

Safety at Speed - S@S
CONFIRMATION OF MAIN CAUSES
DELIVERABLE NO. D1.1.0

Document ID Code: S101.10.03.056.001

Date: 2002-02-25

Contract No. G3RD-CT-2001-00331

CLASSIFICATION AND APPROVAL

Classification: Confidential

DEFINITION

Public after Review:

The document may be freely distributed after successful EC review, given the EC's permission. Publication is governed by the EC Contract and the S@S Consortium Agreement

Confidential for the Duration of the Project:

As for 'Confidential', but only for the duration of the Project. After final Project Approval by the EC, status for reports classified 'Confidential for the Duration of the Project' are automatically down-graded to 'Public'.

Confidential:

The document is for use of the G3RD-CT-2001-00331 Contractors within the S@S Consortium, and shall not be used or disclosed to third parties without the unanimous agreement within the S@S PMC and subsequent EC approval since document classification is part of the EC Contract.

Any executive summary specifically intended for publication may however be made known to the public by the author and/or the Coordinator.

AUTHORS:

| Name | Date | Signature |
|------|------|-----------|
|------|------|-----------|

| | | |
|----------------------|------------------|-------|
| <i>Mauro Pedrali</i> | <u>2002-2-25</u> | _____ |
|----------------------|------------------|-------|

Note: The production of this report has been a joint effort of Mauro Pedrali from D'Appolonia and Thomas Koester and Michael May from Danish Maritime Institute.

APPROVAL:

Approved for release by:

| Name | Date | Signature |
|------|------|-----------|
|------|------|-----------|

| | | |
|--------------------------|------------------|-------|
| <i>Franco Zuccarelli</i> | <u>2002-2-25</u> | _____ |
|--------------------------|------------------|-------|

DOCUMENT HISTORY:

| Issue: | Date: | Initials: | Revised pages: | Short description of changes: File name: |
|--------|------------|-----------|----------------|---|
| 001 | 2001-11-30 | MPE | | First Issue |
| 002 | 2002-02-25 | MPE | | Final Issue to the Co-ordinator and the EC (implementing comments made by ABS) |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

DISCLAIMER

Use of any knowledge, information or data contained in this document shall be at the user's sole risk. Neither the S@S Consortium nor any of its members, their officers, employees or agents accept shall be liable or responsible, in negligence or otherwise, for any loss, damage or expense whatever sustained by any person as a result of the use, in any manner or form, of any knowledge, information or data contained in this document, or due to any inaccuracy, omission or error therein contained.

The European Community shall not in any way be liable or responsible for the use of any such knowledge, information or data, or of the consequences thereof.

CONTENTS

| | |
|---|-----------|
| 1. EXECUTIVE SUMMARY SUITABLE FOR PUBLICATION | 5 |
| 2. INTRODUCTION..... | 6 |
| 3. METHODOLOGY | 7 |
| 3.1 COLLECTION OF INFORMATION | 7 |
| 3.2 LIST OF TECHNICAL AND HUMAN FACTORS..... | 8 |
| 3.2.1 ADREP System | 9 |
| 3.3 ACCIDENT ANALYSIS AND CONFIRMATION OF CAUSES | 11 |
| 3.3.1 Confirmation of relevant causes | 11 |
| 3.3.2 Further adjustments of the list | 12 |
| 3.3.3 Factors on different levels in the causal chain..... | 12 |
| 3.3.4 Bias by tradition and style in accident reports..... | 13 |
| 3.4 FMECA..... | 13 |
| 3.4.1 Failure Causes..... | 14 |
| 3.4.2 System..... | 15 |
| 3.4.3 End Events | 15 |
| 3.4.4 Local Effects | 16 |
| 3.4.5 Relevant Causes | 16 |
| 3.4.6 Prioritised Failure Modes..... | 17 |
| 4. RESULTS (SUMMARY) | 19 |
| 5. COMPARISON WITH SCHEDULE OF WORK..... | 20 |
| 6. CONCLUSION | 21 |
| 7. REFERENCE..... | 22 |
| 8. APPENDIX 1: ACCIDENT/INCIDENT LIST..... | 23 |
| 8.1 DESCRIPTIVE LIST OF HSC ACCIDENTS 1989-2001 | 23 |
| 8.2 NEAR MISSES AND INCIDENTS WITH INSUFFICIENT INFORMATION AVAILABLE:..... | 40 |
| 9. APPENDIX 2: HUMAN AND TECHNICAL FACTORS LIST..... | 42 |
| 9.1 TECHNICAL FACTORS AND ATTRIBUTES..... | 43 |
| 9.2 HUMAN FACTORS AND ATTRIBUTES | 58 |
| 10. APPENDIX 3: CONFIRMATION OF MAIN CAUSES | 71 |
| 11. APPENDIX 4: FMECA SHEETS..... | 74 |
| 11.1 SUMMARY TABLE OF FMECA (FOR COLLISION AND GROUNDING) | 75 |
| 11.2 FAILURE CAUSES | 76 |
| 11.3 LOCAL EFFECTS..... | 79 |
| 11.4 RELEVANT CAUSES | 81 |

1. EXECUTIVE SUMMARY SUITABLE FOR PUBLICATION

The purpose of the work described in this document was to confirm what was foreseen at the proposal level in terms of factors (human and technical) affecting the reference hazards (collision and grounding).

According to this confirmation, the next objective was to better specify and detail what “attributes” should be considered within the models of collision and grounding for each affecting factor.

Finally, a Failure Mode, Effect and Criticality Analysis (FMECA) for a High Speed Craft backed up the work done for the confirmation of main causes.

The work took the form of a ‘system level safety review’, that was performed using as a reference the selected representative type of vessel illustrated by the shipyard.

S@S is the acronym for Safety at Speed, a project supported by the European Commission under the Growth Programme of the 5TH Framework Programme. The support is given under the scheme of RTD, Contract No. G3RD-CT-2001-00331.

2. INTRODUCTION

The purpose of the work carried out in this Task was threefold:

1. Confirming what was foreseen at the proposal level in terms of factors (human and technical) affecting the reference hazards (collision and grounding);
2. Better specifying and detailing what “attributes” should be considered within the models to be developed in Task 1.2, for each affecting factor;
3. Performing a Failure Mode, Effect and Criticality Analysis (FMECA) for a High Speed Craft in order to back up the work done for the confirmation of main causes.

The work took the form of a ‘system level safety review’, that was performed using as a reference the selected representative type of vessel illustrated by the shipyard.

In order to achieve the first two objectives, a preliminary list of technical and human factors was developed against which information retrieved from a list of accidents, incidents and near misses was compared thereafter. The accident list was elaborated thanks to information made available by one partner and through an extensive search over the Internet.

This list of factors was compiled by taking as a reference the ADREP system adopted in the aviation domain where, as far as human factors are concerned, the conceptual model SHELL is used to investigate factors affecting human performances.

The third objective was achieved through a ‘plenary brainstorming exercise’, which was carried out jointly by all the project’s members during a workshop and produced also a common view/understanding across the first four work packages.

3. METHODOLOGY

The confirmation of main causes for collision and grounding and the specification of attributes were carried out over a number of phases, namely:

- Collection of information on past events (not only accidents and incidents, but also near misses);
- Design and development of a preliminary classification frame both for confirming causes and detailing attributes in the modelling phase;
- Comparison of the classification categories against these events and confirmation of main causes;
- Accomplishment of a Failure Mode, Effect and Criticality Analysis (FMECA) to back up the work done in the previous phase;

Results issued from the two confirmation exercises were compared and merged; final comments and suggestions for future work are given.

These phases are further described in the following subchapters that trace back the work accomplished in Task 1.1.

3.1 Collection of information

The objective of this phase was to collect as much information as possible on past event in order to have a first impression of what are the most recurrent causes, both in terms of human and technical factors, leading to collision and grounding.

However, the research did not only address accidents and incidents but also it focussed on near misses, because it is widely recognised that causes leading to serious occurrences can often be found also as precursors in minor events.

The main sources for accident and incident reports was the Internet; about 40 were retrieved and about 30 were either collision, or allision/contact, or grounding. Information on these events are synthetically provided in Appendix 1 and classified as follows:

- Year, Month
- Name (of the vessel)
- Location
- Vessel type
- Incident type
- Casualties
- Description (summary)
- Additional information (e.g., picture, investigation report availability, language)

Unfortunately, for all these occurrences the official investigation report is not always available, in this case only a brief description is provided.

As far as near misses are concerned, they were kindly provided by one of the member of the project but for the sake of confidentiality only the type of information available are reported in this document; these are

- Date
- Major incident or Minor accidents¹
- Site/craft
- Trade/occupation
- Part of body
- Type of injury/damage
- Primary incident category (i.e., categorisation of the primary cause)
- Secondary incident category (i.e., categorisation of the secondary cause)
- Apparent cause (full text description of the causes)
- Remedial recommendation

Behind this first collection exercise there is the intent to build up progressively during the project a common 'database' that can be fruitfully exploited not only by those involved in collision and grounding but also in the other types of hazards.

3.2 List of technical and human factors

The following step was the development of a preliminary list of technical and human factors against which the information contained in the occurrences were compared.

It was not the author's intention to develop a list of "technical and human factors" beyond the scope of the current project. Nevertheless, since this activity had already been started elsewhere in another EU project [THEMES - Thematic Network on Safety Assessment in Waterborne Transport] it was a good opportunity to take advantage of this effort.

The purpose of this list is twofold:

- To be used not only for confirming causes but also as a support in the modelling phase (for providing the 'building block' of fault trees);
- To be used across the four work packages and not only for collision and grounding.

This list had to provide not only an exhaustive set of categories corresponding to all the possible factors, technical and human related, that can lead to an accident but also had to be based on a model, even simple, able to represent both humans' and ship's components and performances.

To develop such a list the ADREP system was taken as a reference, especially for the human factor part; the complete list of technical and human factors is reported in Appendix 2.

¹ No clear definitions were given on the distinction criteria

3.2.1 ADREP System

The Annex 13 of International Civil Aviation Organisation (ICAO) established international procedures for accident and incident investigation and reporting (Chicago Convention, 1947). The Accident/Incident Reporting (ADREP) system is the main instrument for collecting, codifying and disseminating information over an occurrence.

The ADREP classification scheme has been developed and globally recommended by the ICAO as a means of reporting information on occurrences (either incidents or accidents) that are seen as “important for safety and accident prevention”.

A major relevant aspect in the ADREP approach is the highlight on the reporting of factors, i.e. all that “shows why an accident or incident happened”.

To this end, ADREP defines a coding scheme of these factors, structured in an Event-Descriptive-Explanatory scheme (Figure 1).

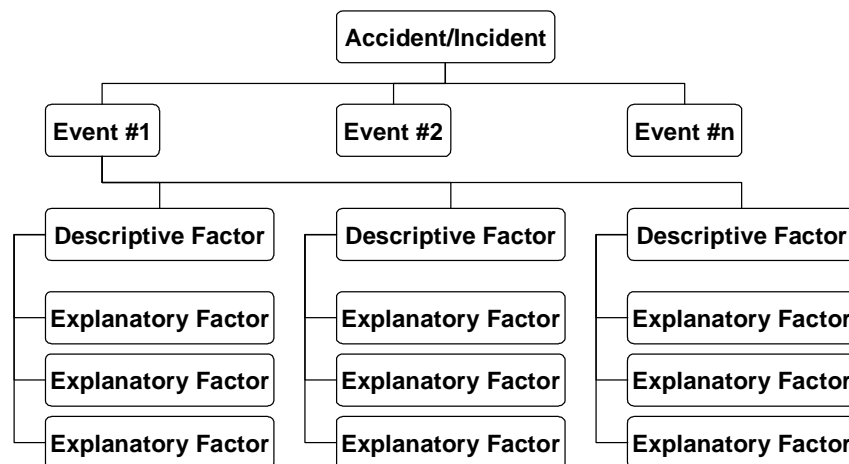


Figure 1: Accident/Incident structure according to ADREP

3.2.1.1 Accident/Incident

According to the Annex 13 an accident has occurred either when (1) a person is fatally or seriously injured, or (2) the aircraft sustains major damage or structural failure, or (3) the aircraft is missing.

An incident is occurrence, other than an accident, associated with the operation of an aircraft, which affects or could affect the safety of operation.

3.2.1.2 Events and Descriptive Factors

Events are elements of a chain that eventually led either to an accident or an incident. Descriptive factors describe, in detail, what happened during an event by listing all phenomena present (normally in chronological order).

For each reported occurrence, an unrestricted number of Events may be identified, and for each event, up to a maximum number of descriptive factors is used to classify/code what happened in detail.

3.2.1.3 Explanatory Factors - codification of Human Factors

The why of an event is explained by the “Explanatory Factors”, determined by ADREP as a maximum number of factors for each Descriptive factor.

The SHELL model (Edwards, 1972) has been taken as a reference for developing a whole set of human factor categories in the new release of ADREP. The SHELL model is a conceptual framework within which the human (Liveware, L) interfaces and interacts with other aviation system components.

According to SHELL, the most valuable and flexible component in the system is the human element, (the liveware), placed at the centre of the model. Each person brings his or her own capabilities and limitations, be they physical, physiological, psychological, or psychosocial. This component can be applied to any person involved with the operation or in support of the operation. The person under consideration interacts directly with each one of the four other elements. Each person and each interaction, or interface, constitute potential areas of human performance investigation.

The peripheral liveware refers to the system's human-human interactions, including such factors as management, supervision, crew interactions and communications.

Hardware refers to the equipment part of a transportation system. It includes the design of work stations, displays, controls, seats, etc.

Software is the non-physical part of the system including organisational policies, procedures, manuals, checklist layout, charts, maps, advisories and, increasingly, computer programs.

Environment includes the internal and external climate, temperature, visibility, vibration, noise and other factors, which constitute the conditions within which people are working. Sometimes the broad political and economic constraints under which the system operates are included in this element. The regulatory climate is a part of the environment inasmuch as it affects communications, decision-making, control, and co-ordination.

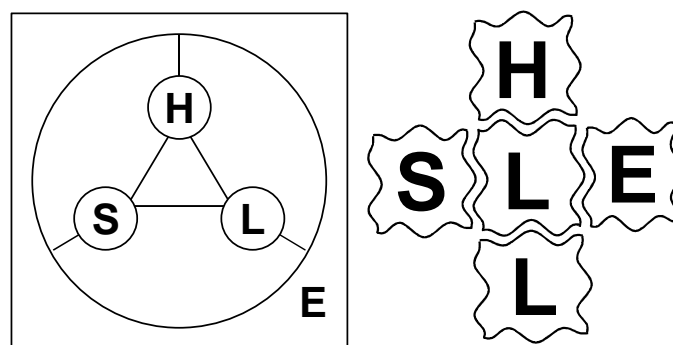


Figure 2: SHELL representation (Edwards, 1972); (Hawkins 1987).

3.3 Accident Analysis and Confirmation of Causes

The activity carried out in this phase had the objective to confirm some of the causes, which are related to collision and grounding, categorised in the previous list of factors.

The content (narrative and analysis) of each accident report was scanned through one time for each factor. A factor could then be considered as confirmed, when it was found mentioned directly in the accident report either by name, synonym or a conceptual equivalent explanation. Further, the factor must be mentioned as a relevant, causal or contributing factor in the accident scenario.

It is important to notice, that a factor could be considered relevant in the development of an accident no matter what the causal status or role of the factor is. For example the absence of fatigue is equivalent to the presence of fatigue in the confirmation of fatigue as a relevant factor. Human factors are relevant in the development of accidents and incidents not only as performance decreasing and contributing factors but also as defence mechanisms and performance enhancing factors.

The causal development of an accident is based on a number of human factors each contributing as inhibitors or exhibitors in the total scenario. It can often be difficult to identify exactly and with certainty which causal role the given human factor was playing. The concept "cause" is therefore used in this activity of confirmation of causes as any human factor, which in one way or another contributes to the overall causal scenario in the development of the accident or incident.

Moreover, a subset of potential attributes related to these factors should have been identified for the modelling phase. This exercise should have been carried out on the basis of the accident list reported in Appendix 1.

Owing to the limited time, this exercise was finally carried out for 4 accidents, whose investigation report was available and only human factors have been ticked out from the list reported in Annex 2. The causes confirmed are reported in Appendix 3.

The result of the exercise leads to four major conclusions explained in detail in these subchapters:

1. Confirmation of relevant factors.
2. The list is not complete, but it can be completed to a certain extent by analysis of further cases.
3. The factors in the list should be seen as factors on different levels in the causal chain leading to an accident.
4. The result of the analysis of the cases is biased by the tradition and style used in the accident reports.

