on the one hand and to reduce the consequences of that accident on the other hand. E.g. by trying to limit the amount of oil outflow that can occur in an instant.

In the case of pollution caused by operational handling regulations are focused on the reduction of the consequences, e.g. by setting limits to the maximum amounts of pollutants in a certain time.

The following main types of pollutants can be distinguished:

- oil
- chemicals
- garbage

- sewage
- ballast water
- TBT
- COx, SOx and NOx

<u>Main Types of Consequences</u>

Environmental consequences may be classified into four main categories (e.g. Vine et al., 1997):

1. Ecological consequences; this category cover impact on the ecosystem in terms of reduced populations of species, reduced quality of habitats, reduced or changed bio- diversity, etc. The governing principle for quantification of such consequences is that the ecosystem with related habitats, processes, flora and fauna have an intrinsic value. Typical consequence parameters are bio-diversity measures, recovery time for populations of species, etc.
2. Human health effects; this category cover mainly chronic effects to humans as a result of exposure to pollution and uptake and accumulation of pollution in the food chain. Humans are top predators in the ecosystem and is of less importance to the ecosystem in terms of consequences following population reductions, reduced reproduction ability, etc. Consequences are typically measured in terms of exposure levels (dose/ concentration/amount) relative to derived no effect levels (e.g. Johnsen et al., 1997).
3. Aesthetic consequences; this category cover impacts on the ecosystem which to a some degree corresponds to ecological consequences. However, the governing principle for quantification of such consequences is that the environment has a value as perceived by man. Typical consequence parameters are area or shore length contaminated and loss of recreational areas. Consequences may be perceived high by public opinion, but may be of less significance in an ecological perspective.
4. Economic consequences; this category of consequences cover all environmental consequences which may be expressed in terms of monetary units. Ecological and aesthetic consequences may therefore to some degree be included in this category. Ecological consequences could be loss of or reduced fish stocks which may be considered important in an ecological perspective.

It should be noted that the categories are partly overlapping (Figure 5.7.5.1). Aesthetic, ecological and human health consequences may be expressed in monetary units. Ecological consequences may be considered from an aesthetic point of view as well, and human health problems may arise from ecological effects.

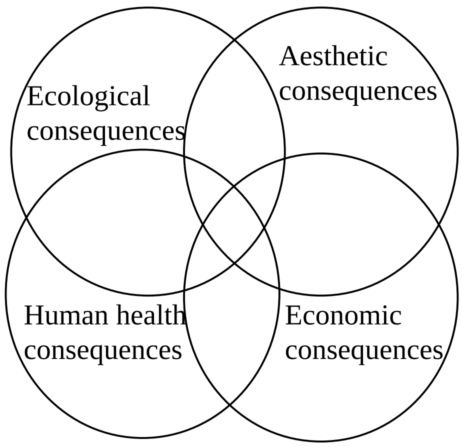

Figure 5.7.5.1: A broad categorisation of environmental consequences

Economic consequences may be quantified based on market consideration (e.g. loss of fish stocks and reduced tourism) and direct payments as part of clean up and restoration. Methods are available to include impact on non-market values such as reduced quality of recreational areas. The economic consequences will vary significantly from case to case depending on quantity spilt. Important factors are weather conditions, the flora and fauna present, the type of pollution (oil is visible and require clean up while chemicals spills often are not seen and is not easily removed from the environment), the public perception of the value of the area contaminated, etc.

Aesthetic consequences may be quantified by area contaminated or exposed to pollution above certain concentration or mass values. In order to further assess the severity of consequences, the public perception on the value of the areas may be taken into account.

Ecological consequences may be quantified in terms of population reductions of species and recovery time for habitats and populations. It is difficult to apply bio-diversity as a consequence measure because of counting problems and possible changes in flora and fauna composition. Moreover, the impact on the ecosystem is very uncertain due to the complex chemical, biological and physical balances that are not known. An applied approach is to focus on Valued Ecosystem Components and describe likely impacts for these as a result of pollution.

Although termed environmental risk assessments or ecological risk assessments, a significant fraction of theses assessments focus on human health problems. A range of consequence measures may then be applicable, such as toxicity levels for acute effects and exposure levels for chronic effects (e.g. carcinogenic and mutagen effects). However, a common approach is to express risk in terms of the ratio between Predicted Environmental Concentration (PEC) and No Effect Concentration (NEC).

