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HAZID for RoPax

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Title: HAZID for RoPax
Executive Summary: A HAZID report on RoPax vessels is produced based on a HAZID meeting, the risk register developed during the HAZID meeting and the consequent follow-up work and discussions on estimating probabilities and consequences of the identified hazards and their ranking. Tangible outcomes of the work reported include the risk register and the ranking of hazards. The aim of the HAZID report (SP4.2.1) is to provide input to the subsequent tasks of SP4.2 (FSA for RoPax vessels), namely the risk analysis / modelling task (SP4.2.2) and the task on cost-benefit analysis and recommendations (SP4.2.3), as well as providing input to SP4.5 (risk-based regulatory framework), the sub-projects of WP5 (risk-based design integration) and the relevant RoPax design sub-projects of WP6 (SP6.3: fast full displacement ferry, SP6.4: the 13th passenger and SP6.5: lightweight composite sandwich structure). A structured approach to identify hazards has been utilised based on studying the various operational phases of a vessel through: *identifying hazards*; *describing their failure modes*; *outlining risk reducing measures that can prevent or mitigate each hazard*; and *estimating their probabilities and consequences*, thus *ranking the hazards*. Eight operational phases were studied, namely: *loading*; *departing quay*; *transit and navigation in coastal waters*; *transit in open sea*; *arriving in port, mooring and preparing for unloading*; *unloading*; *bunkering and treatment of fluid and solid garbage*; *emergency evacuation/drills*. For the purpose of completeness of the HAZID, two further categories were considered (*other hazards* and *ordinary hazards*), the latter not scrutinized for probabilities and consequences, due to their anticipated minor impact. The risk register complied during the HAZID session forms an annex to this report. The HAZID has been conducted based on generic characteristics and features of RoPax vessels with sailing schedules between two or more ports. A total of 62 hazards have been identified in the various phases of operation considered. The top-ranked major hazards identified through the HAZID are: *failure of evacuation equipment during an emergency*; *fire in accommodation, vehicle deck and machinery spaces*; *collisions with other ships while in open sea or navigating in coastal waters;* and *grounding while navigating in coastal waters*. These hazards were evaluated as having a relatively low probability of occurrence but considered to be carrying high consequences. A number of hazards with high frequency, but with low potential consequences were also identified, forming a valuable part of the HAZID, since it demonstrated that a comprehensive range of potential incidents has been identified. The HAZID session was attended by a team being representative for the maritime industry that is involved with design/building/operation of RoPax vessels. The HAZID team comprised representatives from Color Line Marin (shipowner), FSG (shipyard), DNV (classification society), MCA (national administrator), LMG Marin and Safety at Sea (design consultants) and NAME-SSRC (university). The HAZID work facilitates a more focused risk analysis and cost-benefit assessment through pinpointing the challenges regarding design/operation of a RoPax vessel. The HAZID session is a small contribution to the overall aim of the SAFEDOR project, through being the initial step in the FSA work, which feeds into several WPs, as outlined above.

<table>
<tr><th>Work carried out by</th><th>Approved by</th></tr>
<tr><td rowspan="2">Eirik Grønstøl (LMG Marin)
Dimitris Konovessis (NAME / SSRC)

HAZID Participants, see Annex A.1</td><td>Ivan Østvik (LMG Marin)
- name of internal reviewer -
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1 Introduction

1.1 The HAZID Process

A HAZID report on RoPax vessels is produced based on a HAZID meeting, the risk register developed during the HAZID meeting and the consequent follow-up work and discussions on estimating probabilities and consequences of the identified hazards and their ranking.

The HAZID report (SP 4.2.1) forms a part-deliverable for the FSA on RoPax ships (SP4.2), where the other deliverables are on risk analysis and modeling (SP4.2.2) and cost-benefit analysis and recommendations (SP4.2.3).

A structured approach, as this is specified in the IMO FSA Guidelines [1], to identify hazards has been utilised based on studying various typical operational phases of RoPax through:

i) Identifying hazards;
ii) Describing their failure modes;
iii) Outlining risk reducing measures that can prevent or mitigate each hazard; and
iv) Analyzing their frequencies and consequences, thus ranking the hazards.

The operational phases studied were:

- Loading
- Departing quay
- Transit and navigation in coastal waters (arrival and departure)
- Transit in open sea
- Arriving in port, mooring and preparing for unloading
- Unloading
- Bunkering and treatment of fluid and solid garbage
- Emergency evacuation/drills
- Other hazards
- Ordinary hazards/hazards that do not belong to a specific operational phase

The risk register, which forms an appendix to this report, provides a self-explanatory guide to the HAZID process and presents the results from the HAZID meeting. The HAZID meeting has been conducted based on generic characteristics and features of RoPax vessels in schedule between two or more ports. The introductory part of the HAZID session was a general introduction on the FSA scope and the HAZID session.

1.2 HAZID Team

The HAZID meeting was held in Sandefjord, Norway at the Color Line Marine AS offices on 13 and 14 of June 2005. Meeting participants were the following:

Name	Company	Position
Eirik Grønstøl	LMG Marin	HAZID chairman
Dimitris Konovessis	NAME / SSRC	Moderator
Luis Guarin	Safety at Sea Ltd	Moderator
Jan Tellkamp	FSG	Naval Architect
Bjørn Lian	DNV	Principal Surveyor
Keith Tatman	MCA	FSA/Business Development Manager
Rolf Kjaer	Color Line Marine AS	New building Director
Haldor Holum	Color Line Marine AS	Safety Manager
Alan Christoffersen	Color Line Marine AS	Naval Architect/Superintendent
Petter Thuve	Color Line Marine AS	Superintendent
Ole M. Brakstad	Color Line Marine AS	QA/Safety superintendent

The HAZID meeting comprised a number of sessions corresponding to the operational phases studied. In addition to the Color Line Marine participants mentioned in the table above, three additional staff have contributed their knowledge on RoPax operations in specific sessions of the HAZID meeting (Svein Sørensen, Technical Director; Jørn Green, Captain; and Yngve Dahler, Chief Officer).

Estimation of probabilities and consequences were provided after the meeting by the following participants: LMG Marin (1), FSG (1), DNV (1), MCA (1) and Color Line Marine AS (5). Color Line Marine AS delivered one mutual estimate that express the opinion of the five of the Color Line Marine AS's representatives. The participants from NAME / SSRC and Safety at Sea Ltd. did not provide any estimations since they acted as the meeting moderators.

1.3 Related SAFEDOR Tasks

The aim of the HAZID report (SP4.2.1) is to provide input to the subsequent tasks of SP4.2 (FSA for RoPax vessels), namely the risk analysis / modelling task (SP4.2.2) and the task on cost-benefit analysis and recommendations (SP4.2.3), as well as providing input to SP4.5 (risk-based regulatory framework), the sub-projects of WP5 (risk-based design integration) and the relevant RoPax design sub-projects of WP6 (SP6.3: fast full displacement ferry, SP6.4: the 13th passenger and SP6.5: lightweight composite sandwich structure).

2 HAZID of RoPax

2.1 Objective

The objective of the study was to identify hazards that are present for a Ro-Pax in operation, so as to:

i) Provide a direct input to the subsequent risk analysis in SP4.2.2 and cost-benefit assessment in SP4.2.3.
ii) Assist relevant work in WP4, WP5 and WP6.

2.2 Scope

The scope of the HAZID exercise has been to investigate the hazards associated to the operation of RoPax vessels in schedule between two or more ports. No specific vessel was identified as an example object, but most of the practical experiences discussed during the HAZID meeting were from Color Line Marine AS ships. Also experience from Flensburger shipyard was communicated to the experts.

Both Color Line vessels and Flensburger Shipyard designs are listed in the table overleaf. This is to exemplify the ships in mind during the HAZID.