3.3.1 Confirmation of relevant causes

It was possible to confirm the relevance of several factors mentioned in the list of human factors. That does not mean that the factors not confirmed are irrelevant. They can be relevant in other cases not analysed in this study or they can even be relevant in the four cases studied but left out due to biases (please refer to 3.3.4). It can for example be mentioned that the following factors are not issued at all in any of the four reports:

- **Physiological factors and psychosocial factors.** Accident investigators have significant knowledge about technical matters, navigation, anti-collision rules, procedures etc. but there is a general lack of detailed knowledge about human factors, psychology, ergonomics and physiology. The physiological and psychosocial factors can play significant roles as performance shaping factors, but it needs some analytical efforts and psychological expertise to reveal them.
- **Factors related to operational material.** Although not issued in the four analysed cases it can be seen in other cases involving conventional vessels. HSC's are often operating in regular service between two or more well-known harbours. Charts, pilot cards, handbooks etc. are of less significant importance to vessels operating in regular service - the route and the harbours are well-known to the crew, and they do therefore not need to rely on the operational material.
- **Supervision and regulatory activities.** It is not obvious how these factors should affect the safety onboard HSC's directly, but the absence of supervision and regulatory activities could on board vessels with low safety standards and lack of safety culture contribute to a decrease in the overall safety of the vessel.

3.3.2 Further adjustments of the list

It was possible to find relevant examples of factors and attributes in the case material that were actually not included in the list of human factors or factors that should be subdivided in two or more factors. This can lead to an adjustment of the list based on the four available cases. It is in principal possible that the analysis of further cases could lead to further adjustments of the list. The list is in other word not complete, but it can be completed on the basis of cases in the form of accident reports. It seems reasonable to assume that this process can be expressed in terms of a logistic growth: The new contribution to the list from each new case will decrease with an increasing number of cases.

3.3.3 Factors on different levels in the causal chain

It was found, that cognitive factors on the level of processing and the behavioural level was relevant in all of the four cases and that cognitive factors at perceptual level were relevant in three out of four cases. This finding supports the assumption that the factors in the list can act on different levels in the causal chain leading to an accident. Some factors are very close to the accident in this causal chain while others are very far from it. It seems evident that the cognitive factors (and the cognitive performance) - due to the presence in all four cases - are very close to the accident, while the other factors can be seen as performance shaping factors on more distant levels. This assumption is in congruency with the very well known and often cited organisational accident causation model by James Reason (1997).

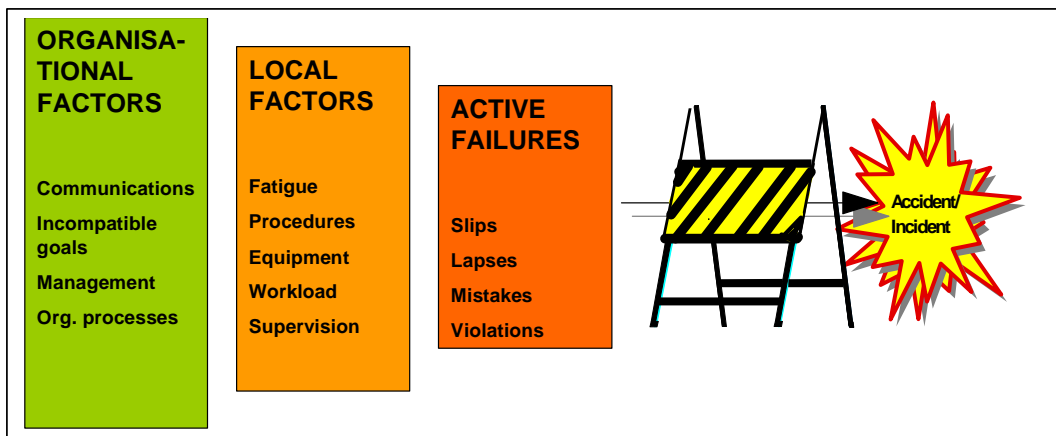


Figure 3: Organisational accident causation model by James Reason (1997).

3.3.4 Bias by tradition and style in accident reports

It was found that there is certain differences in tradition and style in the written accident reports. It can for example be mentioned that Danish accident reports are focused on rules, regulations and violations of these. The differences found between cases are therefore caused by a combination of differences in factors involved and differences in factors identified by the investigator due to national traditions and reporting styles. It could be reasonable to assume that an international use of a common list of factors could eliminate this bias and lead to more comparable results.

3.4 FMECA

The objective of the Failure Mode, Effect and Criticality Analysis (FMECA) for a High Speed Craft was to back up the work done for the confirmation of main causes. As many members as possible from the Safety@Speed project jointly performed the FMECA as a 'plenary brainstorming exercise' at a specially organised workshop. The general objective of this workshop was to generate common understanding of the safety framework, and identify principle parameters. An overall view of the outcome of FMECA for collision and grounding is reported in Appendix 4 and synthesised in Figure 4.

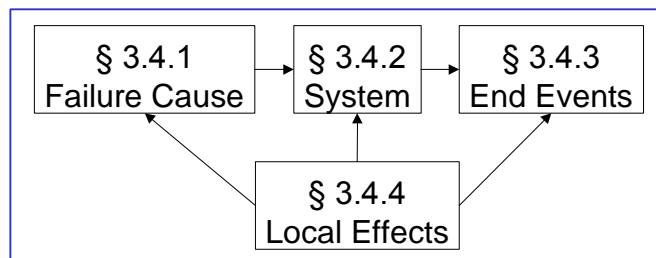


Figure 4: Generic Diagram of the FMECA analysis.

The FMECA process started with the functionality analysis of the vessel in order to define the systems to be examined. Each of the system was then studied for its failure modes, causes of failure, local/end effects on the ship, consequences, probabilities and risk.

The failure modes of each system were then divided according to influence on each WP. For each system a ranking routine was produced for each failure mode according to its risk level. This then provided the main causes.

The description of failure cause, system, end events and local effects tables are given below.

3.4.1 Failure Causes

FMECA revealed that the most recurrent failure causes associated to the failure modes leading either to collision or grounding are the following:

- Bad Design (Ship, Bridge, Navigation, Manoeuvring, Ergonomics)
- Collision
- Communication Failure (Equipment, Internal, External, Language)
- Corrosion
- Electrical failure (Short Circuit, Overload, Loss of Electrical Generation)
- Environment (Internal, External, Abnormal Weather)
- Excessive Loads (Unexpected, Local, Global)
- Excessive Noise Levels
- Excessive Ship Motions and Accelerations
- Excessive Vibration
- Fire
- Grounding
- Inadequate Maintenance
- Inappropriate Actions by passengers (Unintentional, Intentional)
- Inappropriate Crew Action (Time Pressure, Concentration, Attention, Mistake, Fatigue, Risk Taking Behaviour, Excessive Workload, Illness, Lack of Discipline, Lack of Motivation)
- Ingress of Water (Flooding)
- Lack of Information (Missing/Not Available/Incorrect Aids to Operations)
- Lack of Knowledge (Planning, Training, Experience, Procedures, Checklist, Risk Perception, Awareness)
- Local Structural Failure
- Loss of Steering Control
- Mechanical/Physical Failure (to any system/equipment)
- Poor Construction/Installation
- Poor Visibility (Internal, External)
- Reduced Operational Condition (Trim, List, Stability)
- Smoke

These causes are actually grouping those that came out from the FMECA, in Appendix 4 (§ 11.2) the whole list is reported.

3.4.2 System

For the FMECA purposes a number of general 'systems' were defined for which the likely failure modes and causes were identified. These systems are:

| No. | System |
|-----|---------------------|
| 1 | Hullform |
| 2 | Machinery |
| 3 | Structure |
| 4 | General Arrangement |
| 5 | Payload |
| 6 | Safety Systems |
| 7 | Crew |
| 8 | Operations |

3.4.3 End Events

The end events that were formulated for application in the FMECA are:

| FMECA Code | End Event | Details | Consequence |
|------------|-------------------------------|--|-------------------|
| EE1 | Minor damage to ship | Delays, cancellation of one crossing e.g. minor equipment failure | Minor (MI) |
| EE2 | Major damage to ship | Major disruption to service e.g. very limited service only, many cancellations major equipment failure | Major (MA) |
| EE3 | Hazardous damage to ship | Service suspended, no service for a limited period of time | Hazardous (HA) |
| EE4 | Catastrophic damage to ship | Uncontrollable fire, capsized, sinks, abandon ship | Catastrophic (CA) |
| EE5 | Minor damage to cargo | e.g. Dents and scratches to cars on car deck | Minor (MI) |
| EE6 | Major damage | e.g. Loss of 2 or 3 cars | Major (MA) |
| EE7 | Hazardous damage to cargo | e.g. Loss of more than 3 cars | Hazardous (HA) |
| EE8 | Minor injury | Cuts and bruises minor first aid required | Minor (MI) |
| EE9 | Major injury | Requires first aid and possibly a trip to casualty | Major (MA) |
| EE10 | Hospitalisation | Broken limbs, major cuts or burns anything that may require a stay in hospital | Hazardous (HA) |
| EE11 | Death or permanent disability | Death, loss of limbs, life threatening injuries to crew, passengers, public, other marine industries, shore crew and survivors | Catastrophic (CA) |

3.4.4 Local Effects

The possible local effects identified by the FMECA as being directly related to collision and grounding as an end effect are:

- Accelerated Path to End Event
- Broaching
- Cargo (Shift, Leak of Hazardous)
- Collision (Increased Likelihood, Minor)
- Crew Performance (Delayed, Inappropriate, Behaviour, Excessive Workload)
- Crew Behaviour (Discomfort, Deafness, Fatigue)
- Damage to Ship (Other Vessels, Other Systems)
- Delay (Penalty)
- Electrical Failure (Loss of Electrical Generation)
- Excessive Loads (Local Internal, Global)
- Excessive Motions/ Accelerations
- Fire (Delay Fire Suppression, Erroneous Use of System, Uncontrollable, Explosion)
- Grounding
- Human Injury (Major, Minor, Increase Potential, Catastrophic, Panic, Discomfort, Deafness, Stowaways, Sea Sickness)
- Ingress of Water (Flooding)
- Loss of Domestic Services
- Loss of Propulsion
- Loss of Manoeuvrability (Steering)
- Loss of Control of Vessel
- Mechanical Failure (Machinery)
- Near Miss
- Negative Passenger Behaviour (Harassment, Unintentional, Intentional, Confusion)
- Smoke (Uncontrollable spread)
- Structural Failure (Local, Global, Permanent Damage, Loss of Global Strength/ Transverse/ Longitudinal Strength)
- Reduced Operational Condition (Trim, List, Stability)
- Rescue (Delayed, Unable)

These local effects are actually grouping those that came out from the FMECA, in Appendix 4 (§ 11.3) the whole list is reported.

3.4.5 Relevant Causes

The relevant causes, taken from FMECA, have been extracted from Failure Causes List and the prioritised failure modes; these are reported in Appendix 4 (§11.4) and synthesised below in order of importance.

- | |
|--|
| <ul style="list-style-type: none">▪ Electrical failure (Short Circuit, Overload, Loss of Electrical Generation)▪ Mechanical/Physical Failure (to any system/equipment)▪ Poor Construction/Installation▪ Inappropriate Crew Action (Time Pressure, Concentration, Attention, Mistake, Fatigue, Risk Taking Behaviour, Excessive Workload, Illness, Lack of Discipline, Lack of Motivation) |
|--|

- Lack of Knowledge (Planning, Training, Experience, Procedures, Checklist, Risk Perception, Awareness)
- Inadequate Maintenance
- Bad Design (Ship, Bridge, Navigation, Manoeuvring, Ergonomics)
- Environment (Internal, External, Abnormal Weather)
- Local Structural Failure
- Environment (Internal, External, Abnormal Weather)
- Excessive Vibration

- Excessive Noise Levels
- Bad Design (Ship, Bridge, Navigation, Manoeuvring, Ergonomics)
- Environment (Internal, External, Abnormal Weather)
- Inappropriate Actions by passengers (Unintentional, Intentional)
- Inappropriate Crew Action (Time Pressure, Concentration, Attention, Mistake, Fatigue, Risk Taking Behaviour, Excessive Workload, Illness, Lack of Discipline, Lack of Motivation)
- Lack of Information (Missing/Not Available/Incorrect Aids to Operations)
- Lack of Knowledge (Planning, Training, Experience, Procedures, Checklist, Risk Perception, Awareness)
- Environment (Internal, External, Abnormal Weather)
- Smoke
- Excessive Vibration
- Poor Visibility (Internal, External)

- Excessive Motions/ Accelerations
- Fire (Delay Fire Suppression, Erroneous Use of System, Uncontrollable, Explosion)
- Ingress of Water (Flooding)
- Mechanical/Physical Failure (to any system/equipment)

- Inappropriate Crew Action (Time Pressure, Concentration, Attention, Mistake, Fatigue, Risk Taking Behaviour, Excessive Workload, Illness, Lack of Discipline, Lack of Motivation)
- Lack of Information (Missing/Not Available/Incorrect Aids to Operations)
- Lack of Knowledge (Planning, Training, Experience, Procedures, Checklist, Risk Perception, Awareness)
- Bad Design (Ship, Bridge, Navigation, Manoeuvring, Ergonomics)
- Inadequate Maintenance

- Communication Failure (Equipment, Internal, External, Language)

3.4.6 Prioritised Failure Modes

| NO. | SYSTEM | FAILURE MODE | RANK |
|-----|------------|------------------------------------|------|
| 8,5 | Operations | Maneuvering equipment failure | 572 |
| 7,1 | Crew | Environmental degradation of Crew | 450 |
| 7,3 | Crew | Failure to follow procedures | 450 |
| 5,2 | Payload | Movement of cargo-including people | 374 |
| 1,6 | Hullform | Lack of directional control | 161 |
| 7,2 | Crew | Improper use of equipment | 160 |

| | | | |
|------|----------------|---|-----|
| 6,13 | Safety Systems | Failure to Contact Shore-Based Assistance | 146 |
|------|----------------|---|-----|

The whole set of failure modes is reported in Appendix 4.

4. RESULTS (SUMMARY)

The confirmation of main causes related to collision and grounding were essentially carried out through two distinct approaches that provided similar results but not easy to integrate. The main problem in the integration of these results is not only due to the lack of a common terminology between the two approaches, but principally the lack of a 'model of reference', such as the SHELL, in the FMECA.

The first approach is based on the development of 'a priori' list of human and technical factors that were compared against a set of accidents and near misses. The objective was to see which factors (technical and human related) were found in the reports of these occurrences.

The second approach is based on the FMECA and through a brainstorming session a list of likely and prioritised causes was compiled; these are associated to a list of failure modes.

5. COMPARISON WITH SCHEDULE OF WORK

By comparing the prioritised failure modes with the Schedule of Work for the Work package the following can be noted:

- High risk hazards included in the Work package are:
 1. Maneuvering equipment failure
 2. Environmental degradation of Crew
 3. Failure to follow procedures
 4. Movement of cargo-including people
 5. Lack of directional control
 6. Improper use of equipment
 7. Failure to Contact Shore-Based Assistance
 8. Navigational equipment failure
 9. Navigational error in open and congested waters
 10. Navigational error in traffic

- There are no high risk hazards not included in the Schedule of Work that could be considered by the Work Package

- There are no areas of work in the Work Package that are not identified as high risk.

6. CONCLUSION

The results derived from the FMECA are similar but very difficult to be interfaced with what was obtained in the previous case (analysis on past events supported by the list of technical and human factors). What is suggested for the future work of the modelling phase can be summarised as follows:

- Every WPs (1 to 4) should use the list and compare the causes listed in the FMECA exercise against the factors proposed in Appendix 2.
- Since this list of human and technical factors is not frozen yet and needs some more improvements, the feedback from WPs (1 to 4) is highly advocated.
- All the WPs should use the categories of this list as building blocks for fault trees.
- A further parallel work on the analysis of safety critical incidents and near misses could be carried out in order to refine the model during the following phase of the project.
- Expert knowledge from HSC operators should be used as empirical material. This data could be obtained through interviews and questionnaires. HSC operator practice should also be considered as relevant empirical material. This data could be collected through observation, field studies and studies of procedures, operational material etc.

