S A F E D O R

Project No.:	IP-516278
Project Acronym:	SAFEDOR
Project Title:	Design, Operation and Regulation for Safety
Instrument:	Integrated Project
Thematic Priority:	Sustainable Surface Transport

Annual Public Report Year 1

D-7.2.5

Document Id. SAFEDOR-D-7-2-5-Annual Public Report-y1

Due date of Deliverable: 2006-02-28

Actual Submission Date: **2006-03-10**

A. Alisafaki, A.D. Papanikolaou	NTUA-SDL
-document author-	*-organization name of lead contractor for this deliverable-*
A.D. Papanikolaou	Final
-document approved by-	*-revision type-*
2006-03-15	PUBLIC
-date of last update-	*-distribution level-*

Project co-funded by the European Commission within the Sixths Framework Programme (2002-2006)

Disclaimer

Document History

Document ID.	Date	Description
SAFEDOR-D-7.2.5-2006-01-23-NTUA_SDL-PublicReport–rev-0.doc	2006-01-24	First Draft
SAFEDOR-D-7.2.5-2006-02-10-NTUA_SDL-PublicReport–rev-1.doc	2006-02-10	Second Draft
SAFEDOR-D-7.2.5-2006-02-22-NTUA_SDL-PublicReport–rev-2.doc	2006-02-22	1st Review by WP-Leaders
SAFEDOR-D-7.2.5-2006-02-22-NTUA_SDL-PublicReport–rev-3.doc	2006-02-27	2nd Review by WP-Leaders
SAFEDOR-D-7.2.5-2006-02-22-NTUA_SDL-PublicReport–rev-4.doc	2006-03-03	Review by Chairman of Steering Committee
SAFEDOR-D-7.2.5-2006-02-22-NTUA_SDL-PublicReport–rev-5.doc	2006-03-07	3rd Review by WP-Leaders
SAFEDOR-D-7.2.5-Annual Public Report.doc	2006-03-09	Review by Steering Committee
SAFEDOR-D-7.2.5-Annual Public Report-y1.doc	2006-03-10	Final
SAFEDOR-D-7.2.5-2006-02-22-NTUA-SDL-Annual-Public-Report-Year-1.doc	2006-03-15	Final, updated WP3

Document Control Sheet

Title: SAFEDOR Annual Public Report Year 1	
Executive Summary: *The SAFEDOR Public Report Year 1 intends to provide public domain information about the objectives and the 1st year research activities of the European Commission funded project SAFEDOR. The report has been compiled on the basis of contributions of the SAFEDOR workpackage leaders.* *The aim of SAFEDOR is to improve the safety of maritime transportation and to increase European maritime industries' competitiveness through the integration of safety as design objective into ship design and risk acceptance criteria into the approval frameworks. Activities also establish that risk-based design contributes to the maximisation of safety of new ships, while supporting the design and approval of innovative types of vessels. One of the main objectives of SAFEDOR is to provide the risk-based regulatory framework for maritime safety of the future and propose it on international level at IMO. SAFEDOR is the first project that attempts to develop a risk-based regulatory framework for the maritime industry and corresponding design tools to facilitate first principle approaches to safety, addressing the complexity of a fully comprehensive system.* *The conducted research focuses on strategies and technologies to improve maritime safety. A systematic and all-embracing approach to ship safety is being developed that leads to optimising of safety and an effective use of both critical technologies and the wealth of information amassed over years in ship design. Gained knowledge is applied to innovative ship designs and improved safety-critical technologies.* *SAFEDOR involves ship owners, ship builders, equipment manufacturers and various maritime service suppliers with participation of private and public sector organisations. Its subject on maritime safety is inherently multi-disciplinary, involving fluid and structural dynamics, thermodynamics, probabilistic approaches and design knowledge. Thus, SAFEDOR integrates a wide spectrum of RTD activities, plus demonstration and training, and it directly affects most sections of the marine industry. In addition, through early dissemination of project results to IMO and the later proposal to IMO to adopt a novel risk-based regulatory framework, the complete maritime industry is affected.* *The expected outcome comprises the integration of all organisational, procedural, operational, technological, environmental and human related factors concerning safety at sea throughout the entire vessel life cycle; the demonstration of the potential of risk-based frameworks for safety assessment techniques, integrated design environments and optimisation of ship operation processes for safe and economic shipping; and the establishment of methodologies to derive risk-based rules from first principles approach.*	
Work carried out by	**Approved by**
A. Alisafaki A. D. Papanikolaou	A. D. Papanikolaou *- name of internal reviewer -* *- signature on file -* *- signature of internal reviewer and date of acceptance -*

	Pierre C. Sames *- name of external reviewer (Chairman of SC)-* *- signature on file -* *- signature of external reviewer and date of acceptance -*

Contents

1 Introduction

The SAFEDOR Public Report Year 1 intends to provide public domain information about the objectives and the 1st year research activities of the European Commission funded project SAFEDOR. The report has been compiled on the basis of contributions of the SAFEDOR workpackage leaders.

The focus of the project is on risk-based design, operation and regulation of ships. Key objectives target the development of a risk-based design and regulatory framework to support a holistic approach towards maritime safety, development/refinement of advanced first-principles analysis tools, and development of innovative technologies for safe and secure operation. The project also supports the development of innovative ship designs to demonstrate the practicability of the developed methodology. Important first steps of the project constitute high-level Formal Safety Assessment (FSA) studies for selected ship types.

In summary, during the first year of SAFEDOR the following has been achieved:

- Development of design tools for safety performance prediction (WP2)
  - Review of methods for the fast and accurate prediction of flooding of damaged ships in waves
  - Probabilistic assessment of the structural strength of intact and flooded VLCC and LLNG and set-up of reliability analysis model
  - Probabilistic assessment of intact stability
    - Generation of North Atlantic and Mediterranean Sea wave data
    - Preliminary application of the critical wave episode approach to intact ship stability
    - Identification of hazards, instability modes, numerical models and sample ships
  - Prevention of collision and grounding effects
    - A unified model is under development using Bayesian Belief Networks (BBN) for the representation of the operational scenario, the different bridge layout effects and the operator actions involved.
  - Prevention of fire and explosion events
    - Qualitative Design Review (QDR) and Failure Mode and Effect Analysis (FMEA) of container cargo and vessel related fire scenarios and identification of potential fire risk control measures.
    - QDR on human life safety, review of fire accidents/incidents statistics for passenger vessels and hazard identification (HAZID).