Table 1: Experience from the following ships is included in the HAZID [2,3]

Color Line Ships						
Ship	**LOA**	**Pass**	**Cars**	**Lane-meters Trailers**	**BRT**	**Built**
Prinsesse Ragnhild	205	1900	600	900	35855	1981
Kronprins Harald	166	1458	750	1160	31914	1987
Color Festival	168	2000	330	850	34314	1985
Peter Wessel	168	2100	562	750	29704	1988
Color Traveller	141	1100	420	1150	17098	1981
Christian IV	153	1860	480	700	21699	1982
Color Viking	137	1720	370	525	19763	1985
Bohus	123	1165	240	462	9149	1971
Color Fantasy	224	2750	750	1270	74500	2004

Flensburger Shipyard Designs						
Ship	**LOA**	**Pass**	**Cars**	**Lane-meters Trailers**	**Deadweight**	**Built**
Ro-Pax 3200/600	200	542	161	3158	8000	
Ro-Pax 2400/650	191	592	Total 2369		7800	
Ro-Pax 2000/450	140	2000	1440	176	1900	
Ro-Pax 1500	165	1482	-	1830	5350	

It is noted that the HAZID session focused on RoPax operation, thus hazards while at a shipyard for repair/docking are not included in the scope. Hazards to shore side personnel are neither included except from personnel that might assist during bunkering.

2.3 Main Elements of the HAZID

The main elements of the HAZID were the:

- Development of a risk register format to manage the HAZID session.
- Identification of hazards for the operation of a Ro-Pax.
- Identification of risk reducing measures that can prevent or mitigate each hazard.
- Ranking of hazards and suggest risk reducing measures in order of priority for the later risk analysis.
- Preparation of a HAZID study report as an input to the further risk analysis work in SP4.2.

2.4 SWIFT Technique

Structured What-If Checklist (SWIFT) Technique

The description in this sub-chapter is based on the IMO FSA Guidelines [1].

Definition

SWIFT is a systematic team-oriented technique for hazard identification (HAZID). It can be contrasted with other HAZID techniques as follows:

- SWIFT can be used to address systems and procedures at a high level. It considers deviations from normal operations identified by brainstorming, supported by checklists.
- Standard HAZOP (hazard and operability study) is usually applied to process flow at a detailed piping & instrumentation level, and identifies deviations from design intent by means of guide-words. It may be noted that in the marine industry the term HAZOP is often used loosely where the term HAZID (for an operation) would be more appropriate.
- FMEA (failure modes and effects analysis) addresses hardware at the level of detailed equipment items, and does not usually consider the human element.

SWIFT, like standard HAZOP, can be used to address operability issues as well as safety hazards. SWIFT may be used simply to identify hazards for subsequent quantitative evaluation, or alternatively to provide a qualitative evaluation of the hazards and to recommend further safeguards where appropriate.

SWIFT, like any group-based HAZID technique, relies on expert input from the team to identify and evaluate hazards. The SWIFT facilitator's function is to structure the discussion. The SWIFT recorder keeps an on-line record of the discussion on a standard log-sheet. There is no single standard approach to SWIFT - one of its strengths is that it is flexible, and can be modified to suit each individual application.

Procedure utilized in HAZID

- Define RoPax vessel operations. Consider each operation in sequence.
- Brainstorm possible hazards, e.g. "What if...?", "How could...?"
- List but do not discuss hazards yet. Once ideas are exhausted, use previous accident experience to check for completeness.
- Structure the hazards into a logical sequence for discussion, thus building hazard scenarios. Start with the major ones, so that escalation of initiating ones can be cross-referenced. Consider each hazard in turn.
- Consider possible consequences if the scenario occurs.
- Consider safeguards that are in place to prevent the scenario occurring.
- Consider whether additional safeguards are needed
- Record discussion in a risk register/log.
- Reconsider whether any hazards have been omitted.

Generic checklist for HAZID session

- Operating errors and other human factors, e.g. crew error, accidents (falls, trapping, trips, and access to dangerous areas), illness or injury, passenger error, abuse of equipment etc.
- Measurement errors, e.g. passenger numbers, cargo/vehicles, trim, GM, navigation etc.
- Equipment/instrumentation malfunction, e.g. structural failures, equipment failure, control system failure etc.
- Maintenance, e.g. dangerous areas, permit systems, control of modifications, mechanical handling, danger to passengers etc.
- Utility failure, e.g. power, air, fire water, communication systems, lighting etc.
- Integrity failure or loss of containment, e.g. fire, loss of containment.
- Emergency operation, e.g. evacuation, fire etc.
- External factors or influences, e.g. transport accidents, impact, other accidents on-board or near to the ship, terrorism etc.

2.5 HAZID Results

Annex A.2 contains the full risk register. It contains a total of 62 hazards where 58 hazards have been evaluated for frequencies and consequences (four ordinary hazards were also identified, but no evaluation was carried out). The following number of hazards was identified per operational phase:

- Loading (7 hazards)
- Departing quay (8 hazards)
- Transit & navigation in coastal waters (12 hazards)
- Transit in open sea (6 hazards)
- Arriving in port, mooring & preparing for unloading (6 hazards)
- Unloading (6 hazards)

- Bunkering & treatment of fluid & solid garbage (3 hazards)
- Emergency evacuation & drills (8 hazards)
- Other hazards (2 hazards)

3 Ranking of Hazards

This section details the ranking of the hazards identified and listed in the risk register. The probability index in Table 2 and consequence index in Table 3 form an 8 × 5 Risk Matrix, which is an extension of the standard 7 × 4 Risk Matrix contained in the IMO FSA Guidelines [1]. Use of the extended risk matrix was decided in a WP4 planning meeting held in Glasgow on 10 June 2005.

3.1 Probability and Consequence Indices

Table 2: Definition of probability index

PI	Probability	Definition	P (per ship year)
8	Very frequent	Likely to happen once or twice a week	100
7	Frequent	Likely to occur once per month on one ship	10
6	Probable	Likely to occur once per year on one ship	1
5	Reasonably probable	Likely to occur once per year in a fleet of 10 ships, i.e. likely to occur a few times during a ship's life	0,1
4	Little probable	Likely to occur once per year in a fleet of 100 ships, i.e. likely to occur in the total life of a ship's life	0,01
3	Remote	Likely to occur once per year in a fleet of 1000 ships, i.e. likely to occur in the total life of several similar ships	0,001
2	Very remote	Likely to occur once per year in a fleet of 10000 ships	0,0001
1	Extremely remote	Likely to occur once in the lifetime (20 years) of a world fleet of 5000 ships	0,00001

Table 3: Definition of consequence index

SI	Severity	Human safety	Environment	Costs & financial impact	Ship safety & technology	3rd party assets	Equivalent fatalities
1	Minor	Single or minor injuries	Negligible release - negligible pollution - no acute environmental or public health impact	30.000 US$	Local equipment damage (repair on board possible, downtime negligible)	Minor damage	0,01
2	Significant	Multiple or severe injuries	Minor release - minimal acute environmental or public health impact - small, but detectable environ-mental consequences	300.000 US$	Non-severe ship damage - (port stay required, downtime 1 day)	Significa nt damage	0,1
3	Severe	Single fatality or multiple severe injuries	Major release - effects on recipients - short term disruption of the ecosystem	3 mill. US$	Severe damage - (yard repair required, downtime < 1 week)	Severe damage in vicinity of ship	1
4	Catastrophic	Multiple fatalities	Severe pollution - medium-term effect on recipients - medium-term disruption of the ecosystem	30 mill. US$	Total loss (of, e.g. a medium size merchant ship)	Extensiv e damage	10
5	Disastrous	Large number of fatalities	Uncontrolled pollution - long-term effect on recipients - long-term disruption of the ecosystem	300 mill. US$	Total loss (of, e.g. a large merchant ship)	Major public interest	100

3.2 Risk Matrix

The risk matrix is used to assign risk levels to each of the combinations of probability of occurrence and consequence of events. The risk levels assigned in the table are effectively measured on a logarithmic scale:

Risk = Probability × Consequence

log (Risk) = log (Probability) + log (Consequence)

or

RI = PI + SI

Table 4: Risk matrix (RI)

PI	**Probability**	**Consequence/Severity (SI)**				
		1	**2**	**3**	**4**	**5**
		Minor	**Significant**	**Severe**	**Catastrophic**	**Disastrous**
8	Very frequent	9	10	11	12	13
7	Frequent	8	9	10	11	12
6	Probable	7	8	9	10	11
5	Reasonably probable	6	7	8	9	10
4	Little probable	5	6	7	8	9
3	Remote	4	5	6	7	8
2	Very remote	3	4	5	6	7
1	Extremely remote	2	3	4	5	6

Table 5: Abbreviations

Risk category - S	Human Safety
Risk category - E	Environmental
Risk category - C	Costs and finance
Risk category - T	Ship safety and Technology
Analysis - P	Probability (frequency)
Analysis - C	Consequence
Analysis - R	Risk

3.3 Risk Matrix

The main hazards identified are ranked in the two tables below pertaining to high-consequence hazards (Table 7) and high-frequency hazards (Table 8). The hazards are ranked by the risk index for human safety.