7. REFERENCE

P. C. Randgaard (1998). Analysis of the human element in operation of High Speed Marine Crafts, Diploma Thesis, Norwegian University of Science and Technology (NUST), Trondheim 1998.

Edwards, E. (1972). Man and machine: Systems for safety, Proceedings of British Airline Pilots Association Technical Symposium, British Airline Pilots Association, London, U.K., pp. 21-36.

Hawkins, F. H. (1987). Human Factors in Flight, Aldershot, UK, Gower Technical Press.

Reason, J. (1997). Managing the Human and Organizational Response to Accidents, Brookfield, Vermont, Ashgate Publishing.

National Marine Safety Committee (2000). National Standard for Commercial Vessels. Regulatory Impact Statement. Australia (<http://www.nmsc.gov.au>)

Frédéric Capoulade: "Navires à grande vitesse" website
(<http://perso.wanadoo.fr/fcapoulade/>)

FASS WP1 Report (1998) of the EC project "FAstShip Safety"
(<http://perso.wanadoo.fr/fass/>)

8. APPENDIX 1: ACCIDENT/INCIDENT LIST

A quick browse through several databases with maritime accident reports reveals more than 800 reports available for immediate and free download from the Internet. Only a very small number (about 10) of these reports are concerning accidents with HSC. It is nevertheless possible to get very brief information about 40-50 accidents or near-misses with HSC involved, and these are listed in this Appendix. It is not possible to get access to reports on all the accidents mentioned in the list, but about 10 of them are available on the Internet in Scandinavian languages. However, for the benefit of the project the authors think that the most important thing was to start with the available information (sources are indicated), and to increase it during the course of the project.

8.1 Descriptive list of HSC accidents 1989-2001

| | |
|---|---|
| Year, Month | 1989 |
| Name | Apollo Jet |
| Location | Hong Kong |
| Vessel type | Catamaran HSC ferry |
| Incident type | Collsion & Grounding |
| Casualties | 4 dead, 7 injured |
| Description | On the way from the terminal to an overnight berthing location the crew closed down one of the generators during the voyage and inadvertently switched off the electrical power to the main engines and the steering control on the Masters console. Apparently this was caused by language problems: the engineer could only read Chinese but the switches were labelled in English. As a result the craft lost steering and propulsion control from the bridge and the vessel collided with two smaller vessels before grounding. |
| References | Randgaard 1998 |
| Availability of accident report: | Not available |

| | |
|----------------------|--|
| Year, Month | 1991, November |
| Name | Sea Cat (Kvaerner Fjellstrand) |
| Location | Mjømnaosen, Norway |
| Vessel type | Catamaran HSC ferry |
| Incident type | Grounding |
| Casualties | 2 dead, 74 injured |
| Description | The vessel on its way to Bergen was approaching a 90 degrees turn at full speed (which is normal) in reduced visibility. A lighthouse blinking with 5 sec intervals used as turningpoint was overlooked the first time it appeared to portside resulting in a late turn and the vessel continued 100 meters straint ahead off coused, which was enough for grounding the vessel - probably at full speed. The number of injuries was also caused by interior fitting of stairs |

References Randgaard 1998
Classic Fast Ferries cyberzine at
http://users.cybercity.dk/~nmb17249/pdf/cff_2000_7.pdf
Availability of accident report: Not available

Year, Month 1992, February
Name Royal Vacouver
Location Off Vacouver, Canada
Vessel type Catamaran HSC ferry
Incident type Collision
Casualties 19 injured
Description The vessel was sailing from Vancouver to Victoria with 61 passengers in fog. Due to the fog a Ro-Ro ferry on a reciprocal course was not in sight until the last minute before the collision. An emergency turn across the bow fo the Ro-Ro ferry was applied and a few seconds before the collision an emergency stop had been executed. The two navigators on the HSC were distracted by VHF communication and changes in radar range. This lead to a miss-identification of the radar echo.
References Randgaard 1998
Availability of accident report: Not available

Year, Month 1993
Name Condor 10 (Incat)
Location Wellington, New Zeeland
Vessel type HSC
Incident type Allision
Casualties 0
Description Engine failure and contact with pier.
References FASS WP1 report.
Availability of accident report: Not available



Year, Month 1993, March
Name [Not known to DMI]
Location Hong Kong
Vessel type Fast Monohull Ferry
Incident type Grounding
Casualties 0
Description Sailing from central Hong Kong to Discovery Bay in thick fog the vessel hit rocks several miles off normal course.
References Randgaard 1998
Availability of accident report: Not available

Year, Month 1993, July
Name Urzela
Location Off Macau, Hong Kong
Vessel type Jetfoil HSC ferry
Incident type Collision
Casualties 49 injuries
Description In the dark and in rough sea the vessel was leaving Macau for Hong Kong. The vessel collided with a pipeline being towed. The lights on the pipeline were not working and they could not be visually detected from the HSC.
References Randgaard 1998
Availability of accident report: Not available

Year, Month 1993, July
Name The Spirit of Success
Location Hong Kong
Vessel type Catamaran HSC ferry
Incident type Collision
Casualties 6 injuries
Description Early in the morning after only 3 hours of sleep the crew overlooked a steel barge in the sea clutter on their radar and collided with it during the early morning voyage. The barge was at anchor and incorrectly lit.
References Randgaard 1998
Availability of accident report: Not available

Year, Month 1994, October
Name Condor II
Location Off Hobart, Tasmania
Vessel type Catamaran HSC ferry
Incident type Grounding
Casualties 1 injury
Description On passing close to a cliff at full speed on the river (which is normal), the operator had not measured the distance to the cliff correctly, and the vessel hit the cliff and grounded. This distance

error occurred during night operations and was resulted from an incorrect radar setting for one of the radar filters (sea clutter etc.) causing the cliff not to appear on the radar image.

References

Randgaard 1998

Availability of accident report: Not available



Year, Month 1994, December
Name Golden Navigator 2/ Tai Ping
Location Hong Kong
Vessel type Fast Monohull Ferry & Catamaran HSC Ferry
Incident type Collision
Casualties 4 dead
Description Collision between two HSCs in bad weather (poor visibility). The Golden Navigator 2 was cut in half by collision the Tai Ping, and sank. 4 people drowned.
References Randgaard 1998
Availability of accident report: Not available

Year, Month 1995, March
Name Hain Chang / Tai Ping
Location Hong Kong
Vessel type Catamaran HSC Ferry
Incident type Collision
Casualties 14 injuries
Description Collision between two HSCs at about 12 knots (both ships) in poor visibility.
References: Randgaard 1998
Availability of accident report: Not available

Year, Month 1995, April
Name Saint Malo
Location English Channel
Vessel type Catamaran HSC ferry

| | |
|---|---|
| Incident type | Grounding |
| Casualties | 55 injuries |
| Description | The captain observes a fishing buoy, while the vessel is making a turn to port at full speed. He decides to stop the turn but overlooks that the vessel was heading for a cliff. Many of the 308 passengers and crew had serious injuries, but not from the initial impact, but from the subsequent evacuation when the ship listed to port (28 degrees) and emergency exits were submerged. Passengers then had to jump 2-4 meters into life rafts from starboard side. There are also reported language problem involved (French crew and English/German passengers). |
| References | Randgaard 1998 & summary of hospital journal on the evacuation: http://www.basics.freewire.co.uk/Templates/Downloads/WN7.PDF Short MARS report available at: http://www.nautinst.org/mars/mars%5Fgen/marsor03.htm MAIB 1995 report, MARCOM final report. |
| Availability of accident report: | Can be obtained (in English) |

| | |
|---|---|
| Year, Month | 1995, April |
| Name | Condor 10 |
| Location | Queen Charlotte Sound, New Zealand |
| Vessel type | Catamaran HSC ferry |
| Incident type | Grounding |
| Casualties | 0 |
| Description | Grounding of the vessel following a black out of main power. Causal factors included mechanical failure, fault analysis procedures, and faults in setting up and testing the vessel's electrical systems. Recommendations included design changes, better management of maintenance, and more stringent and regular testing procedures. |
| References | Marine Occurrence Report 95-203 from New Zealand TAIC |
| Availability of accident report: | Not available |

| | |
|---|---|
| Year, Month | 1995, September |
| Name | Super Flyte |
| Location | Off Kangaroo Island, Australia |
| Vessel type | Fast Monohull Ferry |
| Incident type | Grounding |
| Casualties | 5 injured |
| Description | Due to navigational error the vessel struck a sandbar outside a buoyed channel. |
| References | Randgaard 1998 |
| Availability of accident report: | Not available |

Year, Month 1996
Name Delphin
Location [Not known to DMI]
Vessel type Catamaran HSC ferry
Incident type Collision
Casualties 0
Description Collision with sailing boat.
References FASS WP1 report.
Availability of accident report: Not available

Year, Month 1996, June
Name [Not known to DMI]
Location Off Procida Island, Italy
Vessel type Fast Monohull Hydrofoil
Incident type Grounding, Capsizing
Casualties 4 dead, 15 injured
Description In thick fog the vessel was sailing from Naples to Procida Island when it suddenly listed, possibly due to a rope around one propeller. The vessel then struck rocks, puncturing the hull and then it capsized. Four passengers were trapped inside the hull and drowned.
References Randgaard 1998
CNN <http://www4.cnn.com/WORLD/9606/10/newsbriefs/>
Availability of accident report: Not available

Year, Month 1996, August
Name Trident 7
Location Off Guernsey, England
Vessel type Catamaran HSC ferry
Incident type Fire
Casualties 1 injury
Description The vessel was sailing from Guernsey to Jersey. A fire broke out in the engine room, but it was extinguished by the CO2 system. Passengers were evacuated.
References Randgaard 1998
Availability of accident report: Not available

Year, Month 1997, March
Name Cat Link II
Location Kalundborg Fjord, Denmark
Vessel type Catamaran HSC Ferry
Incident type Collision
Casualties 0
Description Collision with fishing boat "Lissi" that sinks fast.
References Randgaard 1998
Accident report from DMA

Availability of accident report: Available (in Danish)



| | |
|----------------------|---|
| Year, Month | 1997, April |
| Name | Hoi Bin |
| Location | Hong Kong |
| Vessel type | Catamaran HSC ferry |
| Incident type | Collision |
| Casualties | 1 injured |
| Description | The vessel sailing with 194 passengers on board collided with a barge. One person on the barge was injured. |
| References | Randgaard 1998 http://www.marinelink.com/tod0497.html |

Availability of accident report: Not available

| | |
|----------------------|--|
| Year, Month | 1997, April |
| Name | Hai Yang |
| Location | Hong Kong |
| Vessel type | Catamaran HSC ferry |
| Incident type | Collision |
| Casualties | 27 injured |
| Description | A Ro-Ro ferry punctured the vessels bow on one side as she was sailing from Hong Kong to Zhuhai. |
| References | Randgaard 1998 |

Availability of accident report: Not available

| | |
|----------------------|---------------------|
| Year, Month | 1997 |
| Name | Holyman Diamant |
| Location | Ramsgate, England |
| Vessel type | Catamaran HSC ferry |
| Incident type | Collision |
| Casualties | [Not known to DMI] |

Description The vessel collided with a conventional ferry in Ramsgate port in fog and due to inadequate manoeuvres.
References FASS WP1 Report
Availability of accident report: Not available



Holyman Diamant (on Ostende – Ramsgate route)

Year, Month 1997, July
Name Reef Link II
Location Townsville, Australia
Vessel type Catamaran HSC ferry
Incident type Engine room fire
Casualties 0
Description The vessel carrying 55 passengers left Townsville for Great Barrier Reef although the crew was aware of a fuel leakage. Together with a leaking transfer pump this resulted in a large amount of fuel leaking into the engine room. When the vessel accelerated the bow lifted and fuel oil flowed to the aft and it was ignited by the main engine turbochargers. Another problem addressed by the Australian authorities was that the main engines could not be shut down during the fire.
References Randgaard 1998
National Marine Safety Committee 2000.
Availability of accident report: Not available

Year, Month 1998, January
Name Stena Discovery
Location North Sea
Vessel type Ro-Ro Catamaran HSC ferry
Incident type Structural damage
Casualties 0
Description The Stena Discovery sailing from Harwich, England to Hook van Holland, the Netherlands was structurally damaged by high waves. The vessel lost panels from its bow and 50 cars aboard

were damaged. None of the 900 passengers were injured. Dutch authorities investigated whether the vessel was sailing too fast for conditions. On the other hand it was know by Stena Line at Hook van Holland that waves would be exceeding the 4-meter allowed, but they did not inform the ship. The vessel sailed into a 10-meter wave - maybe at full speed (44 knots) damaging its bow.

References Randgaard (1998),
<http://perso.wanadoo.fr/fcapoulade/juill99.htm>

Availability of accident report: Not available

Year, Month 1998, March
Name Condor 10
Location Barrett Reef buoy
Vessel type 74-metre aluminium wave-penetrating catamaran, of 3,241 gross tonnages.
Incident type Structural damage
Casualties 0
Description Near Barrett Reef buoy Condor 10 encounters a combination of two swell waves from ahead. As the vessel rides up the face of the first wave, the Master stops the engines. The vessel is on the back of the first wave when the bow hits the face of the second wave. The impact forces the bow visor free of its locking pins and as a result the bow visor and bow section sustain damage.
References Maritime Safety Authority of New Zealand, Maritime Accidents 1997-1998.

Availability of accident report: Not available

Year, Month 1998, May
Name Flora
Location Hong Kong Bay
Vessel type Jetfoil HSC ferry
Incident type Collision (or Crash Stop !)
Casualties 122 injured
Description Collision with unidentified underwater object (submarine?), that was never found (?). According to passengers the vessel was sailing off track from its normal route. Another possibility is crash stop due to some mechanical failure (?).
References FAAS WP1 report, <http://perso.wanadoo.fr/fcapoulade>,
Randgaard 1998

Availability of accident report: Not available

Year, Month 1998, May
Name Gråsælen
Location Gabet, Odense Fjord, Denmark
Vessel type High Speed Passenger Vessel
Incident type Engine Room Fire

Casualties 0
Description The engine oil check pin was ejected under huge pressure and hot oil leaked. The hot oil was ignited when it hit the exhaustion manifold and the turbo charger.
References Danish Maritime Authority, Accident Report (Søulykkesrapport), j.nr. 0811.04-52. November 2nd 1998.
Availability of accident report: Available (in Danish)

Year, Month 1998, June
Name Laura
Location Off Helsinki, Finland
Vessel type Hydrofoil HSC
Incident type Grounding
Casualties 0
Description On its way to Tallinn from Helsinki in thick fog with 200 passengers the vessel grounded on rocks.
References Randgaard 1998
Availability of accident report: Not available

Year, Month 1998, June
Name Sunnhordland / Vingtor
Location Haugesund, Norway
Vessel type HSC
Incident type Collision
Casualties 1 injury
Description Near frontal collision between two Norwegian HSCs. Sunnhordland was outbound from Haugesund and Vingtor was inbound from Bergen. The vessels did not follow normal COLREGS navigation rules. One passenger on the deck was injured as the Sunnhordland was struck by Vingtor in the aft salon area.
References Randgaard 1998
Aftenposten
<http://www.aftenposten.no/nyheter/iriks/d113144.htm>
Availability of accident report: Not available

Year, Month 1998, August
Name CAT-LINK V
Location Kalundborg Harbour, Denmark
Vessel type Catamaran HSC ferry
Incident type Structural damage
Casualties 0
Description The stern ramp loosened and fell off during the loading of a buss.
References Danish Maritime Authority, Accident Report (Søulykkesrapport), j.nr. 0811.06-52, February 22nd 1999.
Availability of accident report: Available (in Danish)

| | |
|---|---|
| Year, Month | 1998, September |
| Name | Incat 046 |
| Location | Novo Scotia, Canada |
| Vessel type | Catamaran HSC ferry |
| Incident type | Collision |
| Casualties | 1 dead |
| Description | The fast ferry catamaran "INCAT 046" left Yarmouth, Nova Scotia, for a scheduled crossing to Bar Harbor, Maine, U.S.A. Visibility was near zero in thick fog. Meanwhile, the fishing vessel "LADY MEGAN II" was approaching Yarmouth Harbour after a fishing trip off the Nova Scotia coast. The navigating personnel of both vessels were using radar as the primary instrument to position their vessels. A few minutes after having agreed on a port-to-port passage in the area of a fixed light commonly known as "Bug Light", the vessels collided in the narrow Main Channel. The master of the fishing vessel sustained fatal injuries. |
| References | Randgaard 1998 |
| Availability of accident report: | Not available |



| | |
|---|--|
| Year, Month | 1998, December |
| Name | Te Hukatai |
| Location | Mana, New Zealand |
| Vessel type | HSC ferry |
| Incident type | Grounding |
| Casualties | [Not known to DMI] |
| Description | None |
| References | Marine Occurrence Report 98-217 from New Zealand TAIC (now removed from the index !) |
| Availability of accident report: | Not available |

| | |
|--------------------|-------------|
| Year, Month | 1999, March |
| Name | Te Hukatai |