5.7.6 Methods to Identify Sensitive Areas

General

In order to define the study area the exposure risk for the pollutants in question has to be considered. The exposure risk could be based on indirect measures such as high traffic and potential for accumulation of pollutants in the recipient, or they may be based on quantification of frequencies for concentration/mass/dose. The potential for accumulation may be related to the inverse of the degradation rate and or the physical, chemical and biological characteristics for the area. A diagram could be applied to define criteria to limit the study area (see Figure 5.7.6.1 and 5.7.6.2). It should be noted that the study area may be identified based on screening type methods for quantification of exposure (for example based on traffic intensity and type of area).

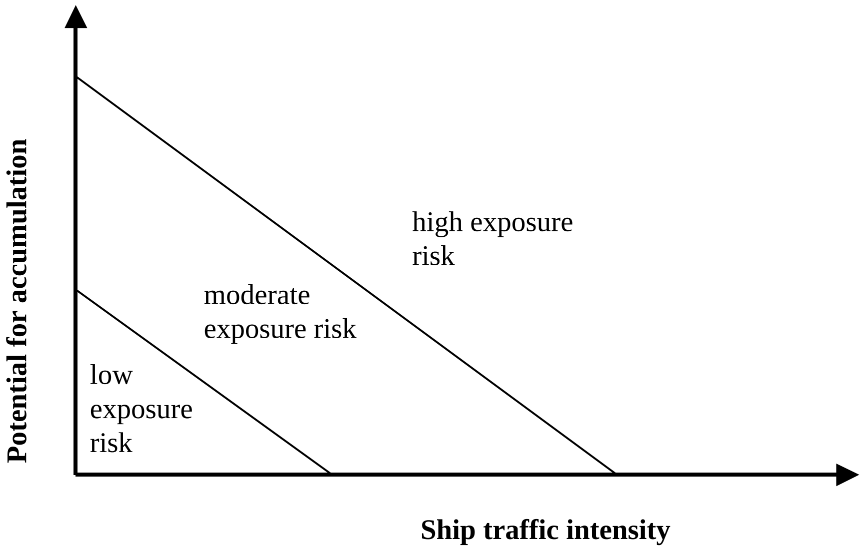

Figure 5.7.6.1: Exposure risk classified by ship traffic intensity and potential for accumulation.

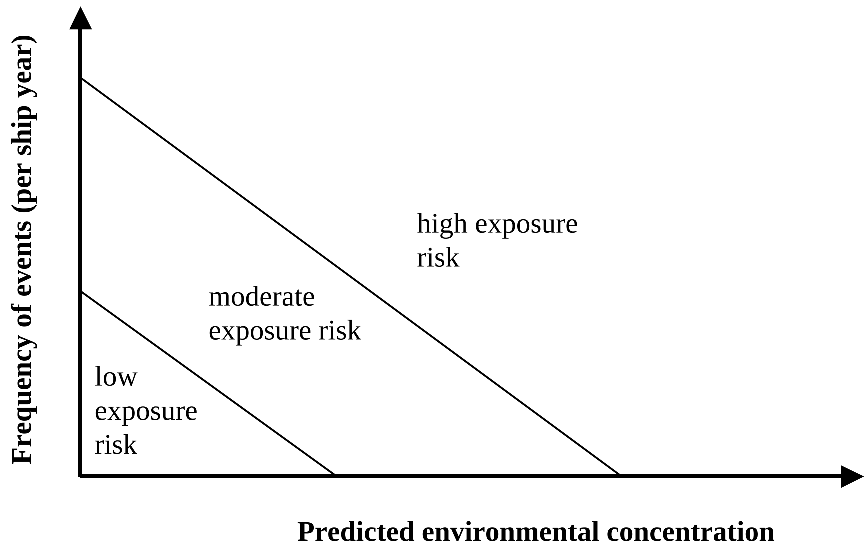

Figure 5.7.6.2: Exposure risk classified by event frequency and predicted environmental concentrations.

Identification of Valued Ecosystem Components

The concept of Valued Ecosystem Component (VEC) was introduced as part of the Adaptive Environmental Assessment and Management (AEAM) model introduced in Canada to identify environmental assessments required related to human industrial activities.