- Innovative safety-critical technologies (WP3)
  - Innovative tool for safety critical ship systems
    - Development of a simulation model for the electrical power bus system considering varying operating conditions.
  - Innovative concepts for safer navigation
    - New concept for describing bridge architectures by a reference model and a first set of end-user requirements.
  - Innovative life saving concepts for passenger ships
    - New concept for an inflatable lifeboat with reduced space required on-board

- Risk-based regulatory framework (WP4)
  - Formal Safety Assessments (FSAs) for Cruiser, RoPax, LNG carrier and Containership
    - HAZIDs and Risk Analyses completed
    - Cost Benefit Analyses and Recommendations under development
  - Risk-Based Regulatory Framework

        - Preliminary version of the overall risk-based approval process
        - Risk evaluation criteria for accidental releases to the environment. Relevant deliverable was made available to the IMO correspondence group, which reviewed and included an extract in the report to MSC 81, including references to the full report.

- Risk-based design framework (WP5)
    - Risk-based design concept
        - Set-up of SAFEDOR risk-based design methodology
        - Development of novel decision-making

- Validation and implementation for innovative ship designs (WP6)
    - Development of eight (8) innovative design concepts for
        - Post-PANAMAX Cruiser ship
        - Cruise Liner
        - Fast Full Displacement ferry
        - 13th Passenger RoPax
        - Light weight composite structure RoPax
        - Shortsea LNG carrier
        - Open-top Feeder Containership
        - AFRAMAX tanker

- Knowledge Management, Dissemination and Training (WP7)
    - Organisation of public workshop at the headquarters of the International Maritime Organisation (IMO) with good participation of professionals and all stakeholders of the maritime industry
    - Issuance of a year 1 public report and newsletter
    - Issuance of a year 1 dissemination and communication plan
    - Issuance of part 1 of the SAFEDOR exploitation plan

2 IP SAFEDOR

SAFEDOR is an Integrated Project responding to the need of the EU maritime industry for evermore-innovative solutions for better quality, cleaner and safer transport.

SAFEDOR constitutes the culmination of eight (8) years of EU-wide concerted effort to foster radical shift from the current maritime safety regime, through the activities of the thematic network SAFER EURORO ("Design for Safety"). SAFEDOR has pooled together an accolade of leading expertise from across the whole maritime spectrum to pursue its vision of strengthening the competitiveness of the EU maritime industry by enhancing safety through innovation. This entails development of a holistic approach that links risk prevention / reduction to ship performance and cost, with safety treated as a lifecycle issue and a design objective, implying focus on risk-based operation and need for risk-based regulations within an integrated risk-based design framework, utilising routinely first-principles tools. This all-embracing system is the key to attaining optimum design solutions and it acts as catalyst to pan-European cooperation with strong structuring and integration effects. SAFEDOR produces a series of prototype ship designs to validate and implement this novel approach and ascertain its practicability. To accelerate transition from conventional to risk-based design, the wider maritime community is inculcated through a rigorous knowledge management, training and dissemination system of all technological, methodological and regulatory developments whilst continuing to nurture, enthuse and fuel a maritime safety culture [1].

Innovation in the transportation industry has to a significant extent been driven by safety. Ship safety has until recently been driven mainly by individual events. Each major catastrophic accident has led to a new safety regulation and subsequent design measures imposed by the International Maritime Organization (IMO) and the classification societies. The integrated project SAFEDOR introduces a risk-based design methodology and regulatory framework that systematically embraces design knowledge and innovation, thus offering economic benefits and competitive advantage to the European maritime industry.

The SAFEDOR project officially started on 15th February 2005, when the kick-off meeting was held at Germanischer Lloyd (GL), in Hamburg. Fifty-three -53- project partners from all sectors within the European maritime industry are participating in the project, the duration of which is until January 2009.

2.1 SAFEDOR Objectives

Risk-based ship design and approval will satisfy the European maritime industries' need to deliver ever more innovative transport solutions to their customers. Risk-based ship design and approval will also satisfy the European society's need to have increasingly safer transport. The proposed research activities will distinctively address both aspects and deliver the foundation for Europe to sustain world-leadership in safety-critical and knowledge-intensive ships, maritime services, products, equipment and related software. A vision was formulated to present these two goals of SAFEDOR:

ENHANCE SAFETY THROUGH INNOVATION TO STRENGTHEN THE COMPETITIVENESS OF THE EUROPEAN MARITIME INDUSTRY

It is the aim of SAFEDOR to provide solutions for both key issues for the European maritime industry. Increasing safety and security of maritime transport cost-effectively is achieved by treating safety as design objective and not as a constraint as in current ship design. Increasing the competitiveness of European industry is achieved by systematic innovation in design and operations encouraged by modernizing the maritime regulatory system towards a risk-based framework. Strategic research objectives are formulated to meet the outlined vision, these being:

- Develop a risk-based and internationally accepted regulatory framework[1] to facilitate first principles approaches to safety
- Develop design methods and tools to assess operational, extreme, accidental and catastrophic scenarios, accounting for the human element, and integrate these into a design environment
- Develop innovative solutions and products for safe, secure and economic operation of ships
- Produce prototype designs for European safety-critical vessels to validate the proposed methodology and document its practicability
- Transfer systematically knowledge to the wider maritime community and add a stimulus to the development of a safety culture
  Improve training at universities and aptitudes of maritime industry staff in new technological, methodological and regulatory developments in order to attain more acceptance of these principles

SAFEDOR objectives and the approach are summarised in Figure 1 showing the two development tracks – one related to risk-based ship design and one related to risk-based ship approval – and the validation and application activities. Figure 2 presents the structure of SAFEDOR development activities and shows the planned timeline. It can be seen that most activities started in year 1 but tasks for completion in year 1

[1] IMO secretariat agreed to act as an observer in SAFEDOR and will thus facilitate to meet the first strategic objective which is of utmost importance. See letter of confirmation in Annex [1].

were only the FSA studies. Further details on the results in year 1 can be found in chapters 6.3, 7,3, 8.3, 9.3 & 10.3.