Location Picton, New Zealand
Vessel type HSC ferry
Incident type Collision
Casualties [Not known to DMI]
Description Collision due to "skipper incapacitation" (?)
References Marine Occurrence Report 99-217 from New Zealand TAIC (now removed from the index !)
Availability of accident report: Not available

Year, Month 1999, May
Name Stena Explorer
Location Off Hollyhead, England
Vessel type Ro-Ro HSC ferry
Incident type Fire
Casualties 0
Description Heating from a gas turbine started a machine room fire on the vessel on its way from Holyhead to Ireland with 224 passengers and crew. Fire was extinguished by the CO2 system.
References <http://perso.wanadoo.fr/fcapoulade>
Availability of accident report: Not available



Year, Month 1999, July
Name Seacat Scotland
Location Off Troon, Ireland
Vessel type Catamaran HSC ferry
Incident type Allision
Casualties 0
Description Propulsion failure seems to have caused an allision with an underwater concrete pile when leaving the harbour at Tron for Belfast. No one was injured but the impact of the collision threw some passengers to the deck. The 40-knot ship is owned by Sea Containers.
References <http://perso.wanadoo.fr/fcapoulade/juill99.htm>,
BBC News online:
http://news.bbc.co.uk/hi/english/uk/newsid_408000/408074.stm



| | |
|---|--|
| Year, Month | 1999, November |
| Name | Sleipner |
| Location | Haugesund, Norway |
| Vessel type | Catamaran HSC ferry |
| Incident type | Grounding & Sinking |
| Casualties | 16 fatalities |
| Description | <p>The high-speed catamaran Sleipner, which had only been in service since August 99, was on a routine journey from Stavanger to Bergen when it hit rocks in an area that is well charted (November 99). It sank in 45 min. Navigational error was the initial cause of the Sleipner ferry disaster according to the official report. The Commission concluded that the navigators did not know where they were when the catamaran ran aground. "At the decisive time, immediately prior to grounding, both navigators were busy, each adjusting his own radar, which distracted their attention from navigation based on visual observations of lights and course run." The length of time it took to release life rafts after the grounding was also criticised. The Commission was unable to see any acceptable reason why the rafts had not been released immediately it became clear that the craft had run aground. Better launching of the life rafts may have significantly increased the number of survivors.</p> |
| References | "Hurtigbåten MS Sleipners forlis 26. november 1999" (2000) |
| Availability of accident report: | Available (in Norwegian with summary in English) |



| | |
|---|---|
| Year, Month | 1999, December |
| Name | Stena Discovery |
| Location | Hook van Holland |
| Vessel type | Ro-Ro |
| Incident type | Engine Room Fire |
| Casualties | 0 |
| Description | A fire broke out in one of the four gas turbines just as the vessel was going into Hoek van Holland harbour. The fire was contained in the machine room but was not stopped before fire fighters at land helped the crew. |
| References | http://perso.wanadoo.fr/fcapoulade |
| Availability of accident report: | Not available |



| | |
|----------------------|----------------------|
| Year, Month | 2000, January |
| Name | Baronen |
| Location | Raunefjorden, Norway |
| Vessel type | HSC ferry |
| Incident type | Allision, Flooding. |
| Casualties | 0 |

Description During its last trip in the dark on the 5th January the *Baronen* struck an underwater rock about 300 away from its normal route. The vessel took in water as a consequence of the collision and was in risk of sinking. The captain tried to blame a floating object for the collision,

References <http://tux1.aftenposten.no/nyheter/iriks/d117691.htm>
<http://perso.wanadoo.fr/fcapoulade>

Availability of accident report: Not available



Year, Month 2000, May
Name Quickcat/Quickcat II
Location Auckland Harbour
Vessel type HSC ferry
Incident type Collision
Casualties 0
Description At about 0914 on Wednesday, 31 May 2000, the passenger ferries *Quickcat* and *Quickcat II* were operating on the ferry service between Waiheke Island and Auckland when they collided about 0.5 miles east of the northern leading light in Auckland Harbour. The visibility in the area at the time of the collision was about 50 m due to fog. There were a total of 127 passengers and 7 crew aboard the 2 vessels, none of whom were injured.

Safety issues identified included:

- the speed of the 2 vessels in restricted visibility
- the inefficient use of radar for collision avoidance
- non-compliance with the collision regulations
- the adequacy of the documented passage plan
- the absence of high-speed navigation techniques
- the number of scheduled ferry services within Auckland enclosed limits and the need for a system to manage vessel traffic.

Safety recommendations were made to the operator and the Auckland Regional Council harbourmaster to address the safety issues.

References Transportation Accident Investigation Commission, New Zealand, <http://www.taic.org.nz/marine/abstracts-m-00.html#00-205>

Availability of accident report: Not available

Year, Month 2000, June
Name Eskil
Location North west of Munkholmen, Sweden
Vessel type Monohull, High Speed Passenger Vessel
Incident type Grounding
Casualties 0
Description The destination was changed in last minute not offering possibility to plan the voyage appropriately. Passengers present on the bridge disturbed the OOW. A buoy was due to the above mentioned circumstances passed on the wrong side and the ship grounded.

References Swedish Maritime Authority. RAPPORT "Passagerarfartyget ESKIL -SBGE- grundstötning 2000-06-05"

Availability of accident report: Available (in Swedish)



Year, Month 2000, August
Name Vaddö
Location Bergs oljehamn, Sweden
Vessel type Monohull, High Speed Passenger Vessel
Incident type Smoke development and evacuation
Casualties 0
Description The engine pistons were reversed after a crash stop. The engine room was then filled with exhaust smoke through the engines intake valves.

References Swedish Maritime Authority. RAPPORT Passagerarfartyget VÄDDÖ - SCFR -rökutveckling och evakuering10 augusti 2000.

Availability of accident report: Available (in Swedish)



| | |
|---|---|
| Year, Month | 2001, March |
| Name | Stena Discovery |
| Location | Off Hook van Holland |
| Vessel type | Ro-Ro Catamaran HSC ferry |
| Incident type | Structural damage |
| Casualties | 0 |
| Description | Shortly after the vessel had left Hook van Holland for Harwich, a trailer on the car deck got out of place and pushed itself as well as three other vehicles through the ship's rear car ramp into the North Sea. The reason for the accident is unknown. "Stena Discovery" returned to Hook of Holland, where the destroyed car ramp was repaired. Fortunately, nobody was injured. Stena's HSS vessels operate at service speeds of up to 44 knots. |
| References | Crusin' home page. http://www.stutt.com/cruising/w-104-1.html |
| Availability of accident report: | Not available |

8.2 Near misses and incidents with insufficient information available:

Year, Month

Name Spirit of Victoria

Location Australia

Vessel type HSC

Incident type

Casualties

Description Nosedive into the back of a large wave at 25 knots

References FastCraft conference, Australia

Availability of accident report: Not available

Year, Month 1991

Name Nordlicht

Location

Vessel type Catamaran HSC ferry

Incident type Near miss (collision risk)

Casualties 0

Description Near collision in fog with passenger vessel "Harlekin". Both masters were at fault in not inquiring about traffic situation at VTS Centre, lack of radar usage, no safe speed and late/inadequate avoidance manoeuvres. Also VTS fault (lack of information and advice to ships, inadequate monitoring).

References FASS WP1 report (Available)

Availability of accident report: Not available

Year, Month 1999, July

Name Stena Discovery

Location Off Harwich, England

Vessel type Ro-Ro Catamaran HSC ferry

Incident type Motion/ wash wave induced man overboard

Casualties 1 dead

Description The accident occurred when a wash wave, generated by HSS Stena Discovery and having grown to about 4 m in height as it encountered the shallow waters on the southern end of the Shipwash Bank, broke over and swamped the angling boat Purdy.

References MarineLog 14.7.200

<http://www.marinelog.com/DOCS/NEWS/MMJul142.html>

And press release from

<http://www.press.dtlr.gov.uk/0007/0474.htm>

Availability of accident report: Not available

Year, Month 2000, February

Name Baronen

Location Valesundet, Norway

| | |
|---|---|
| Vessel type | HSC ferry |
| Incident type | Near miss |
| Casualties | 0 |
| Description | Risk of collision as two HSC passed with about 2 meters distance according to eyewitnesses. |
| References | Aftenposten http://tux1.aftenposten.no/nyheter/iriks/d125834.htm http://tux1.aftenposten.no/nyheter/iriks/d117781.htm |
| Availability of accident report: | Not available |

9. APPENDIX 2: HUMAN AND TECHNICAL FACTORS LIST

This list is actually composed of two parts, while the first one refers to Technical factors the second one deals with Human factors. Moreover, each part has two sections, in the first one the factors are reported, whilst in the second for each factor a list of attributes is provided.

The technical and human factors are respectively structured around a very simple model of the maritime transport system and the SHELL model; a synthetic view of the whole list is provided in the table below.

| TECHNICAL | |
|--|-------------------|
| <i>FACTORS</i> | <i>ATTRIBUTES</i> |
| ▪ Ship | |
| ▪ Shipping | |
| ▪ Vessel traffic services (vts) | |
| ▪ Port & waterways | |
| ▪ Meteorological / environmental information | |
| HUMAN | |
| <i>FACTORS</i> | <i>ATTRIBUTES</i> |
| ▪ Liveware (human) | |
| ▪ Liveware (human) - Environment | |
| ▪ Liveware (human) - Hardware | |
| ▪ Liveware (human) - Software | |
| ▪ Liveware (human) - Liveware (human) | |

The whole list is reported in the following.

9.1 TECHNICAL Factors and Attributes

| SHIP | | |
|--------------------------------|---------------------|--|
| FACTORS | | ATTRIBUTES |
| Ship design | | |
| | Hull design aspects | <ul style="list-style-type: none"> ▪ hull form design ▪ body shapes ▪ systematic series ▪ safety considerations ▪ stem/stern shapes ▪ shallow draught ship designs ▪ arrangement/compartmenat ion design ▪ design of subdivision ▪ general arrangement ▪ tonnage measurements ▪ structural design ▪ complete ship structures ▪ local structure |
| | Engine room design | <ul style="list-style-type: none"> ▪ engine room arrangement design ▪ engine room lay-out ▪ selection of prime movers ▪ selection of auxiliary engines ▪ pipe/pump system design ▪ pipe routing ▪ computer-aided pipe/pump design ▪ pipe friction resistance ▪ engineering design ▪ main engine plants ▪ auxiliary engines ▪ boilers ▪ electrical systems ▪ ergonomoy in engine rooms ▪ automation ▪ energy balance |
| Ship subdivision and structure | | |
| | Subdivision | <ul style="list-style-type: none"> ▪ cargo spaces ▪ main hold ▪ twin deck spaces ▪ shelter deck spaces ▪ trunk hold/hatches ▪ refrigerated cargo spaces ▪ ro-ro spaces ▪ container cells ▪ weather deck arrangements ▪ superstructures ▪ tanks ▪ fuel tanks ▪ water ballast tanks ▪ fresh water tanks ▪ double bottom tanks ▪ side tanks ▪ wing tanks ▪ cargo tanks ▪ deep tanks ▪ gas tanks |

| FACTORS | | ATTRIBUTES |
|---------------------------------------|----------------|--|
| Ship subdivision and structure (cont) | | <ul style="list-style-type: none"> ▪ peak tanks ▪ cofferdams ▪ heeling tanks ▪ machinery spaces ▪ main engine room ▪ auxiliary engine room ▪ factory spaces ▪ machinery stores ▪ pump room ▪ boiler room ▪ control room ▪ winch room ▪ bridge/chartroom/wheelhouse ▪ accommodations ▪ passenger accommodations ▪ crew accommodations ▪ public rooms ▪ stores and workshops ▪ provision rooms |
| | Ship structure | <ul style="list-style-type: none"> ▪ welded structure ▪ bolted structure ▪ riveted structure ▪ hull structure ▪ hull plating ▪ bottom plating ▪ deck plating ▪ bulkheads ▪ hull framing ▪ hull girders ▪ hatchways/hatches ▪ double bottom structure ▪ floors ▪ db girders ▪ appendages ▪ stern and stem structure and stem assembly ▪ construction elements ▪ framework ▪ grillage ▪ sandwich construction ▪ stiffened plate ▪ bracketed structure ▪ girder ▪ web ▪ pillar |
| | Ship materials | <ul style="list-style-type: none"> ▪ steel in ships ▪ mild steel ▪ high tensile steel ▪ stainless steel ▪ clad steel ▪ low temperature resisting steel ▪ casting steel/iron ▪ non-ferrous metals in ships ▪ aluminium ▪ copper |

| FACTORS | | ATTRIBUTES |
|--------------------------|-----------------------|--|
| | Ship materials (cont) | <ul style="list-style-type: none"> ▪ other materials in ships ▪ fire-proof materials ▪ insulation materials ▪ lining ▪ concrete in ships ▪ glass reinforced polyester ▪ frp ▪ plastics ▪ wood |
| | Marine coatings | <ul style="list-style-type: none"> ▪ anti-fouling ▪ paints/coatings ▪ tank coatings ▪ deck covering |
| Ship structural strength | | |
| | Loads | <ul style="list-style-type: none"> ▪ static loads ▪ still water bending moment ▪ hogging/sagging ▪ dynamic loads ▪ standard wave ▪ wave loads ▪ torsional loads ▪ ice strengthening/loads ▪ pressure loads ▪ local loads ▪ collision/grounding loads ▪ leakage ▪ deck loads ▪ sloshing loads ▪ shock wave loads |
| | Strength | <ul style="list-style-type: none"> ▪ general strength theories ▪ longitudinal strength ▪ local strength ▪ collision resistance ▪ superstructures/deckhouses ▪ fracturing/defects ▪ transverse strength ▪ hull surveillance systems & monitoring |
| | (Applied) mechanics | <ul style="list-style-type: none"> ▪ fracture ▪ cracking ▪ fatigue ▪ brittle fracture ▪ buckling |
| | Vibration | <ul style="list-style-type: none"> ▪ hull vibration ▪ longitudinal ▪ transverse and torsional ▪ local vibrations ▪ vibration excitation ▪ propeller excitation ▪ machinery excitation ▪ vibration in superstructure and deckhouse |
| | Noise and acoustics | <ul style="list-style-type: none"> ▪ noise excitation ▪ noise propagation ▪ airborne sound ▪ structure borne sound |
| | Corrosion | <ul style="list-style-type: none"> ▪ corrosion protection ▪ cathodic protection ▪ corrosion control |

| FACTORS | | ATTRIBUTES |
|---------------------|-------------------|--|
| Ship Hydromechanics | | |
| | Ship propulsion | <ul style="list-style-type: none"> ▪ propeller shape ▪ propeller cavitation ▪ propeller erosion ▪ propeller strength ▪ propeller vibration ▪ ship/propeller interaction ▪ rudder/propeller interaction ▪ propeller/towing interaction ▪ nozzle/propeller interaction ▪ propeller protection ▪ engine/propeller interaction ▪ ice/propeller interaction ▪ hydrofoil shape ▪ wings ▪ sailing forces ▪ cylinder shape |
| | Ship resistance | <ul style="list-style-type: none"> ▪ frictional resistance ▪ pressure & eddy resistance ▪ wave resistance ▪ air/wind resistance ▪ residuary resistance/added resistance ▪ resistance in shallow waters ▪ resistance in arctic waters ▪ towing/pushing resistance |
| | Ship stability | <ul style="list-style-type: none"> ▪ static stability ▪ meta centre height ▪ ship rolling ▪ slack tank ▪ icing ▪ following sea ▪ dynamic stability ▪ capsizing ▪ deck wetness ▪ damage stability ▪ floodable length ▪ permissible compartment |
| | Ship performances | <ul style="list-style-type: none"> ▪ ship speed ▪ measured mile ▪ steering performance ▪ stopping ability ▪ turning circle ▪ towing |
| | Ship manoeuvring | <ul style="list-style-type: none"> ▪ course control/driftng ▪ hydrodynamic characteristics of rudder types ▪ automatic manoeuvring ▪ manoeuvring in confined waters ▪ mooring/berthing/anchoring ▪ reversing characteristics ▪ collision control ▪ dynamic positioning ▪ underwater manoeuvring |
| | Ship sea-keeping | <ul style="list-style-type: none"> ▪ comfort ▪ ship motions ▪ roll ▪ sway |