Table 6: Top-ranked high-consequence hazards

No	Hazard	PI	SI	RI
8-2	Failure of evacuation equipment during an emergency	4.78	3.33	**8.11**
4-1 & 3-5	Fire in accommodation while in open sea or navigating in coastal waters	3.89	4.00	**7.89**
8-3	Human error and/or lack of training during an evacuation	4.56	3.22	**7.78**
4-2 & 3-2	Collision with other ships while in open sea or navigating in coastal waters	3.22	3.78	**7.00**
6-1	Fire on vehicle deck while unloading due to accumulation of fuel spills during journey	3.33	3.22	**6.56**
4.1 & 3-4	Fire in machinery spaces while in open sea or navigating in coastal waters	3.44	3.11	**6.56**
8-7	Evacuation arrangements and plans not as effective as designed for	3.44	3.11	**6.56**
8-5	No or reduced visibility and high toxitity due to smoke during evacuation	3.00	3.33	**6.33**
8-4	Evacuating following a fire or explosion	3.11	3.00	**6.11**
3-1	Grounding while navigating in coastal waters	3.22	2.89	**6.11**

Table 8: Top-ranked high-frequency hazards

No	Hazard	PI	SI	RI
8-2	Failure of evacuation equipment during an emergency	4.78	3.33	**8.11**
1-4	Collision between a car and the vessel or between two cars during loading	6.22	1.78	**8.00**
8-3	Human error and/or lack of training during an evacuation	4.56	3.22	**7.78**
4-3	Heavy ship movements due to weather while in open sea	5.89	1.11	**7.00**
1-2	Failure of loading equipment (gangways, ramps, cranes, etc.)	4.67	2.11	**6.78**
3-11	Own wash effect while navigating in coastal waters	5	1.44	**6.44**
9-2	Passengers misbehaving	4.44	2.00	**6.44**
1-1	Relative movement ship-shore while loading	4.89	1.11	**6.00**
1-5	Fire or explosion during loading	4.33	1.56	**5.89**
3-9	Bridge equipment generating too much information while navigating in coastal waters	4.22	1.56	**5.78**

3.4 Risk Scenarios

Based on the HAZID risk register a set of scenarios can be identified. These are summarised in the table below.

Table 7 : Identified scenarios

Scenarios	**Identified Causes**
Collision	Technical errors, Power Failure, human failure, to much/little equipment on board, Disabling control during mooring,
Grounding	Technical errors, Power Failure, human failure, to much/little equipment on board
Fire onboard	Ignition of fuel leakages, electrical failure in cars, ignition in passenger areas (naked flame/cigarettes/fire in galley, laundry areas), ignition of oil spills in engine room,
Occupational accidents	Collision car-passenger, Mis-behaviour of passengers, Loss of control (of ship), Heavy ship movements due to weather

The table above describes some of the identified causes to identified scenarios. All the identified cause-consequence relations are illustrated in Annex A.3.

4 Conclusions

A HAZID report on RoPax vessels was produced based on a HAZID meeting, the risk register developed during the HAZID meeting and the consequent follow-up work and discussions on estimating probabilities and consequences of the identified hazards and their ranking.

The top-ranked major hazards identified through the HAZID are: *failure of evacuation equipment during an emergency*; *fire in accommodation, vehicle deck and machinery spaces*; *collisions with other ships while in open sea or navigating in coastal waters;* and *grounding while navigating in coastal waters*. These hazards were evaluated as having a relatively low probability of occurrence but considered to be carrying high consequences. A number of hazards with high frequency, but with low potential consequences were also identified, forming a valuable part of the HAZID, since it demonstrated that a comprehensive range of potential incidents has been identified.

This ranking provides the input for the hazards that should be analysed in subsequent tasks of the HAZID for RoPax (risk analysis and modeling, cost-benefit analysis and recommendations). The HAZID is considered to have met its aim and scope, since a comprehensive array of hazards has been identified and ranked and also the hazards identified as requiring attention are those expected.

The HAZID report also provides a valuable input to the risk-based design process to be conducted in various other relevant SAFEDOR tasks, in terms of highlighting focus areas in the design process. More specific knowledge/data on the present hazards will be further developed through the subsequent risk analysis, and the FSA reporting.

5 References

[1] International Maritime Organisation (IMO): Guidelines for Formal Safety Assessment (FSA for use in the IMO rule making process, MSC/Cric. 1023 (MEPC/Circ. 392)

[2] Color Line’s web site: http://www.colorline.no/servlets/page?section=1008

[3] Flensburger Schiffbau-Gesellschaft’s web site: http://www.fsg-ship.de

Annex

A.1 HAZID Participants: Short CVs

Jan Tellkamp, FSG

Jan Tellkamp started his career in 1985 as a shipwright at Husum Shipyard, Germany. After working for a couple of years at that yard, he studied Naval Architecture at University of Hamburg (Diplom Ingenieur). His main course was "Operations Research" given by Prof. Odo Krappinger.
He joined the R&D group at FSG directly from the University in 1996. In the first years, he was mainly working on hydrodynamics, eg propeller calculations or seakeeping calculations developing and using tools based on direct physics.

With the EU funded FP5 project NEREUS, he joined the field of Maritime Risk Assessment. In the past years Mr Tellkamp had a number of publications on Decision Making, Risk, etc in high-level conferences, eg The 6th International Workshop on Ship Stability, IMDC03, STAB03.
At FSG he is now responsible for Risk Management at FSG from a research perspective. For the SAFEDOR IP, he is the coordinator for FSG. Within SAFEDOR, he leads a subproject on risk based ship design. Besides SAFEDOR, he initiated a FP6 STREP on decision making in severe weather conditions, ADOPT, which has started recently.

In addition to the responsibilities related to research, Mr Tellkamp is involved in a key position to all risk related activities at FSG. To support his involvement in Risk Management, he was given a DNV training on "Marine Risk Assessment" in the beginning of 2005. Earlier, he underwent a training on "Practical Risk Assessment for Shipping", given by DNV in 2001.

Eirik Grønstøl, LMG Marin

Eirik Grønstøl graduated in 2001 as a Fire engineer with Stord/Haugesund College. Thereafter he proceeded to the College of Stavanger for a master degree in offshore safety. His Master thesis was written in the autumn of 2003 at LMG Marin. When the Master thesis was delivered at the summer 2003 he was offered a position at LMG Marin as a project engineer.

Since the summer of 2003 Mr. Grønstøl has been occupied with various tasks reaching from ISPS, ISM to Fire engineering. Besides Safedor Mr. Grønstøl also has contributed to the EU funded research project LOGBASED.

Bjørn Lian, Det Norske Veritas

Bjørn Lian was graduated from Oslo Technical - Maritime School as a ship engineer in 1980. Just after his graduation he started working as a trainee for DNV at Høvik. Since then he has held several positions within the DNV Company, including work in Newcastle, Korea and Japan. He has held positions such as Surveyor, Approval Engineer and Project Manager. Bjørn has been involved in a wide range of tasks varying from plan approval for fire safety, to surveying and newbuilding supervision. He has also contributed to FSA study and development of new class rules for Compressed Natural Gas carriers. Support to external and internal customers concerning maritime fire safety issues for both newbuildings and ships in operation.