The AEAM model requires that experts within various fields of competence together identify VECs to focus on. A VEC is defined as an "ecological component that is important for local inhabitants, have a national or international profile, or is important for the evaluation of the environmental impact". It is important that the number of VECs is limited and represents a prioritisation.

Quantification of Vulnerability

The vulnerability describes the ecosystem components responds in terms of damage to given levels of exposure of pollutants. Birds are vulnerable to oil pollution because oil will pollute the feathers, reduce isolation and the birds will freeze to death. Feather pollution will also reduce mobility and the possibility for food collection. Fish is less vulnerable to oil pollution. Some habitats are more vulnerable to oil pollution than others because the area is sheltered and will not result in rapid exchange of water masses. Different ecosystem components will respond differently to chemicals as well. Differences may be related to both threshold values for effects and to types of effects (e.g. carcinogenic effects and hormone effects like imposex).

One way if classifying vulnerability is by considering the Valued Environmental Components identified in relation to:

- Time spent within study area
- Exposure time
- The potential for effects
- The potential for recovery after damage

Quantification of value of VEC's

It may be difficult to quantify the value of an identified Valued Ecosystem Component. However, governments and international administrations have identified components in the ecosystem, which have a value in terms of protection needs. This protection value is mainly related to rare species and habitats considered vulnerable to human activities. The protection value may even be ranged according to national, regional and international protection status. The so-called "red lists" may be a useful tool to identify the value of a given VEC. An overview of national and international "red lists" can be found on the Internet site http://www.mnhn.fr/ctn.

Categorisation of sensitive area

A useful approach for categorisation of sensitive areas is to locate the VEC's (which are related to geographical areas) in a diagram with two axes, which classify the vulnerability and value for the VEC's. The number of categories and the approach applied to scale the axis may depend on the study. However, the principle is that areas with VEC's with high value and high vulnerability are more sensitive than areas with VEC's with less value and less sensitivity (Figure 5.7.6.3).

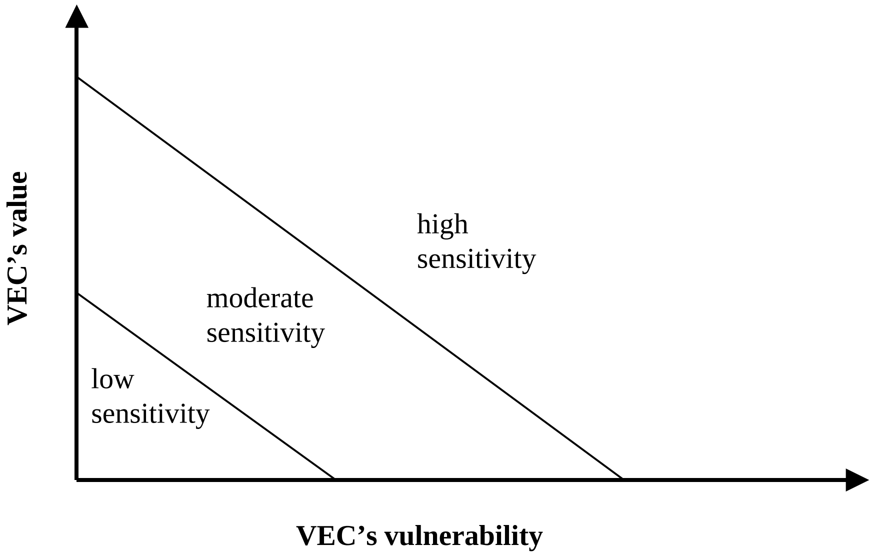

Figure 5.7.6.3: Categorisation of sensitivity based on vulnerability and value of VEC's.

Exposure risk

The exposure risk may be calculated similar to the principals applied to identify the analysis area. However, the estimations done are commonly made on a more detailed level adjusted to the size of the areas for which VEC's are defined. However, on this scale, the diagrams developed and presented in Figures 5.7.6.1 and 5.7.6.2 may be applied to categorise exposure risk for the areas in question. The calculations may be based on simplified algorithms as well as sophisticated models for the transport and fate of the pollution.

Areas of particular importance to be studied further and into more detail may be based on the method applied to identify sensitive areas. However, including screening type estimates for the exposure risk may make a further prioritisation. The Valued Ecosystem Components and the related areas may then be limited by focusing on the most sensitive areas with the highest degree of exposure risk (Figure 5.7.6.4).