| FACTORS | | ATTRIBUTES |
|------------------------------------|--|--|
| | Ship sea-keeping (cont) | <ul style="list-style-type: none"> ▪ yaw ▪ heave ▪ pitch ▪ surge ▪ slamming ▪ propeller racing ▪ squat ▪ broaching ▪ resistance in seaway ▪ local hydrodynamic wave loads ▪ wash ▪ short crested waves ▪ swell waves |
| Ship engineering systems (failure) | | |
| | Ship power plant | <ul style="list-style-type: none"> ▪ steam power plant ▪ steam preciprocating ▪ steam turbine ▪ nuclear propulsion ▪ wind propulsion (rotor, sails, turbine) ▪ re-engined plant ▪ coal-fired plant ▪ simulation propulsion plants ▪ fluidised bed ▪ diesel engine ▪ high-speed engine ▪ medium-speed engine ▪ low-speed engine ▪ twin-bank engine ▪ twin-engine (on-line arrangement) ▪ nitrogen diesel engine (closed cycle) ▪ marine gas turbine ▪ maintenance and repair equipment ▪ combined diesel-gas-turbo-plant ▪ reactor motor ▪ stirling engine ▪ gas engine ▪ hydrogen gas engine ▪ electric propelling machinery ▪ diesel-electric ▪ gas-turbo-electric ▪ steam-turbo-electric ▪ electro-magnetic / magneto hydrodynamic / mhd ▪ water jet (see also 0160418) |
| | Auxiliary engines boilers and piping systems | <ul style="list-style-type: none"> ▪ auxiliary engine ▪ boilers ▪ pressure vessels ▪ steam properties ▪ pumps ▪ piping systems ▪ heating coils |

| FACTORS | | ATTRIBUTES |
|---------|--|--|
| | Electric systems | <ul style="list-style-type: none"> ▪ generators/alternators ▪ shaft generator ▪ turbo generator ▪ exhaust gas generator ▪ electric motors ▪ cables ▪ lighting ▪ electrostatics ▪ tv & video systems ▪ fuel cell/battery |
| | Ship propulsion equipment | <ul style="list-style-type: none"> ▪ propellers ▪ fixed pitch propeller ▪ controllable pitch propeller ▪ ducted propeller ▪ contra-rotating propeller ▪ vertical axes propeller ▪ revolving propeller ▪ thruster/bow propeller ▪ jet thruster ▪ guide propeller ▪ skewed propeller ▪ vane wheel |
| | Shafting | <ul style="list-style-type: none"> ▪ propeller shaft ▪ bearing ▪ coupling ▪ sealing ▪ alignment/balancing ▪ gear box ▪ thrust box ▪ gear wheel ▪ gear teeth ▪ reversible gear ▪ planet gear (epicyclic gear) |
| | Control equipment and systems | <ul style="list-style-type: none"> ▪ engine room control equipment ▪ bridge control equipment ▪ autopilot ▪ automation/expert system ▪ computer application ▪ microprocessor ▪ degaussing system ▪ diagnosis system ▪ voice control ▪ sensor ▪ cargo care and cargo handling control equipment ▪ steering control equipment ▪ hull surveillance equipment |
| | Ship manoeuvring and stabilisation equipment | <ul style="list-style-type: none"> ▪ rudders ▪ fins/stabilisers ▪ steering equipment ▪ side thrusters ▪ anti-rolling tanks ▪ roll damping systems |
| | Ship-borne loading and unloading equipment | <ul style="list-style-type: none"> ▪ deckcranes ▪ derricks ▪ gantry cranes ▪ masts and rigging ▪ doors ▪ hatch covers ▪ lifts |

| FACTORS | | ATTRIBUTES |
|---------|---|--|
| | Ship-borne loading and unloading equipment (cont) | <ul style="list-style-type: none"> ▪ ramps ▪ twistable decks ▪ winches ▪ cargo pumps/pipes ▪ stowage equipment/lashing devices ▪ conveyor systems ▪ discharging valves |
| | Safety engineering equipment and systems | <ul style="list-style-type: none"> ▪ davits ▪ life boats ▪ fire detection ▪ protection end extinguishing equipment ▪ fire fighting systems ▪ fire prevention ▪ carbon-dioxide fire extinguisher ▪ buoys ▪ epirb ▪ jackets ▪ rafts |
| | Deck equipment | <ul style="list-style-type: none"> ▪ mooring equipment ▪ anchoring equipment ▪ towing equipment ▪ pilot and hoist ladders ▪ wire & synthetic ropes ▪ fenders |
| | Special equipment | <ul style="list-style-type: none"> ▪ de-icing equipment ▪ waste disposal equipment ▪ cleaning systems/purification plant/separator ▪ ballast pumping equipment ▪ distillation equipment/desalination ▪ tank washing ▪ gas freeing/inert gas system |
| | Thermal systems | <ul style="list-style-type: none"> ▪ refrigerating system ▪ heating system ▪ air conditioning ▪ air ventilation ▪ heat transfer ▪ compressor ▪ boil-off system/reliquefaction ▪ heat exchanger ▪ cooling system |
| | Sanitary systems | <ul style="list-style-type: none"> ▪ equipment ▪ piping system ▪ disposal arrangement |
| | Exhaust gases | <ul style="list-style-type: none"> ▪ funnels ▪ exhausts ▪ silencers ▪ energy utilisation ▪ waste heat recovery |
| | Catering | <ul style="list-style-type: none"> ▪ galleys ▪ pantries ▪ storage rooms ▪ equipments |

| FACTORS | | ATTRIBUTES |
|---------|--|---|
| | Navigational control systems & instruments | <ul style="list-style-type: none"> ▪ See section below |
| | Position fixing systems | |
| | Communication systems | |

| SHIPPING | | |
|------------|--|--|
| FACTORS | | ATTRIBUTES |
| Navigation | | |
| | Shipping environment | <ul style="list-style-type: none"> ▪ oceanography ▪ wave ▪ wave records ▪ current ▪ freak wave ▪ tidal movement ▪ wind/wave interaction ▪ ocean depth ▪ salinity/temperatures ▪ oceanographic instruments ▪ weather buoys ▪ weather ships ▪ coriolis force ▪ meteorology ▪ weather chart ▪ selected ships ▪ weather forecast ▪ facsimile ▪ gale ▪ hurricane ▪ typhoon ▪ wind ▪ fog ▪ rain ▪ snow ▪ meteorological instruments ▪ astronomy |
| | Path information and rules | <ul style="list-style-type: none"> ▪ nautical charts and projections/electronic chart ▪ chart interpretation ▪ almanac ▪ navigational vocabulary ▪ notice to mariners/navtex ▪ data banks ▪ information systems ▪ visual aids to navigation ▪ lighthouses ▪ beacons ▪ buoys ▪ pilotage service ▪ directions to navigation ▪ emergency manoeuvre rules ▪ company instructions |
| | Navigational control systems & instruments | <ul style="list-style-type: none"> ▪ course control ▪ log ▪ speed control ▪ monitoring systems ▪ depth control/echo sounders ▪ sonar ▪ magnetic compass ▪ gyro compass |

| FACTORS | | ATTRIBUTES |
|---------|---|--|
| | Navigational control systems & instruments (cont) | <ul style="list-style-type: none"> ▪ automatic radar plotting aid (ARPA) ▪ integrated navigation system (INS) ▪ black box |
| | Position fixing | <ul style="list-style-type: none"> ▪ dead reckoning |
| | Position fixing systems | <ul style="list-style-type: none"> ▪ hyperbolic systems ▪ glonass ▪ gps ▪ satellite ▪ satnav ▪ loran ▪ omega ▪ consol ▪ decca ▪ highfix ▪ seafix ▪ artemis ▪ syledis ▪ sonar ▪ plotting ▪ inertial systems ▪ bearings and measurements ▪ visual ▪ celestial navigation ▪ radio ▪ radar ▪ low light level tv ▪ laser |
| | Special navigational circumstances | <ul style="list-style-type: none"> ▪ coastal navigation ▪ navigation under pilotage ▪ berthing ▪ poor visibility ▪ radar detection ▪ electromagnetic interference/emi/emp/emc ▪ adverse weather conditions ▪ arctic/polar conditions ▪ subsea navigation ▪ navigation at very high speed ▪ air navigation ▪ sailing & sailing routes |
| | Communication systems | <ul style="list-style-type: none"> ▪ visual/sound signal ▪ radio systems ▪ telephony ▪ telegraphy ▪ tor ▪ satellite ▪ teletex /seaview /videotex /viewdata system ▪ shipboard communication system |
| | Weather routing | <ul style="list-style-type: none"> ▪ None |
| | Shipping traffic | <ul style="list-style-type: none"> ▪ collision avoidance ▪ collision avoidance systems ▪ rules of the road at sea ▪ fair lanes - fair ways ▪ war conditions ▪ shipping routes |

| FACTORS | | ATTRIBUTES |
|----------------------------|----------------------|--|
| | Traffic separation | <ul style="list-style-type: none"> ▪ None |
| | Traffic guidance | <ul style="list-style-type: none"> ▪ shore-based radar ▪ technical aspects ▪ socio-economic aspects ▪ legal aspects ▪ personnel training ▪ watch keeping |
| Shipboard (mis) operations | | |
| | Cargo stowage | <ul style="list-style-type: none"> ▪ stowage places ▪ deck stowage ▪ underdeck ▪ underhatch ▪ deep stowage ▪ cargo lashing ▪ palletising ▪ stowage planning ▪ draft ▪ stability ▪ strength ▪ trim ▪ assessment of labour and technology ▪ economy of space ▪ rules and regulations in cargo stowage ▪ grain loading ▪ stowage of hazardous cargo ▪ stowage of timber cargo ▪ stowage of containers |
| | Cargo care | |
| | Cargo administration | |
| | Cargo handling | <ul style="list-style-type: none"> ▪ loading and unloading systems ▪ shore-based systems and equipment (see port, etc.) ▪ shipborne systems ▪ underway replenishment ▪ draft survey ▪ heavy lift handling ▪ physical form of cargo ▪ unpacked general cargo ▪ packed general cargo ▪ unitized ▪ pre-sling ▪ pallet ▪ container ▪ flat/cassette ▪ fibc/nylon ▪ containers/dracone ▪ refrigerated cargo ▪ fluidized cargo/slurry transport ▪ pneumatic cargo transport ▪ bagged cargo ▪ liquefied cargo ▪ liquefied gas ▪ cargo in bulk ▪ chemical cargo |

| FACTORS | | ATTRIBUTES |
|---------|------------------------|---|
| | Cargo handling (cont) | <ul style="list-style-type: none"> ▪ economic feasibility of cargo handling systems ▪ integrated transport ▪ cargo damage or loss ▪ safety aspects ▪ transportation systems ▪ automated cargo handling |
| | Engine room operation | <ul style="list-style-type: none"> ▪ mechanised engine room operation ▪ automated engine room operation |
| | Maintenance and repair | <ul style="list-style-type: none"> ▪ machinery maintenance and repair ▪ preventive maintenance ▪ maintenance prediction ▪ condition monitoring ▪ dehumidification/humidity control ▪ planned maintenance ▪ shipboard maintenance ▪ hull maintenance and repair ▪ fouling control |

| VESSEL TRAFFIC SERVICES (VTS) | | |
|---|--------------------|---|
| FACTORS | | ATTRIBUTES |
| VTS component and systems | | |
| VTS operations | | |
| | Weather routing | None |
| | Shipping traffic | <ul style="list-style-type: none"> ▪ collision avoidance ▪ collision avoidance systems ▪ rules of the road at sea ▪ fair lanes - fair ways ▪ war conditions ▪ shipping routes |
| | Traffic separation | None |
| | Traffic guidance | <ul style="list-style-type: none"> ▪ shore-based radar ▪ technical aspects ▪ socio-economic aspects ▪ legal aspects ▪ personnel training ▪ watch keeping |
| VTS procedures | | |
| VTS provision of services | | |
| VTS planning and design | | |
| VTS handling of emergencies/unusual situation | | |
| OPS room management | | |

| PORT & WATERWAYS | | |
|-------------------------------|--------------------------------|---|
| FACTORS | ATTRIBUTES | |
| Port engineering and planning | Port navigation and hydraulics | <ul style="list-style-type: none"> ▪ ship dimensions ▪ ship squat ▪ ship tide ▪ ship trim ▪ underkeel clearance ▪ channel width calculation ▪ harbour hydraulics ▪ tide propagation in branched systems ▪ wind action ▪ current action ▪ wave penetration/storm flood ▪ seiches (inertial oscillations) ▪ mooring forces ▪ suction effect ▪ Port design ▪ harbour projects & studies ▪ terminal design ▪ sea ports ▪ inland ports ▪ facilities ▪ transhipments ▪ stevedoring ▪ storage ▪ warehousing ▪ berths ▪ link span ▪ pavement ▪ piers ▪ quays ▪ rail tracks ▪ operation models & organisations ▪ handling technology |
| | Port protection | <ul style="list-style-type: none"> ▪ building materials ▪ artificial concrete elements ▪ rubble ▪ stone setting ▪ wave action ▪ wave forces ▪ overtopping ▪ run up ▪ refraction ▪ diffraction ▪ type of port protection ▪ breakwater ▪ vertical wall breakwater/barrier ▪ submerged breakwater ▪ jetty ▪ pier ▪ moles ▪ cathodic protection ▪ maintenance ▪ sea level rise |

| FACTORS | | ATTRIBUTES |
|----------------------------|--|---|
| | Littoral drift, sedimentation and morphology in harbours and approach channels | <ul style="list-style-type: none"> ▪ littoral drift ▪ tracers ▪ sediment intrusion ▪ silting ▪ silt movement related to salt water penetration ▪ sediment discharge by rivers ▪ shoaling of estuaries ▪ measures against salinity intrusion ▪ sediment bypassing systems ▪ beach replenishment/nourishment ▪ Water management ▪ fresh water supply ▪ water discharge ▪ distribution model |
| | Tidal inlets on alluvial shores | <ul style="list-style-type: none"> ▪ tidal hydraulics ▪ channel stability ▪ morphological problems |
| Port devices and equipment | | |
| | Mooring devices | <ul style="list-style-type: none"> ▪ wharf ▪ quay ▪ floating quay ▪ fenders ▪ breasting dolphin unit ▪ hydraulic fender ▪ steel fender ▪ rubber fender ▪ wooden fender ▪ energy absorption ▪ impact on fenders ▪ dolphin ▪ buoy ▪ berth |
| | Port and terminal equipment | <ul style="list-style-type: none"> ▪ loading and unloading equipment ▪ floating harbour installation ▪ general cargo crane ▪ portal crane ▪ semi-portal crane ▪ mobile crane ▪ floating crane ▪ unloaders ▪ elevators ▪ container cranes ▪ stevedoring equipment ▪ straddle carrier ▪ side loader ▪ fork truck ▪ conveyor ▪ terminal truck ▪ terminal trailer ▪ grabs ▪ shore-based ro-ro ramps ▪ tanks ▪ sheds ▪ silos |

| FACTORS | | ATTRIBUTES |
|------------------------|---|--|
| | Port and terminal equipment (cont) | <ul style="list-style-type: none"> ▪ warehouses ▪ bonded warehouses ▪ cold storage ▪ storage ▪ residue reception facilities ▪ inland transport equipment ▪ pipeline/slurry transport ▪ equipment designs ▪ device designs ▪ structure designs ▪ transport devices ▪ hoisting devices |
| Port/harbour operation | | |
| | Port functions & information (statistics) | <ul style="list-style-type: none"> ▪ cargo transfer/transhipment (statistics) ▪ long term storage ▪ marketing/processing/planning ▪ clients ▪ customers ▪ vessel servicing ▪ pilotage (see also 0210233) ▪ tug assistance ▪ rescue/fire-fighting/safety aspects ▪ repair/maintenance ▪ dry-docking ▪ traffic management system (vtm, vts) ▪ welfare/missions ▪ customs ▪ smuggling combatment |
| | 0430200 - Port organisation | <ul style="list-style-type: none"> ▪ commercial administration ▪ financial administration ▪ port dues ▪ pilot dues ▪ tug tariff ▪ stevedore costs ▪ dock labour supply and control |
| | Port management | <ul style="list-style-type: none"> ▪ investment planning ▪ port development ▪ financial policy ▪ port capacity ▪ berth throughput ▪ congestion ▪ employment ▪ competition between ports ▪ hinterland development ▪ industrial development ▪ terminal operation |
| Waterways | Canals for inland shipping | <ul style="list-style-type: none"> ▪ Rivers ▪ Interocean ships canals |

| METEOROLOGICAL / ENVIRONMENTAL INFORMATION | | |
|--|----------------------------------|--|
| FACTORS | | ATTRIBUTES |
| Shipping environment | | |
| | weather condition | |
| | | <ul style="list-style-type: none"> ▪ oceanography ▪ wave ▪ wave records ▪ current ▪ freak wave ▪ tidal movement ▪ wind/wave interaction ▪ ocean depth ▪ salinity/temperatures ▪ oceanographic instruments ▪ weather buoys ▪ weather ships ▪ coriolis force ▪ meteorology ▪ weather chart ▪ selected ships ▪ weather forecast ▪ facsimile ▪ gale ▪ hurricane ▪ typhoon ▪ wind ▪ fog ▪ rain ▪ snow ▪ meteorological instruments ▪ astronomy |
| | Special navigational information | <ul style="list-style-type: none"> ▪ coastal navigation ▪ navigation under pilotage ▪ berthing ▪ poor visibility ▪ radar detection ▪ electromagnetic interference/emi/emp/emc ▪ adverse weather conditions ▪ arctic/polar conditions ▪ subsea navigation ▪ navigation at very high speed ▪ air navigation ▪ sailing & sailing routes |