Keith Tatman, Maritime and Coastguard Agency

An operations specialist and risk and acquisition management consultant, with extensive team-working and leadership experience. Adaptable, used to diversity, and mobile. Widely travelled, socially alert and culturally aware. Fluent French. Good grasp of IT applications. Broad maritime and aviation operations practice recently strengthened through commercial experience and awareness, recent procurement achievements and formal management qualifications. Ex-Commander Royal Navy (35 years) and now Head of Risk, Analysis, Prevention, Corporate Governance and Formal Safety Assessment at the Maritime and Coastguard Agency, via two excellent years with RPS Consultants Ltd as a Managing and Principal Consultant. OGC Gateway Review High Risk Project Team Leader, and EFQM Public Sector assessor.

Dr Luis Guarin, Safety at Sea Ltd.

Luis Guarin currently works as Project Manager for the Glasgow-based consulting company Safety at Sea Ltd. He holds a PhD in Naval Architecture (University of Strathclyde, Glasgow, UK) and a MEng in Ship Design and Construction (Technical University of Gdansk, Poland). His areas of expertise, gained over the past 7 years working at the University of Strathclyde and Safety At Sea Ltd, include risk analysis, fire safety, ship evacuation, seakeeping and damage stability. He has been responsible for carrying out a number of FSA studies on structural integrity of bulk carriers and oil tankers navigation in the West of Scotland. In the last two years, he has also being involved in developing design specifications for cruise vessels, in which a significant emphasis has been given to fire and flooding safety. Within the company, he is also actively involved in research and development undertaken in cooperation with the Ship Stability Research Centre (Safety At Sea's sister organisation). In relation to the latter, he is responsible for the development of an integrated fire safety assessment system involving fire engineering calculation and advanced evacuation simulation tools, a development he initiated under the Marie Curie Fellowship Programme.

Dr Dimitris Konovessis, NA-ME / SSRC

Dimitris Konovessis is a Lecturer at the Department of Naval Architecture and Marine Engineering of the Universities of Glasgow and Strathclyde. He holds an MEng on Naval Architecture and Marine Engineering from the National Technical University of Athens (1995) and a PhD on risk-based ship design from the University of Strathclyde (2001). From 1997 he has been employed by the Ship Stability Research Centre at the Universities of Glasgow and Strathclyde, participating as researcher and principal investigator in a number of research projects focusing on the development of the Design for Safety methodology and its implementation, notably SAFER EURORO, NEREUS, ROROPROB, Safety @ Speed, InterSHIP, and currently on SAFEDOR and LOGBASED. He has also participated in a number of industrial projects, namely upgrading of existing Ro-Pax vessels to advanced damage stability and survivability standards (SOLAS '90, Stockholm Agreement standards and the probabilistic framework), impact assessment study on the implementation of the Stockholm Agreement at South European waters and risk analysis studies on the carriage of dangerous goods by small open-deck Ro-Ro ferries. He has published his work in renowned scientific journals and international conferences.

Rolf Kjær, Color Line Marine AS Marine AS

Rolf Kjær is Managing Director of Color Line Marine AS Marine AS in Sandefjord. Color Line Marine AS Marine is the technical/maritime company of Color Line Marine AS and as such he is the Technical Director of Color Line Marine AS. Rolf Kjær took his degree in Naval Architecture at the University of Strathclyde, Glasgow in 1962. He has worked for Det norske Veritas as a Ship Surveyor, Shipping Research Services with projects in various countries, Framnæs Mek. Værksted as a Chief Naval Architect. In 1987 he joined Det Nordenfjeldske Dampskibsselskap, Trondheim as Vice President and in 1989 he became Managing Director of a Ship Management Company within the Skaugen Group of shipping companies which was later to become S & C Marine and subsequently Color Line Marine AS Marine. Rolf Kjær is the Chairman of Passenger Ship Group within Norwegian Shipowners Association and is also member of NORDKOMPASS – Nordic Committee of Passenger Ships. Participation in IMO meetings as member of Norwegian delegation. Speaker at a number of conferences focusing on Safety of Ro/Ro Passenger vessels.

Alan Christoffersen, Senior Design Engineer at Color Line Marine AS Marine AS since the year 2000. Has long experience with damage stability studies on Ro-Ro ferries.

Haldor Holum, For the last ten years Holum has been employed by Color Line Marine AS Marine as QA/Safety Manager. Has long experience from management and operation of Ro-Pax vessels. Holum has also held positions as Platform Manager at submersible flotel and drilling rigs.

Petter Thuve, Hold the position as Technical surveyor at Color Line Marine AS Marine As. Has long experience as chief engineer on Ro-Pax vessels.

Ole M. Brakstad, Safety and QA inspector at Color Line Marine AS Marine. Has earlier experience from the Norwegian Maritime Directorate and as Captain on several cruise liners.

A.2 Risk Register

LMG Marin on behalf of SAFEDOR SP4.2
Risk Register for RoPax FSA

Modified: 01.08.05
By: EGR

No	Hazard	Risk category S	E	C	T	R	Cause	Consequence	RCO measures through design or ISM	Category	Analysis (average score) P	C	R	Additional RCO / Actions
1 - Loading														
1-1	Ship movement - relative movement ship-shore	x		x	x		- Weather, waves, tidal movement, - Movement caused by passing traffic in some ports.	Generally no consequence in most ports. Gangway and ramp connection may be damaged or disconnected. Mooring lines may break. Delay in schedule.	ISM (Risk assessment),	S	4,89	1,11	6,00	Mooring, Facilities (Quay area), Self-Tention vinches, tentional alarm, speed control by port authorities, good weather forcasting, local knowledge of tide and currents, availability of tugs, Stop loading (activity), Stop vehicles and foot passengers, Sto
										C	4,89	1,78	6,67	
										T	4,56	1,56	6,11	
1-2	Failure of loading equippment - gangways, ramps, cranes, etc.	x		x	x		- Ship movement. - Human failure (Wrong operation) - Technical failure.	Ramps and gangways may be damaged or disconnected. Damage to cars and passenger.	Port state control, Enhanced EU-inspection of RO-RO ferries, ISM (Maintenance), Class rules,	S	4,67	2,11	6,78	Aux. Power for hydraulic systems, Maintenance, Good design (fit for purpose) and manufacture, good operation of equipment by user, Longer and more flexible ramps, Improved ship/shore interface in respect of loading ramps and safe mooring.
										C	4,67	1,22	5,89	
										T	4,67	1,00	5,67	
1-3	Trim/List due to cargo handling			x	x		- Human error (Asymmetric loading is typical with heavy trailers). - Wrong shifting of ballast.	Generally no consequence. Bad fuel economy. Damage to ramp.	Heeling tanks, ISM (Risk Assessment), Loading computer, stability manual,	C	2,67	1,00	3,67	Heeling tanks, experienced crew, know-how about cargo/control of weight of cargo (most important for smaller vessels),
										T	2,78	1,22	4,00	
1-4	Collision - Car-ship and car-car, personnel risks, crew, passenger	x		x		x	- Stressed drivers due to new and narrow surroundings. Drivers also rushing to get on board in a hurry. - Condense on car window reducing view. - Bad design (Step ramp results in damaged exhaust.)	Personnel risks. Hitting passenger and driver. Damage to cars (exhaust, car doors, etc.)	ISM (Risk assessment), walkways,	S	6,22	1,78	8,00	Proper crew instructions to drivers, signage, lighting, good "car environment", design of car bredth
										C	6,11	1,78	7,89	
1-5	Fire/Explosion	x		x		x	- Fire starting in car because of hot breaks, internal electric failure and petrol leakage, - Fire starting in refrigerating units connected to the ships electrical system		Detectors, Fire extinguishing, Restriction for size of cargo area, Structural fire integrity, Dangerous cargo in own area, control of ventilation, rules for electrical equipment, ISM requirements for training in emergency situations, No-smoking at car dec	S	4,33	1,56	5,89	Campers checked for gas "containers" before comming on board. Ventilating car deck as required. Gas detectors??? No smoking on car deck
										C	4,33	1,56	5,89	
1-6	Petrol leakage	x		x		x	- Leakage from cars	Fire, explosion.	Restrictions on ignition sources. Open flame, electrical, Ventilation,	S	3,56	1,22	4,78	
										C	3,44	1,22	4,67	
1-7	Moving vehicles	x		x		x	- Poor lashing of vehicles, - Lack of handbrakes, - Cargo within vehicles is not sufficiently lashed.	Damaged cars. Injuries to crew and passengers.	Lashing, Cargo Securing Manual, Signage	S	4,00	1,22	5,22	
										C	3,89	1,22	5,11	