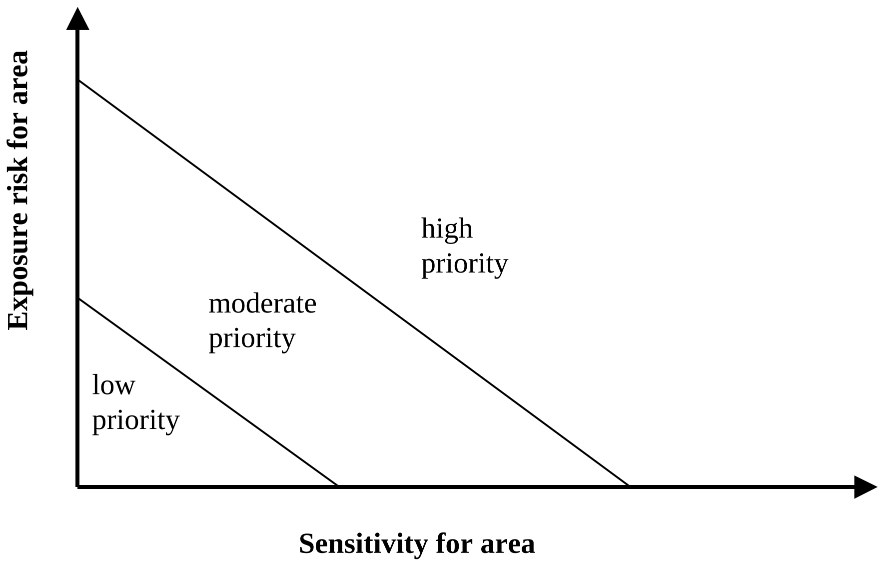

Figure 5.7.6.4: Prioritisation based on exposure risk and the sensitivity of areas.

5.7.7 Addressing the Aspect of Sensitive Areas within the FSA Process

The question of when the aspect of Sensitive Areas is to be addressed in a risk analysis/assessment process has been considered within the project. Below, a clarification to this question is provided, taking the FSA methodology as described in the IMO Interim Guidelines as a basis.

STEP 1

In step 1 of the FSA process the prioritised areas may be taken into account at the end of this step where the identified hazard will be ranked. This will only give a first indication of the consequences of an accident or from an operational pollution to the environment within the prioritised area(s) because in this step there is only a preliminary description of the development of hazards to final outcomes.

In general it can be assumed that the attention will be focussed on the consequence part. However, when it turns out that the risk level within prioritised area(s) are too high, measures may be taken to reduce the consequences of an accident or an operational pollution or to the probability of occurrence.

In this step there will have to be an assessment of the area where the activity takes place, in which special features of that area are addressed (e.g. are there any (special) coral reefs, is it a breeding places, etc.)

STEP 2

In step 2 of the FSA process the risks are further quantified and risk contribution trees are being constructed. Here the consequences for the environment within prioritised areas are further assessed. The ‘special features' from step 1 may be used as input here. In some cases it will be obvious that the consequences may be very severe. Those cases may already have been identified in step 1 (preliminary description of the development of hazards to final outcomes).

STEP 3

In assessing the risk within prioritised areas obviously specific environmental experts will be needed, especially with respect to assessment of the consequences of accidents or operational discharges/emissions. These experts will (maybe for a part) already have been involved in the hazard identification process. Normally this group of experts may also generate (most of) the risk control options. The risk control options may be focussed on reduction of the consequences (e.g. maximisation of an instant oil outflow) or on the reduction of the probability of discharge or emission of pollutants (e.g. routing measures).

STEP 4

In the cost benefit assessment the hardest part will be to estimate the benefits of the risk control option. This may be done in financial terms. Estimation would then have to be made of the value of e.g. specific species that would be lost in case of an accident. The prioritised area in this example would only be such an area e.g. because of the fact that this specific specie can only be found in this area. An accident would in fact exterminate such specie (as an example). Obviously it will not be easy to add a value to this specific specie. Factors like the importance for the whole lifecycle play a role. Furthermore it will depend on the prosperity of the society at a certain point of time. Therefore it can be expected that such estimations will be very subjective. However, the important thing is that we come to an agreement to assign such a value.

Also here the determination of such value will require very specific expertise.