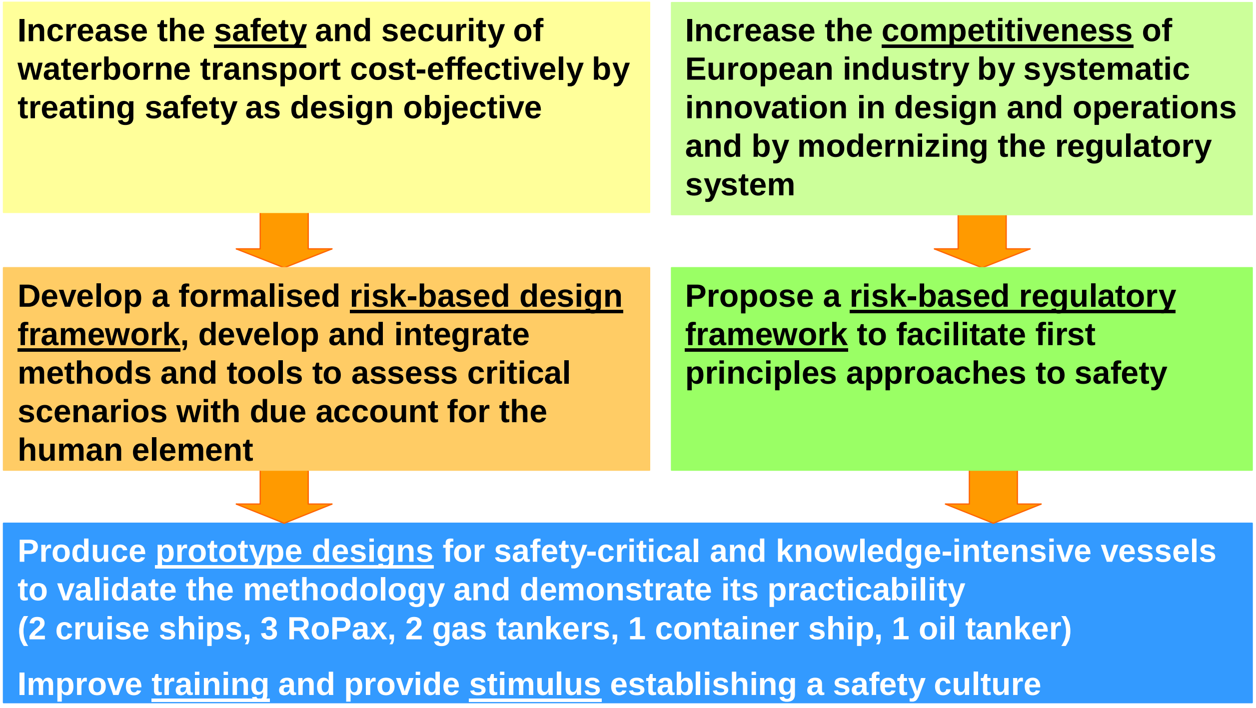

Figure 1: SAFEDOR Objectives & Approach

2.2 SAFEDOR Focus

As introduced above, SAFEDOR development activities focus on risk-based ship design (which is an enhanced ship design process), approval of risk-based ships (which requires an enhanced approval process and a modernised regulatory framework), and sample designs to prove the practicability of the developed risk-based approaches.

Risk-based ship design requires a novel process to incorporate safety as an objective, sophisticated methods and tools to assess ships in extreme and accidental scenarios with due account for the human element and improved knowledge on cost elements in construction and operation of ships. Optimisation of ship designs also needs integration of available tools. SAFEDOR addresses all of the above.

Approval of risk-based designed ships requires a new approval process, which takes into account the rule-challenging character of the innovative ship. Qualitative and quantitative assessments of innovative concepts are required and knowledge on current risk levels is needed to establish suitable risk acceptance criteria. High-level FSA studies of ship types deliver just this piece of information. SAFEDOR addresses these elements and develops a proposal for a modernised regulatory framework to facilitate the above.

Application of the newly gained knowledge to complete ship designs and to selected safety-critical technologies (navigation and life saving) is the third pillar of SAFEDOR. Eight ship designs are developed focusing on aspects that improve safety and / or economics but for some formal reason cannot be approved today.

3 SAFEDOR Structure

To ensure an effective control of the project, the work programme is broken down into a number of work packages (WP) which in turn are divided into Subprojects (SP) and Tasks (TK). Individual partners have been allocated responsibility for technical co-ordination within the respective WPs, SPs and TKs. In summary, SAFEDOR comprises 7 work packages, 32 subprojects and 221 tasks [4].

Risk-based design entails the systematic integration of risk analysis in the design process targeting risk prevention/ reduction as a design objective. An essential pre-requisite to undertaking this is the availability of fast and accurate first-principles tools. This is addressed in work package (WP) 2 of SAFEDOR. Also knowledge of the effect of design changes/measures to enhance safety cost-effectively (considering all major hazards and ensuing accident categories and scenarios) is crucial. This issue is addressed in a number of work packages (FSA studies in WP4, implementation of first –principles tools in WP2 and in WP3). To pursue this activity effectively, it will be necessary to provide an integrated design environment (IT platform) to facilitate and support a holistic approach to ship design (WP5) that enables appropriate trade-offs and advanced decision-making, leading to optimal ship design solutions. The next essential step (design approval) necessitates the development and consolidation of a risk-based regulatory framework to set conditions for design approval that would allow linking ship design performance optimisation with risk minimisation (WP4). To embed the risk-based design process into the heart of the maritime industry, design teams have been assembled representing a large sector of the EU shipping and shipbuilding industries to pursue the design (from concept to approval) of innovative ship types that cannot be approved under the current prescriptive rules (WP6). Finally, a knowledge management, training and dissemination system is put in place to maximise benefits by targeting all the stakeholders of maritime safety and to exploit RTD results by systematic evaluation, consolidation and marketing (WP7) [2].