No	Hazard	S	E	C	T	R	Cause	Consequence	RCO measures through design or ISM	Category	P	C	R	Additional RCO / Actions
2 - Departing quay														
2-1	Collision with other ships/quay	x		x	x	x	- Current and wind. - Inadequate port control. - Poor knowledge of pleasure crafts/Sail ships may lose wind and then speed. - Weather conditions and swell.	Collision with smaller and bigger vessels. Delay. Repairs. Flooding of departments due to hull damage. Collision with other ships may cause a fire.	AIS, Harbour control, three blasts before leaving quay, watch keeping, Port control,	S C T	2,44 2,44 2,33	2,33 2,44 2,33	4,78 4,89 4,67	Three blasts before you og . Cameras, crew at stern to tell captain of smaller vessels. Traffic control, AIS, Weather limitations. Use of tugs.
2-2	Grounding		x	x	x	x	- Current and wind - Swell and bad weather. - Collision avoidance.	Delay. Repairs. Flooding of departments due to hull damage. Evacuation of personnel.	Updated Maps/Charts, Availability of tugs, passage planning, Echo sounders, ISM (Familiarization), Pilot rules, Navigational authorities,	E C T	2,67 2,78 2,78	1,78 2,11 2,00	4,44 4,89 4,78	Knowledge of port condition in design does lead to adequat maneuvering performance.
2-3	Ship not ready for departure			x		x	- Communication problems - Ships physical defective/Technical problems. - Human factors - Black outs - Failure to follow procedures	Delay. Ship is not in its right configuration.	ISM. Testing of equipment. DPA - Captain relationship (Culture and understanding). Cameras, Indication on water tight doors, Procedures,	C	5,00	1,00	**6,00**	
2-4	Loss of control			x	x		- Technical failure - Weather conditions - Human error - Software failure.	Collision, grounding,	Hardwiring of some critical equipment (emergency steering gear), Maintenance, General redundancy, Two people on bridge during navigation, alarms,	S E C T	2,56 2,56 2,56 2,44	1,89 1,78 1,89 1,78	4,44 4,33 4,44 4,22	Hardwiring important equipment.
2-5	Fire/Explosion	x		x		x			Detectors, Fire extinguishing, Restriction for size of cargo area, Structural fire integrity, Dangerous cargo in own area, control of ventilation, rules for electrical equipment, ISM requirements for training in emergency situations, No-smoking at car dec	S C	3,22 3,22	1,67 1,67	4,89 4,89	
2-6	Excessive atmospheric emissions		x	x		x	- Economical cause as use of heavy oil is cheaper that more environmentally friendly fuel. - Starting of cold engines (especially after rain) (Passenger complain due to soot.)	Companys reputation, Fines from government, Costs in connection with equipment changes - filters,	MARPOL Annex 6, Flag administration (port state requirements).	E C	4,67 3,78	1,22 1,67	**5,89** **5,44**	
2-7	Noise		x	x		x	Noise from on board machinery. (probability for complains from residents)	Reputation. Economic consequences to change equipment. Complains from potential customers.	Port state and flag administrations.	E C	3,56 3,56	1,00 1,00	4,56 4,56	
2-8	Unable to close bow door and visor.			x		x	Damage to door by waves.	Delay.	Class rules.	C	4,67	1,89	**6,56**	

No	Hazard	Risk category S	E	C	T	R	Cause	Consequence	RCO measures through design or ISM	Category	Analysis (average score) P	C	R	Additional RCO / Actions
3 - Transit and navigation in coastal waters (Arrival and departure)														
3-1	Grounding (Probability - see above)	x	x	x	x	x	Current and wind. - Swell and bad weather. - Human error/Interaction between pilot and Captain. - Navigation equipment failure. - Collision avoidance. - Propulsion of steering failure (technical) during acceleration or deacceleration.	Delay. Repairs. Flooding of departments due to hull damage. Damage to and evacuation of personnel. Damaged personnel due to moving objects (piano, tv etc).	SOLAS, STCW, ISM (emergency preparedness and familiarization) , Pilots, Familiarization, IMO requirements on maneuverability, Charting and survey, navigational marks, Echo sounder, Redundancy of critical equipment,	S	3,22	2,89	6,11	SOLAS 5-15 Bridge design,
										E	3,22	2,89	6,11	
										C	3,22	3,00	6,22	
										T	3,22	3,00	6,22	
3-2	Collision with ships	x	x	x	x	x	- Crossing traffic in certain areas - Collision avoidance - Technical and Human failure. - Improper training on use of bridge equipment. Maybe to much equipment on bridge. - Communication problems - Sometimes hard to reach the other ship on radio. - L	Flooding of departments due to hull damage. Evacuation. Fire. personnel damage. Damaged personnel due to moving objects (piano, tv etc.)	SOLAS, STCW, ISM, COLREG, Pilots, Familiarization, IMO requirements on maneuverability navigational marks, Echo sounder, Redundancy of critical equipment, AIS,	S	3,22	3,78	7,00	Watch-one bridge design. SOLAS 5-15 Bridge design,
										E	3,22	3,00	6,22	
										C	3,33	3,11	6,44	
										T	3,33	3,00	6,33	
3-3	Collision with fixed objects	x	x	x	x	x	- Offshore installation causing magnetic interference? - Loss of control, - Technical failure, - Human error, - bad navigational information. - Incorrect information. - buoy out of position.	Flooding of departments due to hull damage. Evacuation. Fire. personnel damage. Damaged personnel due to moving objects (piano, tv etc.). Damage to other object.	SOLAS, STCW, ISM (emergency preparedness and familiarization) , Pilots, Familiarization, IMO requirements on maneuverability Charting and survey, navigational marks, Echo sounder, Redundancy of critical equipment,	S	2,22	2,22	4,44	
										E	2,22	2,00	4,22	
										C	2,33	2,22	4,56	
										T	2,22	2,11	4,33	
3-4	Fire/Explosion in machinery spaces	x		x	x	x	Fuel and oil leakage, technical failure, hot surfaces, Engineroom design. Hydraulic systems in casing.	Loss of maneuverability Loss of power, Much smoke may lead to panic. Damage to crewmembers. Flooding of car deck/departments due to fire extinguishing and closed scuppers. CO2 may restrict access to ECR. Spread to other areas. Cost. personnel injuries.	Detectors, Shutdown systems, Fire flaps, alarms, Extinguishing systems, ISM (Training), Structural fire integrity, watch keeping, Shielding of fuel pipes,	S	3,44	3,11	6,56	
										C	3,44	3,33	6,78	
										T	3,33	3,11	6,44	
3-5	Fire in accomodation	x		x	x	x	- Use of naked flame/Sigarettes in waste bins, - laundry activities, - fire in galley/pantry. - Portable electrical equipment.	Move people away from fire location. Reputation. Evacuation. Loss of lives/injuries. More complex problem for the master and crew. Repairs. Interuption of service. Big organization for preparing evacuation. Stability issues due to fire fighting. Large fre	Fire zones (Structural fire integrity), ISM, Detectors, Fire fighting equipment and extinguishers, Requirements for materials, Ventilation, watch keeping, Design of easy escape routes (no dead end corridors),	S	3,89	4,00	7,89	
										C	3,78	3,22	7,00	
										T	3,78	3,11	6,89	