STEP 5

The decision making may be based on the cost-benefit assessment. This would probably be the ideal situation. In that case the decision can be based on the information mainly coming from step 4. In judging the balance between costs and benefits sometimes there may be a need to go back into the process. However, when prioritised areas are involved also emotional or political reasons may play a role. Furthermore the severity of the consequences may be such that it sometimes may be of vital importance to reduce the costs, also when costs and benefits are not quite in balance. This may lead back again to matters like public opinion and thus emotional reasons will play a role.

5.7.8 Fair Competition with other Transport Modes

Shipping is one actor in the transport market, in constant competition with other transport modes, such as rail and road transport for inland and coastal transportation. The issue of fair competition was discussed in the project, as a result of concern raised that environmental risk assessments limited to shipping alone would create an unbalanced picture of shipping related pollution, and possibly in some cases create an unbalanced focus on shipping.

The subject of fair competition can be approached in different ways. The first way of looking at it is by making a comparison between the different transportation modes. It may be the case that in a certain transportation mode formal safety and environmental assessment techniques are being used in an extensive way. In doing this the focus on safety and environmental issues relatively may get more attention than in other transportation modes. This may well have as an effect that in this particular transportation mode more money is spent in enhancing safety and environment. This again may lead to unfair competition. It may be of interest where there really are cases of competition between different transportation modes.

A differentiation has to be made between:

- Inland transport ; and
- Sea-going transport

Inland transport consists of inland shipping, transportation by road and by railways. There is a real competition between these transportation modes when the transportation of goods is considered.

Transportation of goods by air is considered not to be of very great importance. Only goods with a relatively high value (high tech) are transported by air.

The application of safety and environmental assessment techniques in an extensive way may for inland shipping lead to situations where one could speak of unfair competition in comparison with transportation by road or by railroad. However, it also has to be stressed that inland shipping is often promoted to be a relativey safe and environmental friendly means of transportation. The use of the earlier mentioned techniques may contribute to these promotion activities.

Transportation by sea may be competed by transportation by air. However, this is considered not to be relevant, because of the small volumes that go by air. Cargo with a relatively low value will not be transported by air. This means that the use of safety and environmental assessment techniques will not have a real influence on the competitive strength of transportation by sea. The competition within this mode plays a far more important role.

Another way of looking at this is by differentiating between sources of pollution. The different users of a sensitive area all together form the sources of pollution. Pollution may come from the air, from the rivers that are running into or through such an area (pollution from e.g. industrial activities along such a river), from ships and from other activities taking place within that area. There is not a real competition between these sources of pollution in an economical sense. However, it may be the case that there is some kind of 'competition' between the extent to which the sensitive area may be polluted by a certain source.

The basic idea is that each area is capable of carrying a certain load of pollution. The different sources of pollution may all 'contribute' to relatively the same extent.

5.8 Necessary Further Research and Development Activities

All results and conclusions gained from the above described activities were reviewed with regard to the necessary further research and development activities in order to support and facilitate the utilization of safety and environmental assessment approaches in shipping in general and of a common European approach in specific.

A list of relevant research tasks was developed with a description of the contents of each of the tasks. A summary is given in the following paragraphs. For further detail reference is made to /9/.

5.8.1 Common Safety and Environmental Approach

Based on the review of potential users (actors/stakeholders in shipping) and their assessment needs, and the available methods for safety and environmental assessment, it had been concluded in the project that no single methodology has the capability of serving all essential safety and environmental decision problems and needs within shipping. Therefore, rather than trying to develop a common methodology it was concluded that the aim should be to focus on the development of a common European approach. This approach should be capable of being common to all major actors and should consist of several complementary and suitable methods to be applied according to the user needs.

The state of the art review as described in chapter 5.1 showed that potential users have developed and applied specific methods serving their specific needs.

Further and more detailed investigations are necessary to specify and concretise the various particularities of the different users and their specific or typical needs. Based on the characteristics of the existing methods, the similarities and differences have to be better identified in order to end up with an optimised and exhaustive set of suitable methods with a minimum of overlapping.

It is envisaged that a common approach will enhance the communication and the co-operation between the actors/stakeholders within the shipping community with regard to safety and environmental issues.

5.8.2 Risk Acceptance Criteria

Currently no common and agreed risk levels are available to decide if a certain level of risk is commonly acceptable or not. Further research should try to establish a common set of sustainable risk acceptance criteria.