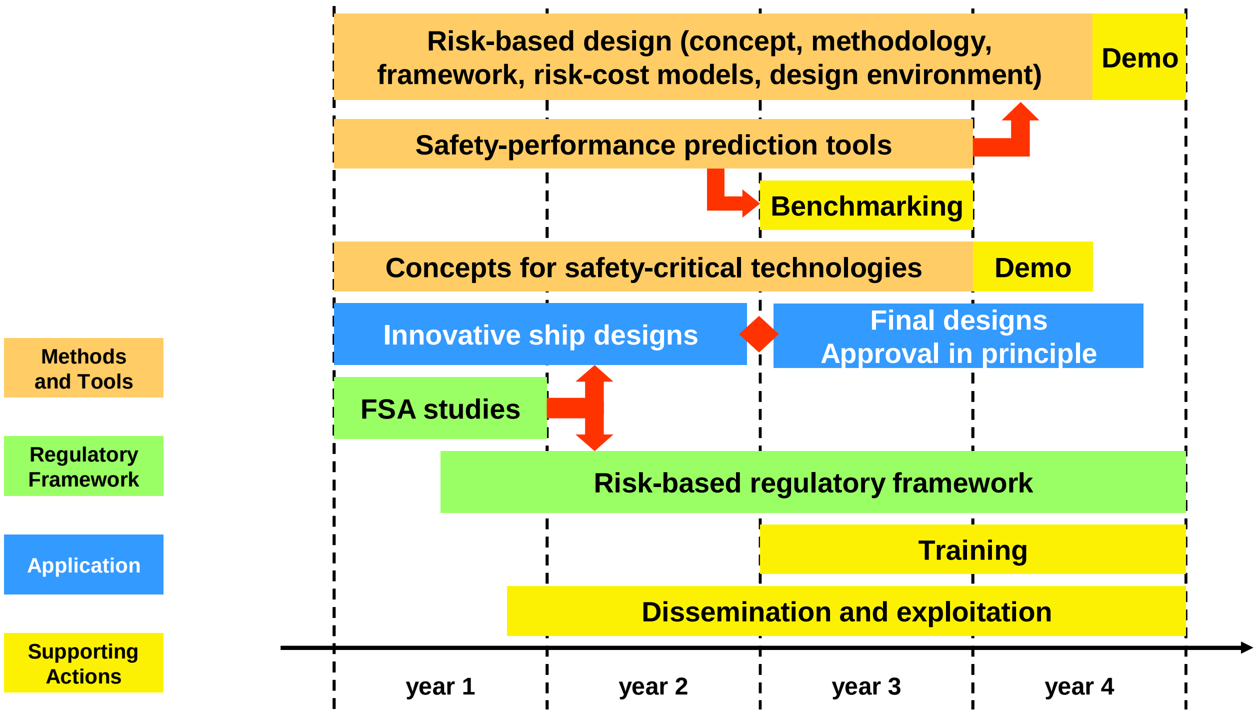

Figure 2: SAFEDOR Road Map

4 SAFEDOR Partnership

The SAFEDOR Consortium comprises 53 organisations from 14 European countries and represents all stakeholders of the maritime industry, namely ship owners, ship yards, maritime equipment manufacturers, engineering consultants, research institutes, software developers, university departments, classification societies and one flag state. The following list provides the 53 participants alphabetically; in brackets the relevant country is indicated.

1. Germanischer Lloyd AG (DE): IP Coordinator
2. Aker MTW Werft GmbH (DE)
3. Alpha Ship Design ApS (DK)
4. Alstom Chantiers de l'Atlantique (FR)
5. Altair Special Maritime Enterprise (GR)
6. ANSYS Europe Ltd. (UK)
7. AVEVA AB (SE)
8. British Maritime Technology (UK)
9. Brodrene AA AS (NO)
10. Carnival plc (UK)
11. Centro per gli Studi di Tecnica Navale (IT)
12. Color Line Marine AS (NO)
13. Columbus Shipmanagement GmbH (DE)
14. D'Appolonia S.p.A. (IT)
15. Danish Maritime Authority (DK)
16. Deltamarin Ltd (FI)
17. Det Norske Veritas AS (NO)
18. DFDS A/S (DK)
19. Fincantieri - Cantieri Navali Italiani S.p.A. (IT)
20. FiReCo AS (NO)
21. Flensburger Schiffbau-Gesellschaft mbH & Co. KG (DE)
22. Fr. Fassmer GmbH und Co. KG (DE)
23. FRESTI (PT)
24. GKSS Forschungszentrum Geesthacht GmbH (DE)
25. Harland & Wolff Heavy Industries Ltd (UK)
26. Instituto Superior Tecnico (PT)
27. ITI Ges. f. ingenieurtechnische Informationsverarbeitung mbH (DE)
28. Leif Hoegh & Co. AS (NO)
29. Lloyd's Register (UK)
30. Lund, Mohr and Giaever-Enger Marin AS (NO)
31. Maritime Research Institute Netherlands (NL)
32. Maritime Simulation Rotterdam b.v. (NL)
33. Martec S. p. A. (IT)
34. Meyer Werft (DE)
35. Napa Ltd (FI)
36. Navalimpianti S.p.a. (IT)
37. Navantia, S.A. (ES)
38. National Technical University of Athens (GR)
39. Peter Dφhle Schiffahrts-KG (DE)
40. RFD Beaufort Limited (IE)
41. RINA SPA (IT)
42. Royal Caribbean Cruise Line (UK)
43. Safety at Sea Limited (UK)
44. SAM Electronics GmbH (DE)
45. Sirehna (FR)
46. Snecma Moteurs (FR)
47. SSPA Sweden AB (SE)
48. Stena Rederi AB (SE)
49. Technical University of Denmark (DK)
50. Umoe Schat Harding AS (NO)
51. University of Hull (UK)
52. Universities of Glasgow & Strathclyde (UK)
53. V. Ships (UK)

The percentage of various affiliation groups participating in SAFEDOR is shown in the following figure:

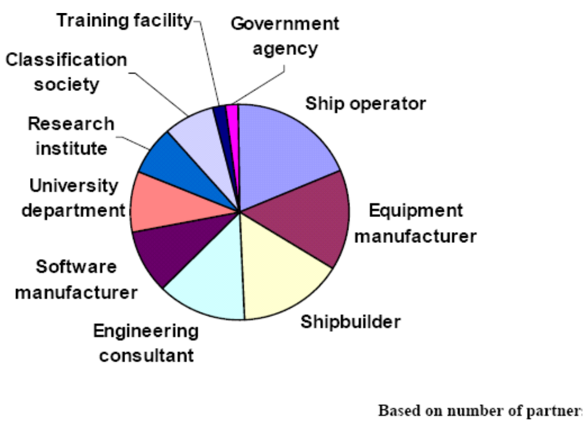

Figure 3: SAFEDOR Partnership

5 WP-1: Project Management

The overall co-ordination and running of the project is the responsibility of the Project Manager who is appointed by the project co-ordinator (Germanischer Lloyd). Representative of the Project Coordinator is the Project Manager Dr. A. Baumgart.