9.2 HUMAN Factors and Attributes

| LIVEWARE (HUMAN) | | | |
|------------------|---|------------------------------|--|
| FACTORS | | ATTRIBUTES | |
| physical | | | |
| | physical characteristics | | |
| | | age and physical limitations | |
| | | anthropometrics | <ul style="list-style-type: none"> ▪ size (human) ▪ reach (human) ▪ strength (human) ▪ weight (human) |
| | sensory limitations | | |
| | | vision | <ul style="list-style-type: none"> ▪ glasses/contact lenses/corrected vision ▪ uncorrected vision, or failure to wear glasses/lenses when required to do so ▪ colour vision ▪ night vision ▪ empty field myopia |
| | | hearing | |
| | | vestibular | |
| | | proprioception | |
| | | mandelbaum effect | |
| | | sensory threshold | |
| | other physical limitations or characteristics | | |
| physiological | | | |
| | illness/incapacitation | | <ul style="list-style-type: none"> ▪ deceased ▪ illness ▪ gastro-enteritis/food poisoning ▪ vertigo/dizziness ▪ pre-existing injury ▪ heart attack ▪ hypoxia/anoxia ▪ hyperventilation ▪ carbon monoxide poisoning ▪ toxic fumes ▪ loss of consciousness/fainting ▪ motion sickness ▪ visual disturbance ▪ decompression/diving ▪ medical history |
| | health/fitness/lifestyle | | <ul style="list-style-type: none"> ▪ stress symptoms ▪ fitness ▪ obesity ▪ diet/meals/meal breaks ▪ blood/sugar level ▪ chronic alcohol abuse |

| FACTORS | | ATTRIBUTES |
|---------------|---------------------------------|---|
| | health/fitness/lifestyle (cont) | <ul style="list-style-type: none"> ▪ alcohol/blood level ▪ alcohol impairment ▪ alcohol -hangover ▪ over-the-counter medication ▪ prescription medication ▪ barred medication/substances ▪ stimulants ▪ illicit drugs ▪ blood donation ▪ disease ▪ pain ▪ smoking ▪ predisposing condition ▪ psychological condition ▪ other health/fitness ▪ other lifestyle |
| | fatigue/alertness | <ul style="list-style-type: none"> ▪ asleep ▪ sleep {deficit, deprivation, disorder, disruption} ▪ fatigue {acute, chronic, motion induced} ▪ circadian dysrhythmia (jet lag) ▪ rest/duty time ▪ other |
| | illusions | <ul style="list-style-type: none"> ▪ vestibular illusions ▪ visual ▪ other illusions |
| | other physiological limitations | |
| psychological | | |
| | personality | <ul style="list-style-type: none"> ▪ personality {general, aggressive, assertive, non-assertive, risk taking} ▪ confidence in {vessel, equipment, self, others, information, automation, VTS} ▪ complacency ▪ 'get-home-itis' or 'press-on-itis' ▪ motivation ▪ attitudes - other |
| | mental/emotional state | <ul style="list-style-type: none"> ▪ arousal level/ alertness ▪ stressed ▪ post incident stress ▪ stress incurred as a result of having experienced a previous incident or stressful situation (usually that day, but could be some time prior to that) ▪ apprehension ▪ anxiety ▪ panic ▪ boredom (emotional state) ▪ denial ▪ other mental/emotional state |

| FACTORS | | ATTRIBUTES | |
|-----------|---------------------|-----------------------|---|
| cognitive | perceptual level | | <ul style="list-style-type: none"> ▪ perception ▪ attention ▪ monitoring {automation, displays/instruments, outside world, radio channels, a person} ▪ boredom/monotony (attention) ▪ vigilance ▪ distraction ▪ fascination/fixation/canalised attention ▪ attention habituation ▪ attention - other |
| | | situational awareness | <ul style="list-style-type: none"> ▪ spatial disorientation ▪ geographic disorientation (lost) ▪ temporal disorientation/ time horizon ▪ visual disorientation ▪ losing 'the picture' ▪ situational awareness and automation ▪ other orientation |
| | level of processing | | |
| | | knowledge | <ul style="list-style-type: none"> ▪ knowledge {general, up-to-date, of regulatory requirements, maritime, of vessel systems, of company procedures and policies, of voyage procedures, of VIS procedures, of harbour procedures, of maintenace procedures, of anti collision rules, meteorological} ▪ knowledge acquisition/learnin g ▪ knowledge other |

| FACTORS | | ATTRIBUTES | |
|---------|-------------------|--|---|
| | | information processing / decision making | <ul style="list-style-type: none"> ▪ decision making ▪ mental capacity ▪ comprehension ▪ recognition failure ▪ misunderstanding ▪ assumption incorrect ▪ false hypothesis ▪ confirmation bias ▪ mind set/expectancy ▪ habituation ▪ information processing other |
| | | judgement | <ul style="list-style-type: none"> ▪ spatial judgement ▪ judgement of risk of collision ▪ timing/speed judgement ▪ other judgement |
| | | planning | <ul style="list-style-type: none"> ▪ voyage planning ▪ pre-voyage planning ▪ in-voyage planning ▪ in-voyage planning (e.g. change of plans in response to weather, planning for even distribution of workload, etc) ▪ preparedness ▪ maintenance task planning ▪ other planning |
| | | workload management | <ul style="list-style-type: none"> ▪ prioritisation/task scheduling ▪ timing ▪ unforeseen task additions ▪ task shedding ▪ task allocation ▪ other workload management |
| | behavioural level | | human error |

| FACTORS | | ATTRIBUTES | |
|-----------------------|-------------------------------|------------|---|
| | | actions | <ul style="list-style-type: none"> ▪ action timing ▪ action/ error by a third party ▪ other action/error |
| Personal | | | |
| | skill | | <ul style="list-style-type: none"> ▪ seamanship ▪ ship handling ▪ CRM/seamanship ▪ e.g. inadequate crew resource management skills / seamanship (see also interactions - crew/team resource management, cross-checking) ▪ competence/ability ▪ past record ▪ skill ▪ skill maintenance with {automation, age, lack of practice} ▪ negative transfer ▪ negative transfer, e.g. interference of old skills after having transferred to a new environment or type of ship (e.g. transfer from conventional ship to HSC). ▪ reaction time ▪ non-standard technique ▪ other technique/skill |
| | experience and qualifications | | <ul style="list-style-type: none"> ▪ qualifications, certificates, ratings ▪ experience ▪ total hours/years experience ▪ general inexperience ▪ experience {in position, on vessel, of harbour, of fairway, of waters, of route, other} ▪ use of tooling and equipment |
| | recency | | <ul style="list-style-type: none"> ▪ recency {in position, on vessel} ▪ recent experience with {harbour, fairway, waters, route} ▪ recency in direct operational activity ▪ other recency |
| other liveware issues | | | |

| LIVEWARE (HUMAN) - ENVIRONMENT | | | |
|--------------------------------|------------------------------|------------|--|
| FACTORS | | ATTRIBUTES | |
| physical environment | | | |
| | harbour | | <ul style="list-style-type: none"> ▪ harbour characteristics, conditions or lighting/markings (including disturbing lights) ▪ approach aids ▪ harbour infrastructure ▪ obstructions to vision at the harbour ▪ harbour facilities |
| | vessel traffic service (VTS) | | <ul style="list-style-type: none"> ▪ Vessel traffic service incorrect/inappropriate/ inadequate e.g. lack of VTS |
| | information | | <ul style="list-style-type: none"> ▪ weather information ▪ information on harbour or waterway conditions ▪ other information |

| FACTORS | | ATTRIBUTES |
|--------------------------------------|-----------------------------------|---|
| | weather/visual conditions | |
| | workspace environment | <ul style="list-style-type: none"> ▪ space ▪ access (for maintenance) ▪ visibility from workspace / workplace ▪ air quality in workplace ▪ ambient pressure ▪ cold ▪ heat ▪ illumination/lighting ▪ glare ▪ humidity ▪ noise in the workplace ▪ ozone ▪ pollution/fumes ▪ radiation ▪ vibration ▪ other internal workspace environment issues |
| | other human-environment interface | |
| | | |
| psychosocial | job satisfaction | |
| | morale/motivation | |
| | cultural issues | |
| | domestic issues | <ul style="list-style-type: none"> ▪ domestic event/crisis ▪ family pressure ▪ financial problems/issues ▪ interpersonal conflicts ▪ significant lifestyle change ▪ mental pressure (domestic) |
| | | |
| | psychosocial - other | |
| organisational and regulatory issues | pressures | <ul style="list-style-type: none"> ▪ company/commercial pressures ▪ specific company problems ▪ management/supervision problems ▪ managerial operating pressures |
| | labour relations | <ul style="list-style-type: none"> ▪ employee-management relations ▪ industrial action ▪ union/professional group |
| | Management /personnel policies | <ul style="list-style-type: none"> ▪ operational policies ▪ operational control ▪ operational support ▪ recruitment ▪ staffing ▪ manning/resource allocation ▪ crew pairing ▪ scheduling ▪ maintenance scheduling ▪ seniority/promotion/career progression ▪ terms and conditions/pay/incentives ▪ requirements |
| | | |
| | | |

| FACTORS | | ATTRIBUTES |
|-------------------------------------|---|---|
| | Management /personnel policies (cont) | <ul style="list-style-type: none"> ▪ instructions/ directives/orders ▪ shift work/rosters/duty time ▪ manning ▪ temporary or unexpected staff shortages |
| | regulatory authority policies and practices | |
| operational task demands | | |
| | workload | <ul style="list-style-type: none"> ▪ overload/task saturation ▪ high workload due to staff/skills shortages ▪ underload ▪ workload transition ▪ unexpected demands ▪ extraneous tasks ▪ administrative workload ▪ unusual/unfamiliar situation ▪ emergency situation ▪ flow control |
| | time pressures | |
| | operational mental pressure | |
| | training/examination/check situation | <ul style="list-style-type: none"> ▪ training in progress ▪ crew training in progress ▪ training/ examination or check in progress ▪ VTS training in progress ▪ controller training/ examination or check in progress ▪ other training situation |
| | miscellaneous operational task demands | <ul style="list-style-type: none"> ▪ task demands caused by other vessel passengers ▪ disruptive passengers ▪ task demands or problems caused by disruptive passengers ▪ technical problem/ failure ▪ technical support ▪ pilotage |
| other liveware – environment issues | | |

| LIVEWARE (HUMAN) - HARDWARE | | |
|-----------------------------|--------------------------------------|--|
| FACTORS | | ATTRIBUTES |
| hardware | | |
| | workplace equipment/workplace design | <ul style="list-style-type: none"> ▪ design/ergonomics ▪ workplace seat design ▪ problems associated with seat design (e.g. lack of seat adjustment resulting in inability to reach certain controls, poor seat comfort leading to back etc) ▪ workspace layout ▪ workspace layout (e.g. bridge layout) ▪ workplace instruments design |

| FACTORS | | ATTRIBUTES |
|---------|---|--|
| | workplace equipment/ workplace design (cont) | <ul style="list-style-type: none"> ▪ instruments design (e.g. similar instruments giving very different information, possibly leading to confusion) ▪ workplace electronic displays design ▪ electronic displays design (e.g. navigating through complicated menus) ▪ workplace controls design ▪ workplace controls and displays design/integration ▪ problems associated with controls and displays (e.g. lack of integration where the autopilot display can indicate one mode but the 'hard' mode switch can be selected to a different mode, the software overriding the hardware) ▪ workplace controls and displays illumination ▪ illumination of bridge equipment (e.g. glare making it difficult to see whether an indicator light is on or off) ▪ workplace controls and displays location ▪ location of controls or displays ▪ workplace controls and displays movement, e.g. failure to apply good ergonomic principles to control and display movement (e.g. using digital indicators when analogue would be more appropriate) ▪ operation of workplace equipment ▪ general problems associated with the operation of the equipment (e.g. easy to knock one switch accidentally when selecting another) ▪ motor workload within the workplace ▪ problems with motor activity required, e.g. too much button pressing ▪ reach/vision restrictions within the workplace ▪ difficulties in seeing or reaching controls or displays (e.g. important indicators in peripheral vision)(see also physical characteristics - anthropometrics/ size/ reach/ strength/weight) ▪ personal comfort within the workplace ▪ alerts/warnings within the workplace ▪ standardisation within the workplace ▪ reliability of workplace equipment |

| FACTORS | | ATTRIBUTES |
|---|--|--|
| | vessel equipment other than workplace design | <ul style="list-style-type: none"> ▪ design/ergonomics of other equipment of the vessel ▪ alerts/warnings of other equipment on the vessel ▪ standardisation of other vessel equipment ▪ reliability of other vessel equipment |
| | | |
| | vessel maintenance equipment | <ul style="list-style-type: none"> ▪ design/ergonomics of maintenance tools/equipment ▪ reliability of vessel maintenance equipment |
| | | |
| | safety equipment | <ul style="list-style-type: none"> ▪ design/ergonomics of safety equipment ▪ reliability of safety equipment |
| | | |
| | VTS equipment | <ul style="list-style-type: none"> ▪ ergonomics/design of VTS equipment ▪ radar display ▪ VTS communications equipment ▪ reliability of VTS equipment ▪ other VTS equipment |
| | | |
| suitability of design/ ergonomics for training purposes | | |
| suitability of design for maintenance purposes | | |
| information / data sources | | |
| | data sources | <ul style="list-style-type: none"> ▪ radar information ▪ problems with radar information (e.g. not available, inaccurate, misleading, intermittent, etc) ▪ GPS information ▪ problems with GPS information (e.g. not available, inaccurate, misleading, intermittent, etc) ▪ other instruments ▪ problems with information from instruments other than radar and GPS (e.g. not available, inaccurate, misleading, intermittent, etc) ▪ human data source ▪ VTS data source ▪ problems with information from (other) VTS units (see also communications and physical environment – vessel traffic service) ▪ information from other vessels or land based stations ▪ other information/ data sources |
| | | |
| | communications media | <ul style="list-style-type: none"> ▪ VHF/HF frequencies ▪ telephone ▪ data link communications medium ▪ other communications media |

| FACTORS | | ATTRIBUTES |
|---------|-------------------------------------|--|
| | alarms | <ul style="list-style-type: none"> ▪ fire/smoke alarms ▪ water ingress alarms ▪ watch alarms ▪ VTS alarms/alerts ▪ other alarms |
| | automation design and functionality | <ul style="list-style-type: none"> ▪ user friendliness of automation ▪ system mode awareness ▪ generating additional workload ▪ compatibility with hardware and instrumentation ▪ reliability of automation ▪ disconnect of automation |
| | use of automation | <ul style="list-style-type: none"> ▪ training in use of automation ▪ reliance on automation ▪ use of automation ▪ complacency with automation |
| | other liveware – hardware issues | |