In addition, it is very difficult for decision-makers to make conclusions when human life and environmental damage is to be held up against economic values. There is a need for an approach to secure balanced solutions.

5.8.3 Risk Management

There is a concern in the shipping community on how shipping as an industry can best utilise the knowledge created as a result of ISM, e.g. all the data generated in accordance with Chapter 9 of the ISM Code.

A concern is that the risks identified during the design stage are not sufficiently and consistently communicated to the operational phase.

5.8.4 Risk Communication

Risk is a function of the frequency and consequence of undesired events. Currently, however, this concept is not sufficiently understood by the society. Because of this, there is a lack of awareness of risk aspects, which also limits the society's alertness to such information. This makes it difficult to communicate risk. While accidents with higher frequencies but minor consequences are often perceived as indicators of low risk, accidents with severe consequences but low frequencies are often considered as indicators of high risk, even if the risk levels of both should be equal.

The safety culture in operation as well as the safety culture in the society will change only when the risk concept is adequately understood. Therefore, initiatives are proposed to improve risk communication.

5.8.5 Organisational Changes Associated with the Common Approach

The implementation of a common approach within the shipping industry implies changes to a various degree in the way the organisations deal with safety and environmental issues. Some organisations are already implementing risk based approaches, e.g. ship owners implementing the ISM Code or charterers using vetting schemes, while some other actors might still be sticking to a traditional way of dealing with safety and environmental issues.

5.8.6 Case Studies

Experience has to be gained with formal assessment methodologies, covering both safety assessment aspects and environmental assessment aspects. The effectiveness and usefulness of methodologies that are seen as appropriate for various application areas in shipping can be verified/evaluated by carrying out case studies.

5.8.7 Human and Organisational Factors, Databases

Other aspects which need further development in order to facilitate the utilization of a safety and environmental assessment approach in shipping are related to human and organisational factors and to accident/incident and reliability data.

5.8.8 Suggested Research Tasks

No.	Research Areas
1.	**Common Safety and Environmental Approach**
1.1	Verify the list of users, and investigate and verify their decision problems and needs as provided in /6/. Verify the identification of methods as provided in /6/ and define suitable combinations of methods to form a common approach for the identified user groups based on the more detailed overview of decision problems and needs. As basic information it is referred to Ch. 4 in /6/ and Ch. 6 in /4/.
1.2	Identification of gaps and weaknesses of the available methods in relation to the updated list of decision problems and needs, and definition of necessary improvements and further developments.
2.	**Human and Organisational Factors**
2.1	Create a general knowledge and awareness of human and organisational factors, and encourage implementation of these factors in safety and environmental analysis. Aspects that may be included may also address items such as creating a socially positive working environment, developing working procedures (compare to aviation), developing protective barriers for the cases of unavoidable errors, developing decision making support systems.
2.2	Establish databases covering these factors to increase the knowledge of causes and their distribution for all types of accidents, and develop cause and effect models based on theory and databases.
2.3	Use the models and databases for prioritising and quantifying human factors to increase the accuracy when integrated in risk analysis.

No.	Research Areas
3.	**Risk Acceptance Criteria**
3.1	Inventorise and compare the different kind of standards and risk criteria in Europe which are used to address and assess risk to people (e.g. individual, societal), to the environment and to property. This inventory could be a basis for initiatives to harmonise such standards and criteria within Europe.
3.2	Introduce measures to evaluate human life and environmental values and loss of such values in economic terms.
3.3	Development of tools and models for practical cost benefit effectiveness of safety control measures within the ALARP region.
4.	**Databases**
4.1	Investigation into the establishment of a accident data base system in Europe.
4.2	Design of an incident reporting system.
5.	**Case Studies**
5.1	The implementation of case studies on formal safety and environmental impact assessment. Topics for such case studies have to involve both safety as well as environmental aspects. Such a topic could e.g. be the ballast water exchange at sea. Besides of safety aspects like stability and loading of the ship's structure, environmental aspects involve e.g. the transfer of micro-organisms from one marine environment to another.
6.	**Risk Management**
6.1	Establishment, implementation and continuos development of a safety management (and environmental protection) system. E.g. ISM Chapter 9 requires a system for investigating, recording and analysing undesired events.
6.2	Investigation of possible improvement of transfer of knowledge gained from safety, availability and risk analysis during the design stage to the risk management on board the ship as well as on shore.
7.	**Risk Communication**
7.1	Risk is a combination of frequency and consequence of undesired events. Currently, however, this concept is not sufficiently understood by the society. Because of this, there is a lack of awareness of risk aspects, which also limits the society's alertness to such information. This makes it difficult to communicate risk. While accidents with higher frequencies but lower consequences are seen as „normal„ events, accidents with high consequences but low frequencies are often considered as disastrous, even if the risk levels of both are equal. Safety culture in operation as well as society will only change when the risk concept is adequately understood. Therefore initiatives are proposed to improve risk communication.
8.	**Organisational changes associated with the common approach**
8.1	The implementation of a common approach within the shipping industry implies changes to a various degree in the way the organisations deal with safety and environmental issues. Some organisations are already implementing risk based approaches, e.g. ship owners implementing the ISM Code or charterers using vetting schemes, while some other actors might still be sticking to a traditional way of dealing with safety and environmental issues. It is suggested that research is done to clarify the necessary changes within the various organisations.