Since 2002, the Steering Committee has set the mission objectives for SAFEDOR. Members of the Steering Committee are:

- Carnival plc, Owner, United Kingdom: Mr. Tom Strang
- Danish Maritime Authority, Flag State, Denmark: Mr. Christian Breinholt
- DNV, Class Society, Norway: Dr. R. Skjong
- Germanischer Lloyd, Class Society, Germany: Dr. P.C. Sames (Chairman)
- Navantia Yard, Spain: Mr. Antonio Perez de Lucas
- SAM Electronics, Manufacturer, Germany: Dr. W. Hensel
- Univ. Glasgow & Strathclyde, University: United Kingdom: Prof. D. Vassalos

The Project Management Committee (PMC), which consists of the 7 WP managers, coordinates the Work Packages. The PMC is also responsible for monitoring the technical progress and deciding on the project strategies, as far as the technical execution is concerned.

The Project Management Committee consists of all work package leaders. It is chaired by the project manager. The members of the Project Management Committee are:

WP-1. Dr Andreas Baumgart (chairman), Germanischer Lloyd
WP-2. Prof. Jørgen J. Jensen, Technical University of Denmark
WP-3. Mr Karl-Christian Ehrke, SAM Electronics
WP-4. Dr Rolf Skjong, DNV
WP-5. Prof. Dracos Vassalos, Universities of Glasgow & Strathclyde
WP-6. Mr Francisco del Castillo de Comas, Navantia
WP-7. Prof. Apostolos Papanikolaou, National Technical University of Athens

The management structure mirrors the work package structure and this is presented in Figure 4.

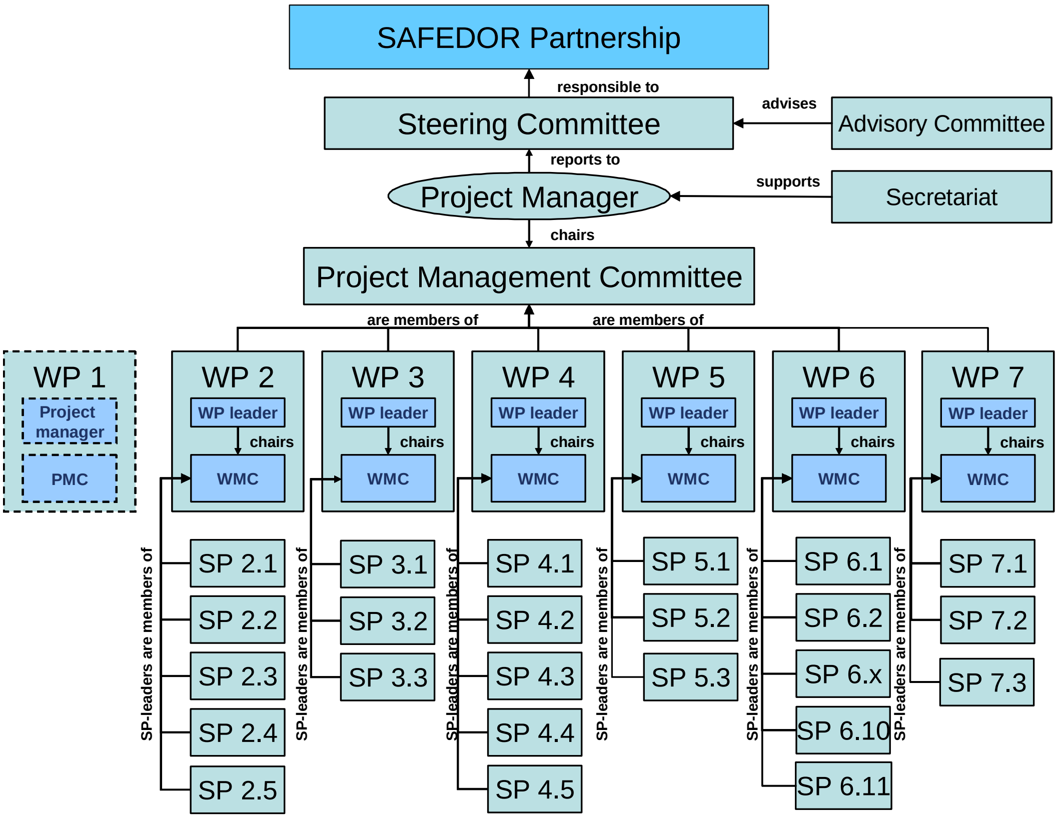

Figure 4: Management structure of SAFEDOR

6 WP-2: Design tools for safety performance prediction

6.1 Summary description of workpackage objectives

Risk-based design demands advanced tools to predict the safety performance of a given ship design. It is the specific objectives of work package 2:

- To develop and / or refine such advanced design tools
- To enable integration of the tools into a design environment
- To evaluate risk and the effect of risk-control options

with the aim to provide tools for fast and reliable evaluation of various risks associated with failure of the ship or its subsystems. Thereby, WP6 dealing with design of actual ship project might be able to

- make a fast screening of various scenarios in order to identify the important ones
- make a detailed analysis of those scenarios thereby identified
- suggest appropriate risk control options

6.2 Contractors involved

The WP-2 Leader is the Danish Technical University, DTU, www.mek.dtu.dk, represented by Prof. Jørgen Juncher Jensen (phone: + 45 45 25 1384, fax: + 45 45 88 43 25, e-mail: jjj@mek.dtu.dk).

All the contractors involved in WP-2 are:

- SP 2.1: Fast and accurate flooding prediction
  SSRC (SP-Leader), FSG, MARIN, NAVANTIA, NTUA, FIN
- SP 2.2: Probabilistic assessment of the strength of ship structures
  DNV (SP-Leader), IST, DTU, NAVANTIA
- SP 2.3: Probabilistic assessment of intact stability
  DNV (SP-Leader), DTU, FSG, GKSS, GL, NAVANTIA, MARIN, NTUA, SSRC, FIN
- SP 2.4: Prevention of collision and grounding events
  DTU (SP-Leader), GL, DAPP, DNV, MSR, FSG, IST
- SP 2.5: Prevention of fire and explosion events
  SSRC (SP-Leader), GL, CFX, FSG

6.3 Work performed - Results achieved so far

SP 2.1Fast and accurate flooding prediction

The primary goal of this subproject is to devise a robust methodology capable of modelling realistically the behaviour of a damage ship in severe seas during progressive flooding that may lead to sinking/capsizing. It is also within the scope of this subproject to evaluate a number of identified risk control measures that can be considered at early stages of the design process to improve ship survivability in critical scenarios.

A review of the pertinent literature on stochastic methods for non-linear processes has been performed, including the available research on predictions of water ingress and egress and, the damaged ship response and survivability in random wave environment.