| LIVEWARE (HUMAN) - SOFTWARE | | |
|-----------------------------|--|--|
| FACTORS | | ATTRIBUTES |
| operational material | | |
| | workplace manuals, checklists and charts | <ul style="list-style-type: none"> ▪ workplace manuals ▪ workplace checklists (normal) ▪ emergency and abnormal workplace checklists ▪ maps, charts |
| | maintenance engineering material | |
| | operational material - other | <ul style="list-style-type: none"> ▪ notices and advisory material ▪ other publications ▪ vessel safety instructions ▪ regulations ▪ pilot card ▪ other handbooks/manuals ▪ other checklists ▪ written information - other |
| procedures | | |
| | normal procedures | |
| | emergency and abnormal procedures | |
| | VTS procedures | |
| | harbour procedures | |
| | maintenance procedures | |
| | company procedures | |
| | other procedures | |
| custom and practice | | |

| FACTORS | | ATTRIBUTES | |
|----------------------------------|-------------------------------|------------|--|
| training | | | |
| | basic/ initial training | | <ul style="list-style-type: none"> ▪ training syllabus |
| | specific training | | |
| | simulator training | | |
| | on-the job training | | |
| | emergency training | | |
| | CRM/ TRM training | | |
| | recurrent training | | <ul style="list-style-type: none"> ▪ loft (training) |
| | route training | | |
| | miscellaneous training issues | | <ul style="list-style-type: none"> ▪ use of automation ▪ use of maps/ charts ▪ use of manuals ▪ other miscellaneous training |
| Other liveware - software issues | | | |

| LIVEWARE (HUMAN) - LIVEWARE (HUMAN) | | | |
|-------------------------------------|---------------------------|------------|---|
| FACTORS | | ATTRIBUTES | |
| Communications | | | |
| | oral/aural communications | | <ul style="list-style-type: none"> ▪ communications between crew members ▪ communication with the pilot ▪ vessel-vessel communications ▪ vessel-shore communications ▪ VTS-vessel communications ▪ company communications ▪ party line information ▪ overheard information between two other vessels, or between VTS and another vessel (including loss of 'party line' information with the advent of data link) ▪ shore-shore communications ▪ language ▪ accent ▪ phraseology ▪ read-back/hear-back ▪ call sign or ship name confusion ▪ noise interference with communication (see also noise in the workplace) ▪ aural/oral interpretation/misinterpretation |

| FACTORS | | ATTRIBUTES |
|---------------------|-------------------------------|---|
| | written / read communications | <ul style="list-style-type: none"> ▪ documentation for communication of information ▪ documentation incomplete / missing ▪ maintenance engineering task sheets/cards ▪ problems with using maintenance engineering task sheets/cards as a means of recording and passing information (see also other operational material - maintenance task cards and progress sheets) ▪ pilot sheets/cards ▪ problems with using pilot sheets/cards as a means of recording and passing information (see also other operational material - maintenance task cards and progress sheets) ▪ use of log book to communicate information ▪ communications using data link ▪ teletype communications ▪ keying error ▪ handwriting ▪ misreading ▪ acknowledgements/feedback loop - written/keyed/visual |
| | visual signals | <ul style="list-style-type: none"> ▪ light signals ▪ flag signals ▪ emergency signals ▪ signals given by the manoeuvres of a vessel |
| Interactions | | |
| | team skills / CRM / TRM | <ul style="list-style-type: none"> ▪ coordination (CRM/TRM) ▪ incompatibility (CRM/TRM) ▪ confidence/trust (CRM/TRM) ▪ cross-checking (CRM/TRM) ▪ authority gradient ▪ peer pressure/conformity ▪ assertiveness within the team ▪ briefing between team members ▪ self feedback ▪ joint decision process ▪ group climate (CRM/TRM) ▪ team preparation/ planning ▪ team workload management |
| | formal coordination | |
| | shift/watch/team changeover | |
| | other interactions | |
| supervision | | |
| | operational supervision | |
| | supervision during training | |
| | quality control | |
| | standards | |

| FACTORS | | ATTRIBUTES |
|----------------------------------|-------------------------|---|
| regulatory activities | | |
| | regulatory procedures | |
| | regulatory standards | <ul style="list-style-type: none"> ▪ design standards ▪ certification standards |
| | | |
| | regulation | |
| | inspections | |
| | monitoring (regulation) | |
| | surveillance | |
| | audit | |
| checks | | |
| other liveware - liveware issues | | |

10. APPENDIX 3: CONFIRMATION OF MAIN CAUSES

The accidents that were considered in this exercise were the following:

- CatLink II - Official accident report number 0811.01-40 by the Danish Maritime Authority (Søfartsstyrelsen) July 1, 1997 (in Danish).
- Eskil - Official accident report by the Swedish Maritime Authority (Sjöfartsverket) March 27, 2001 (in Swedish).
- Saint Malo - Unofficial MARS report published on the internet (in English).
- Sleipner - Official accident report from the Accident Investigation Commission (Undersøkelseskommissjonen) November 8, 2000 (in Norwegian).

The results are reported in the following tables

| LIVEWARE (HUMAN) | | | | | |
|-------------------------|---|------------|-------|------------|----------|
| | | CatLink II | Eskil | Saint Malo | Sleipner |
| physical | physical characteristics | | | | |
| physical | sensory limitations | | | | |
| physical | other physical limitations or characteristics | yes | | | |
| physiological | illness/incapacitation | | | | |
| physiological | health/fitness/lifestyle | | | | |
| physiological | fatigue/alertness | | | | |
| physiological | illusions | | | | |
| physiological | other physiological limitations | | | | |
| psychological | personality | | | yes | yes |
| psychological | mental/emotional state | | yes | | |
| cognitive | perceptual level | yes | | yes | yes |
| cognitive | level of processing | yes | yes | yes | yes |
| cognitive | behavioural level | yes | yes | yes | yes |
| personal | skill | | | yes | yes |
| personal | experience and qualifications | | | | yes |
| personal | recency | | | yes | |
| other liveware issues | | | | | |

| LIVEWARE (HUMAN) - ENVIRONMENT | | | | | |
|---------------------------------------|-----------------------------------|------------|-------|------------|----------|
| | | CatLink II | Eskil | Saint Malo | Sleipner |
| physical environment | harbour | | | | |
| physical environment | VTS | | | | |
| physical environment | information | | | | |
| physical environment | weather/visual conditions | yes | | yes | |
| physical environment | workspace environment | | | | |
| physical environment | other human-environment interface | | | yes | |
| psychosocial | job satisfaction | | | | |
| psychosocial | morale/motivation | | | | |
| psychosocial | cultural issues | | | | |
| psychosocial | domestic issues | | | | |

| LIVEWARE (HUMAN) - ENVIRONMENT | | | | | |
|---------------------------------------|---|-----|-----|--|--|
| psychosocial | psychosocial - other | | | | |
| organisational and regulatory issues | pressures | yes | yes | | |
| organisational and regulatory issues | labour relations | | | | |
| organisational and regulatory issues | management/personnel policies | yes | yes | | |
| organisational and regulatory issues | regulatory authority policies and practices | | | | |
| operational task demands | workload | | | | |
| operational task demands | time pressures | yes | yes | | |
| operational task demands | operational mental pressure | | | | |
| operational task demands | training/examination/check situation | | | | |
| operational task demands | miscellaneous operational task demands | | yes | | |
| other liveware-environment issues | | | | | |

| LIVEWARE (HUMAN) - HARDWARE | | | | | |
|------------------------------------|--|------------|-------|------------|----------|
| | | CatLink II | Eskil | Saint Malo | Sleipner |
| operational material | workplace manuals, checklists and charts | | | | |
| operational material | maintenance engineering material | | | | |
| operational material | operational material - other | | | | |
| procedures | normal procedures | yes | | | yes |
| procedures | emergency and abnormal procedures | | | | |
| procedures | VTS procedures | | | | |
| procedures | harbour procedures | | | | |
| procedures | maintenance procedures | | | | |
| procedures | company procedures | yes | | | yes |
| procedures | other procedures | yes | | | yes |
| procedures | custom and practice | yes | | | yes |
| training | basic/initial training | | | | |
| training | specific training | | | | yes |
| training | simulator training | | | | |
| training | on-the job training | | | | |
| training | emergency training | | | | |
| training | CRM/TRM training | | | | |
| training | recurrent training | | | | |
| training | route training | | | | |
| training | miscellaneous training issues | | | | yes |
| other liveware - software issues | | | | | |

| LIVEWARE (HUMAN) - SOFTWARE | | | | | |
|------------------------------------|--|------------|-------|------------|----------|
| | | CatLink II | Eskil | Saint Malo | Sleipner |
| hardware | workplace equipment/workplace design | | yes | | yes |
| hardware | vessel equipment other than workplace design | | | | |
| hardware | vessel maintenance equipment | | | | |
| hardware | safety equipment | | | | |
| hardware | VTS equipment | | | | |
| hardware | suitability of design/ergonomics for training purposes | | | | |
| hardware | suitability of design for maintenance purposes | | | | |
| information/ data sources | data sources | yes | | | |
| information/ data sources | communications media | | yes | | |
| information/ data sources | alarms | | | | |
| information/ data sources | automation design and functionality | | | | |
| information/ data sources | use of automation | | | | yes |
| other liveware - hardware issues | | | | | |

| LIVEWARE (HUMAN) - LIVEWARE (HUMAN) | | | | | |
|--|-----------------------------|------------|-------|------------|----------|
| | | CatLink II | Eskil | Saint Malo | Sleipner |
| communications | oral/aural communications | | | | yes |
| communications | written/read communications | | | | |
| communications | visual signals | | | | |
| interactions | team skills/CRM/TRM | yes | yes | | yes |
| interactions | formal coordination | | | | yes |
| interactions | shift/watch/team changeover | | | | |
| interactions | other interactions | | yes | | |
| supervision | operational supervision | | | | |
| supervision | supervision during training | | | | |
| supervision | quality control | | | | |
| supervision | standards | | | | |
| regulatory activities | regulatory procedures | | | | |
| regulatory activities | regulatory standards | | | | |
| regulatory activities | regulation | | | | |
| regulatory activities | inspections | | | | |
| regulatory activities | monitoring (regulation) | | | | |
| regulatory activities | surveillance | | | | |
| regulatory activities | audit | | | | |
| regulatory activities | checks | | | | |
| other liveware-liveware issues | | | | | |

11. APPENDIX 4: FMECA SHEETS.

This appendix contains a number of subchapters, each one referring to a specific phase of the FMECA exercise and addressing collision and grounding. These subchapters refer to:

- Summary table of FMECA (for collision and grounding)
- Failure Causes
- Local effects
- Relevant Causes

11.1 Summary table of FMECA (for collision and grounding)

| NO. | SYSTEM | FAILURE MODE | RANK | UN | A1 | A2 | NOTES |
|------|----------------|---|------|----|----|----|---------------------|
| 8,5 | Operations | Maneuvering equipment failure | 572 | 4 | 3 | 4 | EE2, EE3, EE4, EE11 |
| 7,1 | Crew | Environmental degradation of Crew | 450 | 3 | 4 | 3 | EE3, EE4, EE11 |
| 7,3 | Crew | Failure to follow procedures | 450 | 3 | 4 | 3 | EE4, EE3, EE11 |
| 5,2 | Payload | Movement of cargo-including people | 374 | 2 | 9 | 0 | EE10, EE11 |
| 1,6 | Hullform | Lack of directional control | 161 | 1 | 2 | 4 | EE4 |
| 7,2 | Crew | Improper use of equipment | 160 | 1 | 2 | 3 | EE4 |
| 6,13 | Safety Systems | Failure to Contact Shore-Based Assistance | 146 | 1 | 1 | 1 | EE11 |
| 8,4 | Operations | Navigational equipment failure | 62 | 0 | 5 | 2 | |
| 8,1 | Operations | Navigational error in open and congested waters | 51 | 0 | 4 | 3 | |
| 8,3 | Operations | Navigational error in traffic | 42 | 0 | 3 | 6 | |
| 2,1 | Machinery | Lack of propulsion | 40 | 0 | 3 | 4 | |
| 2,3 | Machinery | Auxiliaries failure | 40 | 0 | 3 | 4 | |
| 2,4 | Machinery | Electrical generation failure | 40 | 0 | 3 | 4 | |
| 7,4 | Crew | Communication failure | 40 | 0 | 3 | 4 | |
| 6,9 | Safety Systems | Structural Failure for Subdivision | 38 | 0 | 3 | 2 | |
| 3,6 | Structures | Local failure of bow | 30 | 0 | 2 | 6 | |
| 2,2 | Machinery | Lack of stabilization | 29 | 0 | 2 | 5 | |
| 8,6 | Operations | Communications equipment failure | 29 | 0 | 2 | 5 | |
| 8,2 | Operations | Navigational error in harbour | 17 | 0 | 1 | 5 | |
| 6,11 | Safety Systems | Failure of VTS | 5 | 0 | 0 | 5 | |

11.2 Failure Causes

| Type | Cause Failure | Failure Mode (Rank) |
|--|--|--|
| | Aids to navigation out of place or missing | 8.1 (51) – 8.3 (42) – 8.2 (17) |
| | Foreign objects | 8.5 (572) |
| | Multi ship | 8.3 (42) |
| Bad Design (Ship, Bridge, Navigation, Manoeuvring, Ergonomics) | Bad Design-increase strength | 6.9 (38) |
| | Complexity of navigational aids | 7.1 (450) |
| | Equipment layout | 7.4 (40) |
| | Inadequate equipment | 7.4 (40) |
| | Inappropriate design | 3.6 (30) |
| | Inappropriate mechanical/ control law design | 2.2 (29) |
| | Poor design | 7.2 (160) |
| | Poor design of bridge equipment | 8.1 (51) – 8.3 (42) – 8.2 (17) |
| | Poor design of communication equipment | 8.6 (29) |
| | Poor design of external aids to navigation | 8.1 (51) – 8.3 (42) – 8.2 (17) |
| | Poor design of maneuvering equipment | 8.5 (572) |
| | Poor design of navigational equipment | 8.4 (62) |
| | Poor functionality of bridge equipment | 8.3 (42) |
| Poor layout | 7.2 (160) | |
| Collision | Collision | 3.6 (30) |
| Communication Failure (Equipment, Internal, External, Language) | Language | 7.4 (40) |
| | Local interference | 8.6 (29) |
| | Failure of communication system | 6.13 (146) |
| | Misunderstanding/Communication (Internal and external) | 8.1 (51) – 8.3 (42) – 8.2 (17) |
| Corrosion | Corrosion | 6.9 (38) – 3.6 (30) |
| Electrical failure (Short Circuit, Overload, Loss of Electrical Generation) | Electrical failure | 8.5 (572) – 8.4 (62) – 8.6 (29) |
| | Electrical generation failure | 2.1 (40) – 2.3 (40) – 2.2 (29) |
| | Short circuit | 2.4 (40) |
| Environment (Internal, External, Abnormal Weather) | Complexity of route | 7.1 (450) |
| | Environment | 8.6 (29) |
| | Sea state | 8.5 (572) – 7.1 (450) – 8.4 (62) – 8.1 (51) – 8.3 (42) |
| | Temperature | 8.5 (572) – 8.4 (62) – 8.6 (29) |
| | Wind/Tide | 8.2 (17) |
| Excessive Loads (Unexpected, Local, Global) | Unexpected loads | 3.6 (30) – 2.2 (29) |
| Excessive Noise Levels | Background noise | 7.1 (450) – 7.4 (40) |
| Excessive Ship Motions and Accelerations | Excessive motions | 5.2 (374) |
| | Excessive ship motions | 2.2 (29) |
| Excessive Vibration | Vibration | 8.5 (572) – 7.1 (450) – 8.4 (62) – 3.6 (30) – 8.6 (29) |
| Fire | Fire | 5.2 (374) – 2.1 (40) – 2.3 (40) – 2.4 (40) – 3.6 (30) – 2.2 (29) |