No	Hazard	Risk category S	E	C	T	R	Cause	Consequence	RCO measures through design or ISM	Category	Analysis (average score) P	C	R	Additional RCO / Actions
3-6	Fire in cargo area	x		x	x	x	- Electrical problems in vehicles - Hull vibration may cause electrical problems on cars or connection between ship and trailers(refrigeration plants). - Gas/Petrol leakage. - Electric magnetism. - Open fire (from eg. smoking watchman.)	Free surfaces. Fast fire escalation. Smoke ingress in accomodation. Huge potential if not controled. Injuries to crew members. Cost. Reputation.	Fire zones (Structural fire integrity), ISM, Detectors, Fire fighting equipment and extinguishers, Requirements for materials, Ventilation, watch keeping,	S	3,22	2,22	5,44	
										C	3,22	3,11	6,33	
										T	3,11	2,44	5,56	
3-7	Loss of control and instrumentation	x	x	x	x	x	- Technical failure (equipment failure and power failure). Eg. Loss of cooling water, Mechanical damage, - Human error.(including Fatigue) - Software error	Collision, Grounding. personnel injuries.	Maintenance, redundancy, ISM (Identification of critical systems, training, drills), Rules and regulations, Minimum manning certification (to prevent fatigue), Class requirements, IEC, ISO	S	3,22	2,78	6,00	Design. Human - Machine interface,
										E	3,22	2,11	5,33	
										C	3,22	2,44	5,67	
										T	3,11	2,33	5,44	
3-8	Power failure.	x		x			Sediments in fuel. - Water in fuel.	Shifting of cargo. Loss of C&I.	Redundancy of filter, size of filters, measures to prevent ingress of water in fuel tanks, maintenance, separators, fuel quality requirements from the manufactor of main engine, MARPOL,	S	3,67	1,78	5,44	Fuel survey program by classes. Fuel sampling.
										C	3,44	1,89	5,33	
3-9	To much equipment on bridge.	x			x		Human error in design and in operation.	Hard for captain to receive all the available information.	STCW, SOLAS 5-15, Class requirements,	S	4,22	1,56	5,78	
										T	4,22	1,78	6,00	
3-10	Inadequate display of information.	x			x		Human error in design and in operation.	Hard for captain to receive all the available information.	SOLAS (minimum standards for ECDIS /ARPA)	S	3,67	1,11	4,78	
										T	3,67	1,11	4,78	
3-11	Big waves created by the ship itself	x		x		x	- Bad design. - Speed.	Threat to kids and dogs at the beaches. Damage to quays and smaller boats. Damage to environment.	speed restrictions, port control, use of favourable designs,	S	5,00	1,44	6,44	
										C	4,33	1,11	5,44	
3-12	Lost effect of stabilizer	x				x	- Low speed or equipment failure, - poor design of system, - poor specification of system performance,	Excessive rolling, Damage to cargo, ship and personnel. Shifting of cargo, Seasickness,	Design - acceptable rolling,	S	2,67	1,22	3,89	

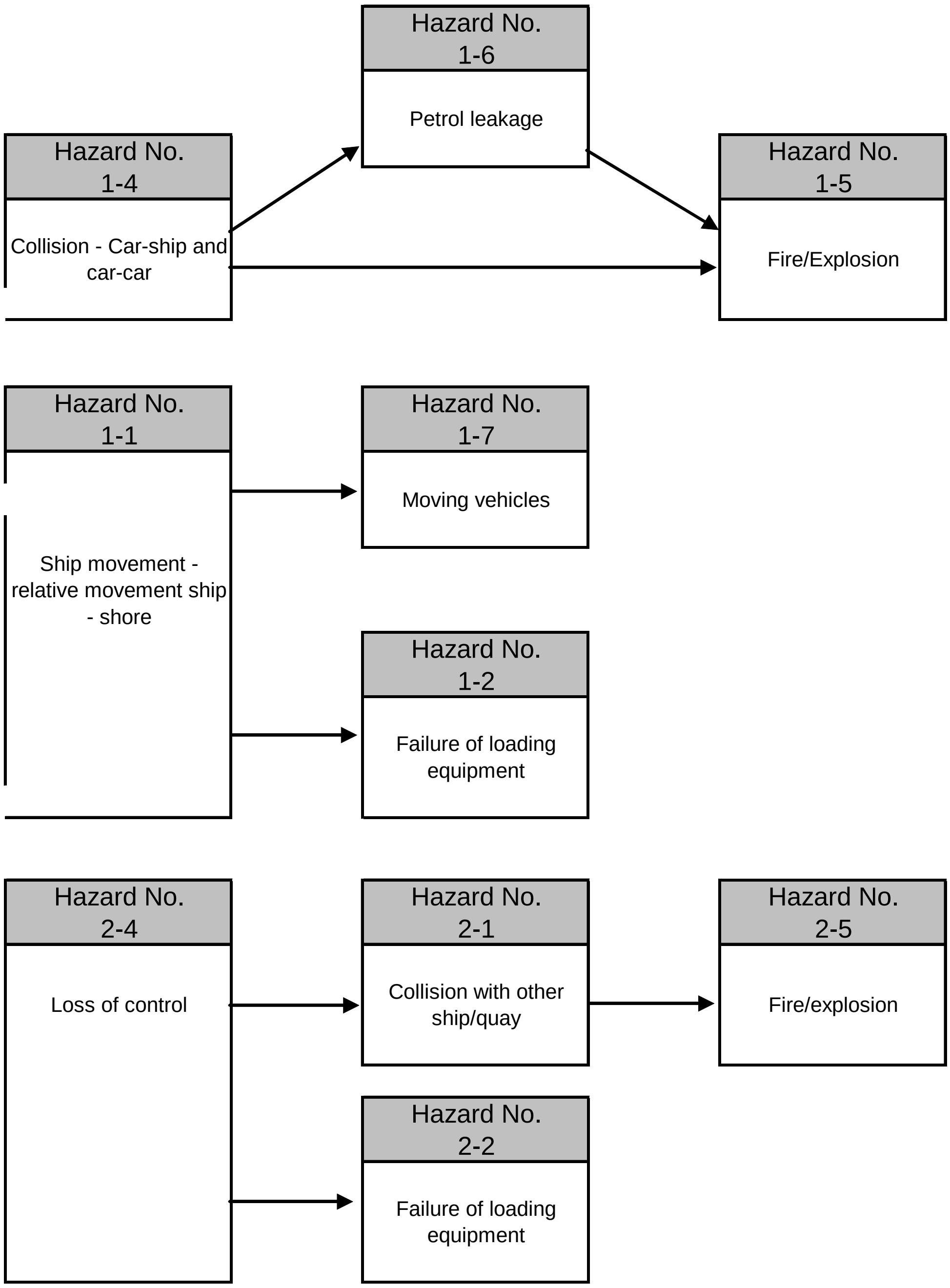
No	Hazard	Risk category S	E	C	T	R	Cause	Consequence	RCO measures through design or ISM	Category	P	C	R	Additional RCO / Actions
4 - Transit in open sea														
4-1	Fire/Explosion	x		x	x	x		Covered by item 3-4 to 3-6		S				
										C				
										T				
4-2	Collision with other ships	x	x	x	x	x	TSS	Covered by item 3-2		S				
										E				
										C				
										T				
4-3	Heavy ship movements due to weather	x			x	x	- wrong speed and course	personnel damage, damage to ship and cargo.	Safety construction certificate and class rules, routing, weather forecasting, Systems to prevent tripping when propeller is above water,	S	5,89	1,11	**7,00**	
										T	5,78	1,11	**6,89**	
4-4	Structural failure of steel construction	x	x	x	x	x	- Severe weather , - high speed, - poor maintenance and survey - poor design.	Ingress of water. Loss of vessel.	Safety construction certificate and class rules, Loadline, survey, port state control,	S	1,44	3,22	4,67	
										E	1,44	3,11	4,56	
										C	1,44	3,44	4,89	
										T	1,44	3,22	4,67	
4-5	Smashing windows	x		x	x	x	- Severe weather, - Wrong speed,	Ingress of water, black out	ISO standards, class rules,	S	2,22	2,22	4,44	
										C	2,22	2,22	4,44	
										T	2,56	2,22	4,78	
4-6	Structural damage			x	x		- Severe weather (fore part, slamming), high speed, -poor maintenance, - poor survey, - poor design.	Dending, buckling. Repair required.	Class rules, Survey and inspection,	C	3,89	2,44	**6,33**	
										T	3,78	2,00	**5,78**	
5 - Arriving in port, mooring and preparing for unloading														
5-1	Fire/Explosion							Covered by item 3-4 to 3-6		S				
										E				
										C				
										T				
5-2	To early opening bow doors	x			x	x	- Human error. - Bad design. - "Faulty" procedures	- Scoop water, - capsize,	SOLAS regulations (Sub divisional criteria), STCW, ISM (Critical operation).	S	3,22	1,89	**5,11**	Better information flow between designer and operator.
										T	2,89	1,78	4,67	