The main findings are:

- The existing deterministic SOLAS regulations are simplistic, as they ignore the environment from the assessment.
- The latest regulations building on probabilistic concept of subdivision might not in all cases be adequate, as they rely on traditionally-derived static stability characteristics of the ship.
- The time-domain simulations are too slow for routine applications, as well as they are still not quantitatively accurate in modelling dynamics of damaged ships.
- Model experiments are too expensive and time-consuming for use in the design process.

It seems that the only technique to comprehensively consider complex relationship between specifics of the damage, ensuing instantaneous water ingress, its spread through the architecture of the internal subdivision, the environment, ship loading conditions and the ship response, is that of model experiment or numerical simulation, until proper understanding of this relationships is established, and subsequent simpler generic models are developed.

SP 2.2. Probabilistic assessment of the strength of ship structures

The primary goal of this subproject is to apply structural reliability analysis to calibrate a design equation for the limit states corresponding to: hull girder collapse due to global bending moments. With increased computational capacity, it is now possible to link state-of-the-art first principle analysis tools for load effects and capacity into probabilistic analysis models. Structural Reliability Analysis can then efficiently be used for the calibration of design codes to a consistent reliability level. In addition, cost-effectiveness analysis will be used to evaluate the target reliability level and risk control options.

At the first meeting of the subproject, two ships were selected as case vessels; i.e. a large tanker for oil (VLCC) and a large liquefied natural gas (LLNG) carrier. All relevant data for the ships were collected and made available to the group. For these ships, the response amplitude operators (RAOs) of the hull girder bending moment for the intact case and for some selected cases of flooded and heeled condition are determined. This task is completed for the VLCC and almost completed for the LLNG. The effect of flooding on the still water bending moment is also calculated.

Hull girder bending moment capacity calculations have been carried out, where also the effect of damages is taken into account. This task is completed for the VLCC and ongoing for the LLNG. The so-called “model correction factor” will be used for the capacity assessment in the reliability analysis. A successful example application of this approach has been demonstrated on a plate-buckling problem.

A reliability analysis model has been defined, in which the results from the hydrodynamic analysis (RAOs) and the capacity calculation are to be utilised. In the case of damaged condition, it is a challenge to identify the most likely critical scenarios. In order to do this, work with a Bayesian network model is ongoing, where distributions of the damage size and location will be established. The intention is to use this model as a screening tool to find the appropriate conditions to be subjected to a more detailed reliability analysis. This tool is expected to be useful for this type of screening evaluations also for other ship sizes and types.

SP 2.3 Probabilistic assessment of intact stability

The primary goal of this subproject is to develop and evaluate the necessary elements of a probabilistic framework aimed at quantifying the probability of capsizing (or of exceeding specified extreme motion levels) for any given ship. As there is no unique solution to this problem, several probabilistic approaches will be compared. This includes stochastic wave data, which will serve as input to existing state-of-the-art large-amplitude ship motion codes, suitable for modelling intact ship capsize in extreme seas. In addition, possible risk control options will be identified and assessed from a ship design and operation perspective.

Generation of North Atlantic wave data by GKSS and wave data for the Mediterranean by NTUA have been completed. A workshop to discuss numerical models has been held. Application of the comprehensive approach for stability investigation has not been started yet, but preliminary results have been obtained for the critical wave episode approach.

Hazards, instability modes, numerical models and sample ships have been identified. A number of ships have been selected and made available for computations: a ROPAX ferry (Navantia), a small container feeder (GL), a cruise ship (Fincantieri); the possibility for a large containership is still pending.

SP 2.4 Prevention of collision and grounding events

The primary goal of this subproject is to provide a methodological approach that is capable of predicting the probability of collision and grounding events taking into account ship systems, environment and people by estimating:

- the causation factor, with due account to the integrated bridge system;
- the probability of disabled ship as function of ship type;
- the probability of a disabled ship drifting towards objects etc,

and by effectively assessing the resulting damage distributions following collision and grounding. Suitable Risk Control Options that affect the probability of collision or grounding will be identified and evaluated.

One objective was to analyse the role of the crew in a collision or grounding event. The focus is on emergency response actions that is to say the ship under power is assumed to be already on a collision route. The links between the human element (the crew) and organizational elements (bridge equipment, operational conditions, level of fatigue etc) have been analysed and assessed using the framework proposed by Hollnagel (1998). The current status of the network is still under construction; some states of the variables have to be defined and the consequent probability distribution, in order to be completed.

During the first six months it was tried to integrate the above model within the representation and assessment method chosen for the overall Probabilistic Safety Assessment evaluation, a Bayesian Belief Networks (BBN), but this was abandoned because it was not really possible to judge the impact of each influencing factor on the overall picture. Therefore, it has been decided to switch to a more naturalistic approach to the operator model mostly relying on the use of the Expert Judgement for identifying main elements of performance in relation to collision and grounding scenario.

The "scenario" part of the network had to be modified in order to:

- consider a node (replacing OOW Task node) representing the surveillance status
- consider "time to take action" node (very short, short, medium,…) which influences the human reliability
- take into account the apparent collision angle (ahead, side), this implies to consider the width of sectors to consider for the watch
- consider the different times (detection, interpretation, planning, execution).

The modification of the scenario determined major changes in the operator model, as well. A new network was then outlined, without fully considering the underlying probability distribution just to display the main elements identified and the possible relation among them. A unified model is now being built using BBN for the representation of the scenario, the different bridge layout effects and the operator actions involved. The causation model is broken down into objects for the scope of clarity; each object is a Bayesian Network representing part of the bigger picture (Scenario, Detection, Planning of action etc) connected to each other through the input-output nodes, as shown in the following figure:

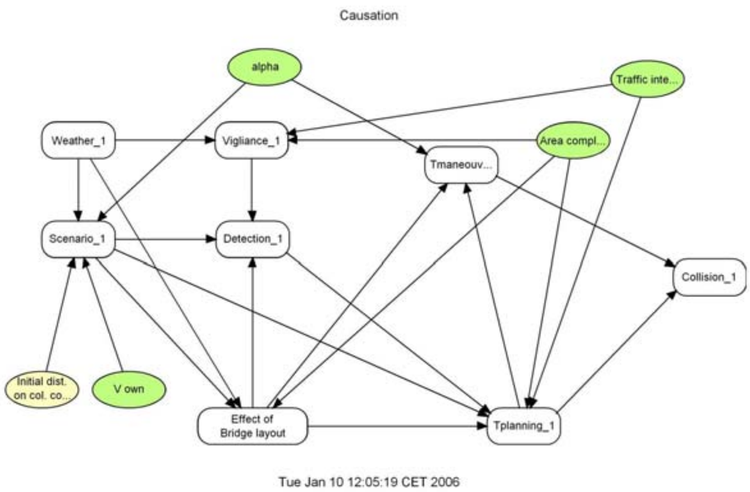

Figure 5: Causation model for collision and grounding events

SP 2.5 Prevention of fire and explosion events

The primary goal of this subproject is to identify ship design issues that can be addressed with new and/or alternative design and arrangements, for which fire protection is an important design factor. The project also intends to develop and demonstrate a risk assessment methodology encompassing first-principle fire engineering science, the implementation of which intends to allow the achievement of the fundamental fire safety objectives implicit in the new SOLAS regulations, namely prevention of the occurrence of fire and explosions, containment and suppression of fire and smoke and the provision of adequate and readily accessible means of escape for passenger and crew.