| Type | Cause Failure | Failure Mode (Rank) |
|--|---|---|
| Grounding | Grounding | 3.6 (30) |
| Inadequate Maintenance | Bad Maintenance | 6.9 (38) |
| | Inadequate maintenance | 2.1 (40) |
| | Lack of maintenance | 3.6 (30) – 8.6 (29) |
| | Maintenance | 8.5 (572) – 8.4 (62) |
| | Poor maintenance of equipment | 7.2 (160) |
| Inappropriate Actions by passengers (Unintentional, Intentional) | Disruptive passengers | 7.1 (450) |
| Inappropriate Crew Action (Time Pressure, Concentration, Attention, Mistake, Fatigue, Risk Taking Behaviour, Excessive Workload, Illness, Lack of Discipline, Lack of Motivation) | Excessive workload | 7.1 (450) – 7.2 (160) – 7.4 (40) |
| | Failure of human action | 6.11 (5) |
| | Failure to secure | 3.6 (30) |
| | Fatigue | 3.6 (30) |
| | Fatigue of crew | 7.1 (450) – 7.2 (160) – 7.4 (40) |
| | Heavy workload | 7.1 (450) – 7.3 (450) – 7.2 (160) – 7.4 (40) |
| | Human communication system | 6.13 (146) |
| | Human error | 1.6 (161) |
| | Illness | 7.1 (450) – 7.3 (450) – 7.2 (160) – 7.4 (40) |
| | Inappropriate speed/heading for environmental condition | 1.6 (161) |
| | Inappropriate securing-crew responsibility | 5.2 (374) |
| | Incapacity | 8.3 (42) |
| | Lack of attention | 7.3 (450) – 7.2 (160) – 8.1 (51) – 8.3 (42) – 7.4 (40) – 8.2 (17) |
| | Lack of concentration | 7.3 (450) – 7.2 (160) – 8.1 (51) – 8.3 (42) – 7.4 (40) – 8.2 (17) |
| | Lack of discipline | 8.5 (572) – 7.1 (450) – 7.3 (450) – 7.2 (160) – 8.4 (62) – 8.1 (51) – 8.3 (42) – 7.4 (40) – 8.6 (29) – 8.2 (17) |
| | Lack of motivation | 7.3 (450) – 7.2 (160) – 7.4 (40) |
| | Overload | 2.4 (40) |
| | Poor interaction | 7.4 (40) |
| | Risk taking behavior | 8.3 (42) |
| | Route recording error | 8.4 (62) – 8.1 (51) – 8.3 (42) |
| | Time pressure | 7.1 (450) – 8.1 (51) – 8.3 (42) |
| | Unintentional openings | 6.9 (38) |
| Usage of equipment | 7.4 (40) | |

| Type | Cause Failure | Failure Mode (Rank) |
|--|---|---|
| Ingress of Water (Flooding) | Flooding | 2.4 (40) |
| | Flooding List and trim | 5.2 (374) |
| | Inappropriate securing-passengers responsibility | 5.2 (374) |
| Lack of Information (Missing/Not Available/Incorrect Aids to Operations) | Charts are out of date, not available | 8.4 (62) – 8.1 (51) – 8.2 (17) |
| | Lack of information | 7.3 (450) – 7.2 (160) – 7.4 (40) |
| | Too much information | 7.3 (450) – 7.2 (160) – 7.4 (40) |
| Lack of Knowledge (Planning, Training, Experience, Procedures, Checklist, Risk Perception, Awareness) | Lack of experience | 8.5 (572) – 8.4 (62) – 8.6 (29) – 8.1 (51) – 8.3 (42) – 8.2 (17) |
| | Lack of knowledge | 7.3 (450) – 7.2 (160) – 7.4 (40) |
| | Lack of planning | 8.1 (51) – 8.3 (42) |
| | Lack of procedures/checklist | 8.5 (572) – 8.4 (62) – 8.1 (51) – 8.3 (42) – 8.6 (29) – 8.2 (17) |
| | Lack of training | 8.5 (572) – 7.3 (450) – 7.2 (160) – 8.4 (62) – 8.1 (51) – 8.3 (42) – 7.4 (40) – 8.6 (29) – 8.2 (17) |
| | Loss of situational awareness | 8.1 (51) – 8.3 (42) – 8.2 (17) |
| | Not knowing where others are | 8.3 (42) |
| | Not knowing where you are | 8.1 (51) |
| | Risk perception | 8.3 (42) |
| | Local Structural Failure | Structural failure |
| Structural failure due to damage | | 6.9 (38) |
| Loss of Steering Control | Lack of steering capability | 1.6 (161) |
| Mechanical/Physical Failure (to any system/equipment) | Auxiliary (to electric generation) systems failure | 2.4 (40) |
| | Electronic fault | 6.11 (5) |
| | Electronic/hydraulic systems failure | 2.2 (29) |
| | Engine essential auxiliary systems failure | 2.1 (40) |
| | Engine mechanical failure | 2.1 (40) |
| | Hydraulic failure | 8.5 (572) |
| | Mechanical failure of closing devices | 3.6 (30) |
| | Mechanical failure of hand brakes, lashing gear, etc. | 5.2 (374) |
| | Mechanical/automation failure | 1.6 (161) |
| | Mechanical/electronic systems failure | 2.3 (40) |

| Type | Cause Failure | Failure Mode (Rank) |
|---|---|------------------------------------|
| Mechanical/Physical Failure (to any system/equipment) cont | Prime mover failure | 2.4 (40) |
| | Propulsion unit mechanical failure (internal/external factors) | 2.1 (40) |
| | Shafting line systems mechanical failure | 2.1 (40) |
| | Stab. System mechanical failure | 2.2 (29) |
| Poor Construction/Installation | Installation problem | 8.5 (572) - 8.4 (62) - 8.6 (29) |
| | Poor construction | 3.6 (30) |
| Poor Visibility (Internal, External) | Poor visibility | 8.1 (51) - 8.2 (17) - 8.3 (42) |
| | Visibility | 7.1 (450) |
| Reduced Operational Condition (Trim, List, Stability) | Insufficient directional stability | 1.6 (161) |
| Smoke | Smoke | 7.1 (450) |

11.3 Local Effects

| Type | Local effect | Failure mode (Rank) |
|---|---|---|
| Accelerated Path to End Event | Accelerate path to end event | 6,9 (38) |
| Broaching | Broaching | 1,6 (161) |
| Cargo (Shift, Leak of Hazardous) | Cargo shift | 2,2 (29) |
| | Large-scale cargo shift | 5,2 (374) |
| | Localized cargo shift | 5,2 (374) |
| Collision (Increased Likelihood, Minor) | Collision | 8,2 (17) - 8,6 (29) - 2,1 (40) - 7,4 (40) - 8,3 (42) - 8,1 (51) - 8,4 (62) - 7,2 (160) - 1,6 (161) - 7,1 (450) - 7,3 (450) - 8,5 (572) |
| | Increased likelihood of collision | 6,11 (5) |
| Crew Performance (Delayed, Inappropriate, Behaviour, Excessive Workload) | Poor coordination between crew/passengers | 8,6 (29) |
| | Excessive workload | 7,2 (160) - 7,1 (450) |
| Crew Behaviour (Discomfort, Deafness, Fatigue) | Fatigue of crew | 7,2 (160) - 7,1 (450) |
| Damage to Ship (Other Vessels, Other Systems) | Damage to other systems | 7,2 (160) |
| | Damage to other vessels | 8,2 (17) - 8,3 (42) - 8,5 (572) |
| | Damage to systems | 7,4 (40) - 7,1 (450) - 7,3 (450) |
| Delay (Penalty) | Delays | 8,2 (17) - 8,6 (29) - 8,3 (42) - 8,1 (51) - 8,4 (62) - 8,5 (572) |
| | Penalty | 8,2 (17) - 8,6 (29) - 8,3 (42) - 8,1 (51) - 8,4 (62) - 8,5 (572) |

| Type | Local effect | Failure mode (Rank) |
|--|--|--|
| Electrical Failure (Loss of Electrical Generation) | Loss of electrical generation | 2,3 (40) |
| Excessive Loads (Local Internal, Global) | Excessive loads | 2,2 (29) |
| Excessive Motions/Accelerations | Excessive motions/accelerations | 1,6 (161) |
| | Excessive ship motions/accelerations | 2,2 (29) |
| Fire (Delay Fire Suppression, Erroneous Use of System, Uncontrollable, Explosion) | Fire | 2,3 (40) - 2,4 (40) - 7,2 (160) - 5,2 (374) - 7,3 (450) |
| Grounding | (Grounding) | 8,6 (29) |
| | Grounding | 8,2 (17) - 2,1 (40) - 7,4 (40) - 8,1 (51) - 8,4 (62) - 7,2 (160) - 1,6 (161) - 7,1 (450) - 7,3 (450) - 8,5 (572) |
| Human Injury (Major, Minor, Increase Potential, Catastrophic, Panic, Discomfort, Deafness, Stowaways, Sea Sickness) | Discomfort of passengers | 7,4 (40) - 7,2 (160) - 7,1 (450) - 7,3 (450) - 8,2 (17) - 8,3 (42) - 8,1 (51) - 8,4 (62) - 8,5 (572) |
| | Human injury | 2,2 (29) - 2,4 (40) |
| Ingress of Water (Flooding) | Flooding | 3,6 (30) - 2,4 (40) |
| | Flooding (sea water inlet valve/ bilge system failure) | 2,3 (40) |
| | Progressive flooding | 6,9 (38) |
| Loss of Domestic Services | Loss of domestic services | 2,3 (40) |
| Loss of Propulsion | Loss of propulsion | 2,3 (40) |
| Loss of Manoeuvrability (Steering) | Loss of steering control | 2,1 (40) |
| | Loss of maneuverability | 2,4 (40) |
| Loss of Control of Vessel | Loss of control | 8,2 (17) - 7,4 (40) - 8,3 (42) - 8,1 (51) - 7,2 (160) - 7,1 (450) - 7,3 (450) - 8,5 (572) |
| Mechanical Failure (Machinery) | Machinery failure | 2,4 (40) |
| Near Miss | Near miss | 8,2 (17) - 8,6 (29) - 8,3 (42) - 8,1 (51) - 8,4 (62) - 8,5 (572) |
| Negative Passenger Behaviour (Harassment, Unintentional, Intentional, Confusion) | Confusion of passengers | 8,6 (29) |
| Smoke (Uncontrollable spread) | Speed reduction | 2,2 (29) - 2,1 (40) |
| Structural Failure (Local, Global, Permanent Damage, Loss of Global Strength/ Transverse/ Longitudinal Strength) | Structural damage | 8,2 (17) - 8,1 (51) - 8,4 (62) - 8,5 (572) |
| | Global failure | 3,6 (30) |
| Reduced Operational Condition (Trim, List, Stability) | Increased heeling/trim | 6,9 (38) |
| | Reduction in stability | 6,9 (38) |
| Rescue (Delayed, Unable) | Delayed rescue or untimely rescue | 6,13 (146) |

11.4 Relevant Causes

| Cause Failure | | Failure Mode | Rank |
|--|--|----------------------|------|
| Electrical failure (Short Circuit, Overload, Loss of Electrical Generation) | Electrical failure | 8.5 | 572 |
| | Foreign objects | 8.5 | 572 |
| Mechanical/Physical Failure (to any system/equipment) | Hydraulic failure | 8.5 | 572 |
| | Poor Construction/Installation | Installation problem | 8.5 |
| Inappropriate Crew Action (Time Pressure, Concentration, Attention, Mistake, Fatigue, Risk Taking Behaviour, Excessive Workload, Illness, Lack of Discipline, Lack of Motivation) | Lack of discipline | 8.5 | 572 |
| | Lack of Knowledge (Planning, Training, Experience, Procedures, Checklist, Risk Perception, Awareness) | Lack of experience | 8.5 |
| | Lack of procedures/checklist | 8.5 | 572 |
| | Lack of training | 8.5 | 572 |
| | Inadequate Maintenance | Maintenance | 8.5 |
| Bad Design (Ship, Bridge, Navigation, Manoeuvring, Ergonomics) | Poor design of maneuvering equipment | 8.5 | 572 |
| Environment (Internal, External, Abnormal Weather) | Sea state | 8.5 | 572 |
| Local Structural Failure | Structural failure | 8.5 | 572 |
| Environment (Internal, External, Abnormal Weather) | Temperature | 8.5 | 572 |
| Excessive Vibration | Vibration | 8.5 | 572 |

| | | | |
|--|---------------------------------|-----------|-----|
| Excessive Noise Levels | Background noise | 7.1 | 450 |
| Bad Design (Ship, Bridge, Navigation, Manoeuvring, Ergonomics) | Complexity of navigational aids | 7.1 | 450 |
| Environment (Internal, External, Abnormal Weather) | Complexity of route | 7.1 | 450 |
| Inappropriate Actions by passengers (Unintentional, Intentional) | Disruptive passengers | 7.1 | 450 |
| Inappropriate Crew Action (Time Pressure, Concentration, Attention, Mistake, Fatigue, Risk Taking Behaviour, Excessive Workload, Illness, Lack of Discipline, Lack of Motivation) | Excessive workload | 7.1 | 450 |
| | Fatigue of crew | 7.1 | 450 |
| | Heavy workload | 7.1 – 7.3 | 450 |
| | Illness | 7.1 – 7.3 | 450 |
| | Lack of attention | 7.3 | 450 |
| | Lack of concentration | 7.3 | 450 |
| | Lack of discipline | 7.1 – 7.3 | 450 |
| | Lack of motivation | 7.3 | 450 |
| Lack of Information (Missing/Not Available/Incorrect Aids to Operations) | Time pressure | 7.1 | 450 |
| | Lack of information | 7.3 | 450 |
| Lack of Knowledge (Planning, Training, Experience, Procedures, Checklist, Risk Perception, Awareness) | Too much information | 7.3 | 450 |
| | Lack of knowledge | 7.3 | 450 |
| | Lack of training | 7.3 | 450 |

| Cause Failure | | Failure Mode | Rank |
|--|------------|--------------|------|
| Environment (Internal, External, Abnormal Weather) | Sea state | 7.1 | 450 |
| Smoke | Smoke | 7.1 | 450 |
| Excessive Vibration | Vibration | 7.1 | 450 |
| Poor Visibility (Internal, External) | Visibility | 7.1 | 450 |

| | | | |
|---|---|-----|-----|
| Excessive Motions/Accelerations | Excessive motions | 5.2 | 374 |
| Fire (Delay Fire Suppression, Erroneous Use of System, Uncontrollable, Explosion) | Fire | 5.2 | 374 |
| Ingress of Water (Flooding) | Flooding List and trim | 5.2 | 374 |
| | Inappropriate securing-crew responsibility | 5.2 | 374 |
| | Inappropriate securing-passengers responsibility | 5.2 | 374 |
| Mechanical/Physical Failure (to any system/equipment) | Mechanical failure of hand brakes, lashing gear, etc. | 5.2 | 374 |

| | | | |
|---|---|-----|-----|
| Inappropriate Crew Action (Time Pressure, Concentration, Attention, Mistake, Fatigue, Risk Taking Behaviour, Excessive Workload, Illness, Lack of Discipline, Lack of Motivation) | Human error | 1.6 | 161 |
| | Inappropriate speed/heading for environmental condition | 1.6 | 161 |
| Reduced Operational Condition (Trim, List, Stability) | Insufficient directional stability | 1.6 | 161 |
| Loss of Steering Control | Lack of steering capability | 1.6 | 161 |
| Mechanical/Physical Failure (to any system/equipment) | Mechanical/automation failure | 1.6 | 161 |

| | | | |
|---|---------------------------------|------|-----|
| Inappropriate Crew Action (Time Pressure, Concentration, Attention, Mistake, Fatigue, Risk Taking Behaviour, Excessive Workload, Illness, Lack of Discipline, Lack of Motivation) | Excessive workload | 7.2 | 160 |
| | Fatigue of crew | 7.2 | 160 |
| | Heavy workload | 7.2 | 160 |
| | Illness | 7.2 | 160 |
| | Lack of attention | 7.2 | 160 |
| | Lack of concentration | 7.2 | 160 |
| | Lack of discipline | 7.2 | 160 |
| | Lack of motivation | 7.2 | 160 |
| Lack of Information (Missing/Not Available/Incorrect Aids to Operations) | Lack of information | 7.2 | 160 |
| | Too much information | 7.2 | 160 |
| Lack of Knowledge (Planning, Training, Experience, Procedures, Checklist, Risk Perception, Awareness) | Lack of knowledge | 7.2 | 160 |
| | Lack of training | 7.2 | 160 |
| Bad Design (Ship, Bridge, Navigation, Manoeuvring, Ergonomics) | Poor design | 7.2 | 160 |
| | Poor layout | 7.2 | 160 |
| Inadequate Maintenance | Poor maintenance of equipment | 7.2 | 160 |
| Communication Failure (Equipment, Internal, External, Language) | Failure of communication system | 6.13 | 146 |
| | Human communication system | 6.13 | 146 |