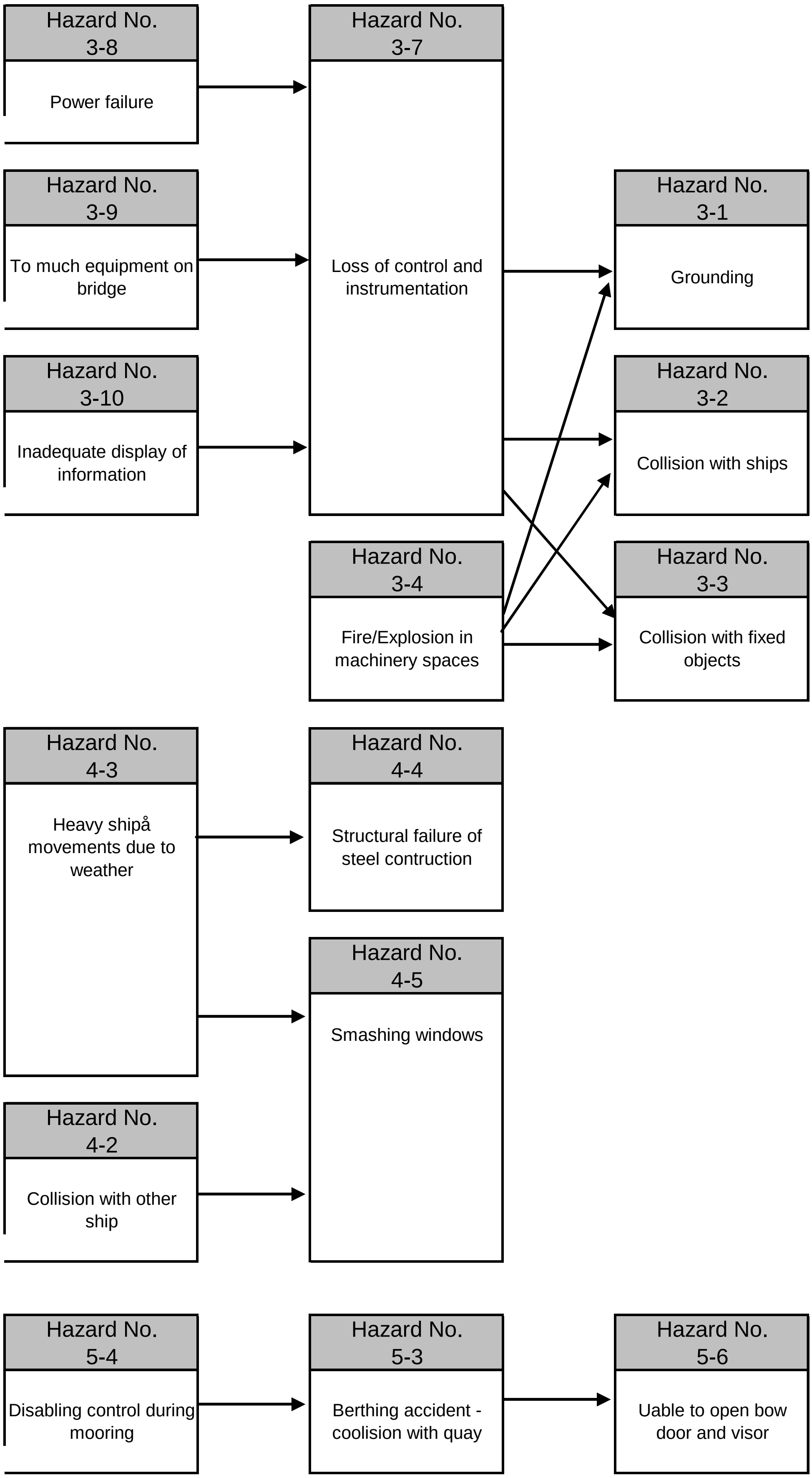
No	Hazard	Risk category S	E	C	T	R	Cause	Consequence	RCO measures through design or ISM	Analysis (average score) Category	P	C	R	Additional RCO / Actions
5-3	Berthing accidents - collision with quay.			x	x	x	- Failure of technical eq. - Human error (includes wrong speed) - Weather conditions.	Damage to personnel, vessel and cargo. Delay in schedule. Damage to quay.	Low speed, available tugs, pilots/exemptions, rules for control systems, port control	C T	4,33 4,00	2,67 2,44	7,00 6,44	
5-4	Disabling control during mooring. Mooring ropes in the water.				x	x	- Malfunction of winches. - Bad communication - Stressed operation.	Mooring ropes in thruster.	Maintenance, Crew training and information,	T	4,78	1,22	6,00	Ship-shore interface
5-5	Picking up the pilot.	x					- Swell and speed.	personnel injuries.	SOLAS requirements for embarkation equipment, National standards (Flag state),	S	3,00	1,89	4,89	
5-6	Unable to open bow-door and visor			x		x	- Damage to door by waves.	Delay.	Class rules.	C	5,11	2,44	7,56	
6 - Unloading														
6-1	Fire/Explosion	x		x	x	x	- Spill from cars accumulated during journey	High congestion of people on deck. Damage to cars, ship and passsengers.		S C T	3,33 3,33 3,22	3,22 3,11 2,78	6,56 6,44 6,00	
6-2	Collision car-car, car-ship, car-passenger							Covered by item 1-4		S E C T				
6-3	Car break-downs			x				Stressfull situation for other passengers. Delay in schedule.		C	6,33	1,56	7,89	
6-4	Ship movement	x				x	Mooring failure.	Ramp loosing contact with quay.		S	3,44	1,89	5,33	