Fire and explosions constitute one of the accident categories that most contribute to the risk to ship operations. Fire safety is also one of the few areas where current ship safety regulations define explicit safety goals and functional requirements in addition to allowing an alternative performance-based approach to demonstrate safety equivalence. In this context, SP2.5 is aiming at exploring the potential for using alternative fire safety approaches with a view to identifying gaps and making developments to fill identified gaps in two areas: (i) human life safety and (ii) cargo (container) safety. The first step in this direction was taken by conducting a task denominated Qualitative Design Review (QDR) and was the focus of the activities during the first year.

The Qualitative Design Review (QDR) on cargo fire safety was approached with a review of fire accidents/incidents statistics associated with container vessels. Subsequently, design and construction issues related to Container and Ro-Ro vessels were reviewed with a view to defining the potential for fire risk reduction by design. Cargo transported in containers was analysed with a view to gain insight into fire development potential in containers. A hazard identification session and a Failure Mode and Effect Analysis (FMEA) were conducted with a view to identifying specific container-vessel-related fire scenarios and potential fire risk control measures. Two specific situations were identified in need of quantitative fire engineering calculations.

The QDR on human life safety was approached in the same manner as above, namely review of fire accidents/incidents statistics for passenger vessels and hazard identification (HAZID) sessions.

The objective is also to identify critical design scenarios for evaluating human life safety in fires. The qualitative information and limited statistical information will be used to build a "diagnosis" tool based on Bayesian Network technology that can be used for design purposes.

6.4 Anticipated End Results - Intentions for use and impact

The main objective of workpackage 2 is the development of advanced tools to predict the safety performance of a given ship design and their integration into a risk-based design procedure. This will enable will enable the design teams of workpackage 6, dealing with the design of actual ship projects, to

- make a fast screening of various scenarios in order to identify the important ones
- make a detailed analysis of those scenarios thereby identified
- suggest appropriate risk control options

The links of workpackage 2 to all other subprojects of SAFEDOR are outlined below.

SP 2.1 Fast and accurate flooding prediction

This subproject is linked to other subprojects as illustrated in the figure below.

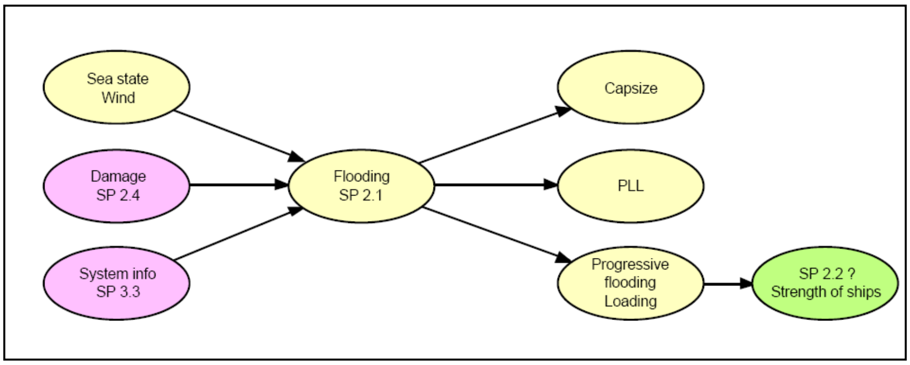

Figure 6: Interaction diagram for SP2.1

SP 2.2 Probabilistic assessment of the strength of ship structures

This subproject is linked to other subprojects as illustrated in the figure below.

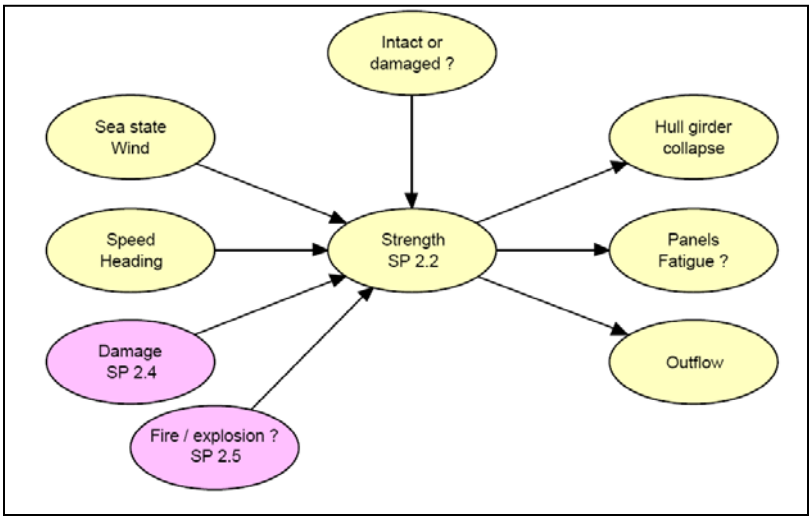

Figure 7: Interaction diagram for SP2.2

SP 2.3 Probabilistic assessment of intact stability

This subproject is linked to other subprojects as illustrated in the figure below.

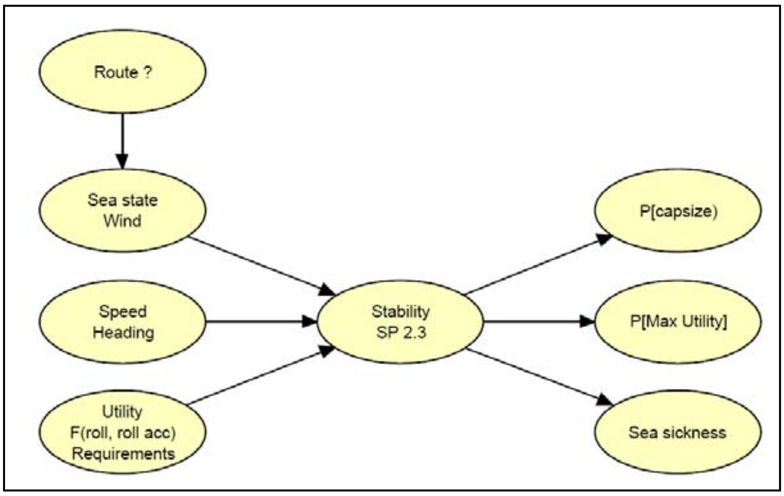

Figure 8: Interaction diagram for SP2.3

SP 2.4 Prevention of collision and grounding events

This subproject is linked to other subprojects as illustrated in the figure below.