6 Conclusions

The work programme and the intentions of the project had been achieved successfully.

One of the major findings was that currently there is no common methodology available which would have the capability to serve all essential safety and environmental decision problems and needs within shipping. Instead, it was found recommendable to focus on the development of a common approach, common to all major actors and consisting of several complementary suitable methods to be applied according to the user needs.

For this purpose it was suggested to review and verify the list of potential users developed in the project and investigate and verify their decision problems and needs on the basis of the relevant results produced in the project. This would provide a more detailed overview of decision problems and needs, which is necessary to define suitable combinations of methods to form a common approach for the identified user groups.

It was concluded that further investigations into the establishment of an accident/incident database system in Europe is necessary for facilitation of formal assessment methodologies in shipping.

This would be also supported by overcoming the existing lack of common and agreed risk levels in shipping. Therefore it was concluded that the establishment of a common set of risk acceptance criteria should be initiated.

It was felt important to support the performance of case studies on formal safety and environmental impact assessment, in order to gain experience with the assessment methodologies, to demonstrate their potentials and/or limitations and to improve them, if necessary.

The implementation of a common safety and environmental assessment approach in shipping will imply changes to a various degree in the way the organisation deal with safety and environmental issues. It was felt that a clarification of those necessary changes within the various organisations is needed.

Finally, the necessity was seen to improve the understanding of the risk concept by the shipping community and the society, as it was felt that the safety culture in operation as well as the safety culture in the society will only change when the risk concept is adequately understood.

7 References

/1/ Summary Report

/2/ Exploitation and Dissemination Report

/3/ Final Report for Publication

/4/ Deliverable D1: Review and Discussion of Current Methodologies in Formal Safety and Environmental Assessment

/5/ Final Report of Workshop A: Review on State of the Art of Current Databases and Accident/Incident Reporting Schemes in Shipping

/6/ Final Report of Workshop B: Evaluation of Assessment Methods and How to Integrate Human and Organisational Factors

/7/ Final Report of Workshop C: Evaluation of How Assessment Techniques Can Be Used for the Rule Making Process in the Maritime Industry

/8/ Final Report of Workshop D: Aspects linked with the Environmental Sensitivity of Marine Areas

/9/ Final Report of Workshop E: Further Research

/10/ CA-FSEA Hand-out at a PanEuropean Transport Conference

8 Annex Publications, conferences, presentations

8.1 A 1 Publications

Projects objectives, background, work programme and results have been published through the CA-FSEA Web Site: http://www.germanlloyd.org/fsea

8.2 A 2 Conference attendances with presentation of the project and results

Conference	Presentation
Pan European Transport Conference, Helsinki, 1997	Hand-out: Secretariat of the Concerted Action on FSEA, represented by H.A. Vie
Sealoc Workshop, Naples, 1998	Paper: Secretariat of the Concerted Action on FSEA - P. Securius, H.A. Vie: Maritime Industrial and Social Requirements and Benefits from Safety and Environmental Assessment
	Paper: M. Dogliani, K. Metselaar: FSA Impact on EU
Building Bridges, Waterborne Transport Reserach, Rotterdam, 1999	Presentation: Secretariat of the Concerted Action on FSEA - P. Securius: Results and conclusions from CA-FSEA