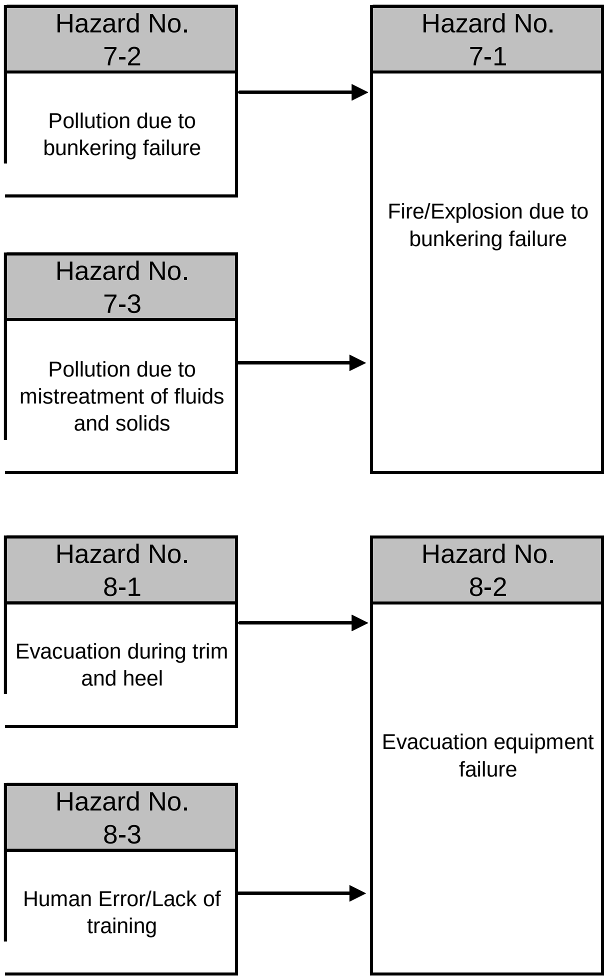
No	Hazard	Risk category S	E	C	T	R	Cause	Consequence	RCO measures through design or ISM	Category	Analysis (average score) P	C	R	Additional RCO / Actions
6-5	Failure of loading equipment - gangways, ramps, cranes, etc.							Covered by item under "1-Loading".		S	3,67	2,11	5,78	
										C	3,67	1,78	5,44	
										T	0,33	0,11	0,44	
6-6	Pollution due to cargo spill		x	x		x	- Physical impact to cargo	Smaller spills		E	2,67	2,11	4,78	
										C	2,67	2,00	4,67	
7 - Bunkering and treatment of fluid and solid garbage														
7-1	Fire/Explosion due to bunkering failure.	x	x	x	x	x	Electical "transmitters" eg. Mobile phones or ambulances. Human error. Fatigue for personnel.	Damage to ship and crew. Delay. Reputation.	Bunkers station is segregated from the car deck. ISM (critical operation), MARPOL Annex 1, Port state regulations/controls, Contingency plans,	S	2,56	2,78	5,33	
										E	2,00	2,78	4,78	
										C	2,00	2,78	4,78	
										T	1,89	2,44	4,33	
7-2	Pollution due to bunkering failure		x	x		x	Broken hoses, connection, poorly maintained. Over filling. Human error Poor design. Ship-shore communication. Equipment failure.	Fines for pollution. Reputation. Environmental cons.	MARPOL, Port state regulations,	S	4,11	1,44	5,56	
										E	4,11	2,78	6,89	
										C	4,11	2,78	6,89	
										T	4,00	1,56	5,56	
7-3	Pollution due to mistreatment of fluids and solids.		x	x		x	Human error Equipment failure. (Broken hoses, connection, poorly maintained.)	Fines. Reputation. personnel Injuries.Health hazards. Environmental cons.	MARPOL, Port state regulations,	E	4,78	2,56	7,33	
										C	4,44	2,56	7,00	
8 - Emergency Evacuation/Drills														
8-1	Evacuation during trim and heel.	x			x	x	Difficulties in launching lifeboat and MES. Difficult mastering equipment. Slow reaction/awareness time by passengers. Inappropirate assistance to passenger from crew. Lack of plans, training and experience.	Loss of lives. personnel injuries. Longer evacuation time.	ISM, SOLAS, STCW, Flag state regulations,	S	3,00	2,22	5,22	
										T	2,89	2,22	5,11	
8-2	Evacuation Equipment failure	x			x	x	Poor maintenance Lack of training. Faulty life-rafts/poor design. Conditions to extreme. Human error.	Larger number of injuries. Longer time to evacuate. Lifeboats falling down during operation.	MED (EU), Maintenance, training,	S	4,78	3,33	8,11	
										T	4,56	1,89	6,44	
8-3	Human error/Lack of training.	x			x	x	Company policy. Language/Communication. Error and violations. Rules and regulations require "irrelevant" training (eg. Training with other equipment that will be used on board). Stress.	Larger number of injuries. Longer time to evacuate. Lifeboats falling down during operation.	STCW, ISM,	S	4,56	3,22	7,78	
										T	4,56	2,67	7,22	

No	Hazard	Risk category S	E	C	T	R	Cause	Consequence	RCO measures through design or ISM	Category	Analysis (average score) P	C	R	Additional RCO / Actions
8-4	Evacuation during fire and explosion	x			x	x	Escape routes may be unavailable due to smoke and heat. (P: Less than fire/explosion)	Large demand for crew activities (fifi and evacuation).	ISM (critical operation), Port state regulations/controls, Contingency plans, Use of approved materials only, signage, drills,	S	3,11	3,00	6,11	
										T	3,00	2,00	5,00	
8-5	Lack of or reduced visibility and high toxicity due to smoke.	x			x	x	Materials on board may be toxic. Fire doors are not closed. Lost control of fire. (P: Same as fire)	Life saving appliances not accessible. Reduced possibilities to receive help from helicopters. Escape routes blocked.	Personal equipment, Emergency Escape Breathing Devices, Low location lighting, fifi equipment, Use of approved materials, drills, ventilation control,	S	3,00	3,33	6,33	
										T	3,00	2,67	5,67	
8-6	Lack of information and control	x			x	x	Human failure.	Extended evacuation time. More injuries.	ISM, Fire control plan, Emergency preparedness, SOLAS (training manual/fire operational booklet)	S	2,44	1,67	4,11	
										T	2,33	1,33	3,67	
8-7	Evacuation calculation and ship arrangement do not coherent.	x				x	Conversions. Human error in design and approval. Lack of multidicipline operation during design.	Extent of evacuation time. More injuries. Buildt in bottlenecks in evacuation. Escape plans that do not work in real-life.	Class approval, SOLAS,	S	3,44	3,11	6,56	Better communication between architect and personnel doing the calculation.
										E	3,13	1,75	4,88	
										C	3,13	2,00	5,13	
										T	3,13	1,75	4,88	
8-8	Operation of the FRC in heavy weather from ropax by ordinary seamen.	x					Rules and regulations. Irrational rules. (2 accident in good weather)	Not possible to launch or pick up FRC in bad weather.	Sound judgement by the master.	S	3,33	2,89	6,22	Irrational SOLAS rules. Suitable equipment for picking up personnel in rough sea is missing.
										E	2,75	1,00	3,75	
										C	2,88	1,88	4,75	
										T	2,75	1,75	4,50	
9 - Other hazards														
9-1	Irrational behaviour by crew members	x					- Lack of training, - Stress, - Fatigue, - Personnel in mental unbalance - Communication problems, (3 events last year)	Wrong operation of equipment,		S	3,67	2,22	5,89	
										E	3,38	2,13	5,50	
										C	3,38	2,25	5,63	
										T	3,38	2,13	5,50	
9-2	Mis-behavior by passengers	x				x	- Human nature, - alcohol, - "hooligans", - delays, - industrial actions,	- Loss of reputatiton, '- delays, '- personnel injuries, '- damaged equipment.	ISPS, Design prevents passengers to get access to critical equipment/areas.	S	4,44	2,00	6,44	
10 - Ordinary hazards														
10-1	Safety for children	x				x	Children climbing in horisontal handrails. Injuries caused by closing doors.	Kids fall over board. Squeesed fingers.						Better design of railings. Prevent climbing (eg. Use of plexi-galss, vertical railings…)
10-2	Safety for disabled													
10-3	Persons falling in stairs													
10-4	Rotating equipment causing damage to inspection crew.						Lack of physical protection in front of equipment. Lack of training.							
End of risk register														

A.3 Cause- Consequence Relations




Hazard No. 3-8
Power failure
Hazard No. 3-7
Loss of control and instrumentation
Hazard No. 3-9
To much equipment on bridge
Hazard No. 3-1
Grounding
Hazard No. 3-10
Inadequate display of information
Hazard No. 3-2
Collision with ships
Hazard No. 3-4
Fire/Explosion in machinery spaces
Hazard No. 3-3
Collision with fixed objects
Hazard No. 4-3
Heavy shipå movements due to weather
Hazard No. 4-4
Structural failure of steel contruction
Hazard No. 4-5
Smashing windows
Hazard No. 4-2
Collision with other ship
Hazard No. 5-4
Disabling control during mooring
Hazard No. 5-3
Berthing accident - coolision with quay
Hazard No. 5-6
Uable to open bow door and visor


Hazard No.
7-2
Pollution due to bunkering failure
Hazard No.
7-1
Fire/Explosion due to bunkering failure
Hazard No.
7-3
Pollution due to mistreatment of fluids and solids
Hazard No.
8-1
Evacuation during trim and heel
Hazard No.
8-2
Evacuation equipment failure
Hazard No.
8-3
Human Error/Lack of training