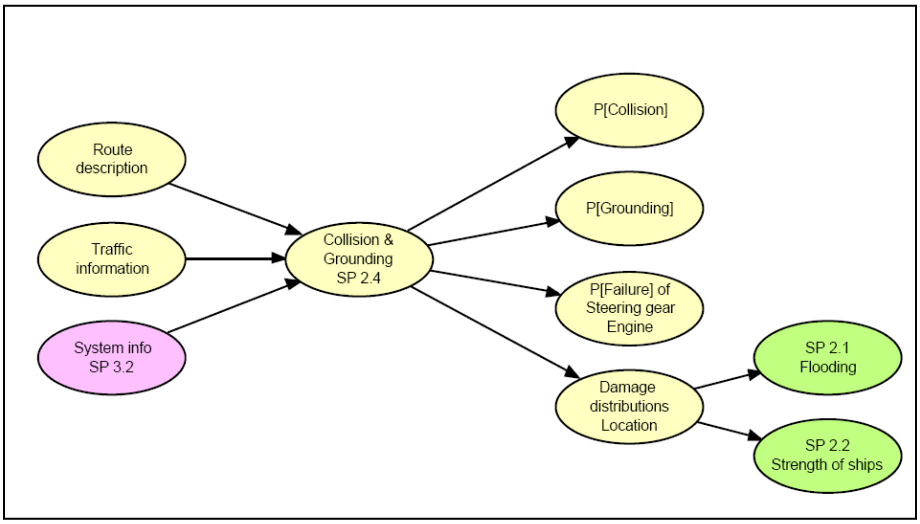

Figure 9: Interaction diagram for SP2.4

SP 2.5 Prevention of fire and explosion events

This subproject is linked to other subprojects as illustrated in the figure below.

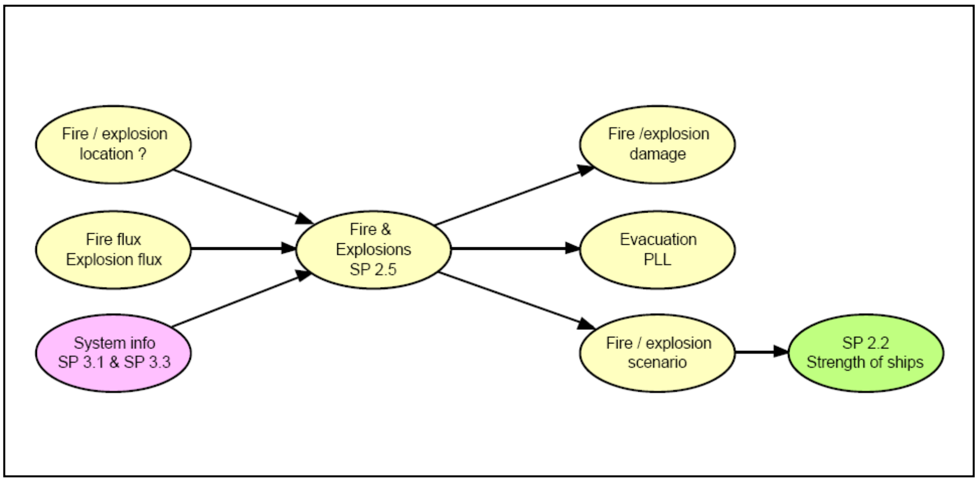

Figure 10: Interaction diagram for SP2.5

7 WP-3: Innovative safety-critical technologies

7.1 Summary description of workpackage objectives

Design changes having influence on the risk level are called risk-control-options (RCOs). In risk-based design innovative products can be powerful RCOs. Therefore, it is the objective of work package 3

- To develop innovative technologies to support safe operation
- To develop specific tools which support safety (in the related RCOs under evaluation)
- To evaluate their risk-reducing potential

WP 3 focuses on specific innovative and safety-critical technologies that will improve the safety of ships. Three issues known to be safety-critical have been selected for improvement through the work in this workpackage that look into the performance of certain systems and procedures adopted onboard ships and seek way to improve them by incorporating the risks at the design stage. It targets some of the prescriptive limitations imposed by the rules and regulations in force today and exposes their limitations and will propose solutions that are both safe and cost effective. All subprojects focus on known important risk control options.

If successful, some of the solutions found could be immediately applicable, and this is one of the reasons that operators are strongly represented in this work-package. Thus, the effectiveness is to be demonstrated in reality.

The work has been divided into 3 subprojects:

- SP 3.1: Innovative Tool for Safety Critical Ship Systems
- SP 3.2: Innovative Concepts for Safer Navigation
- SP 3.3: Innovative Life Saving for Passenger Ships

7.2 Contractors involved

The WP 3 leader is SAM Electronics GmbH (SAM), represented by Karl-Christian Ehrke,
Tel. +49-40-8825-2868, Email Karl-Christian-Ehrke@sam-electronics.de.

All the contractors involved in WP-3 are:

- SP 3.1: Innovative Tool for Safety Critical Ship Systems
  ITI (SP-Leader), GL, HULL, FSG, SAM
- SP 3.2: Innovative Concepts for Safer Navigation
  SAM (SP-Leader), DAPP, FRES, MAR, CAR
- SP 3.3: Innovative Life Saving for Passenger Ships
  CAR (SP-Leader), RFD, FIN, NAVANTIA, LR, USH, FASS

7.3 Work performed - Results achieved so far

SP 3.1: Innovative tool for safety critical ship systems

The objective of subproject 3.1 is the development of a tool supporting the safety analysis of ship systems developed with simulation techniques and not complying with current rules. A further objective is the development of techniques to reduce unnecessary redundancy in ship systems. That means, not all components are doubled as required by some rules, but only those in the safety critical path.

In the first year, the main focus was on the development of initial methods for fault tree conversion and FMEA.

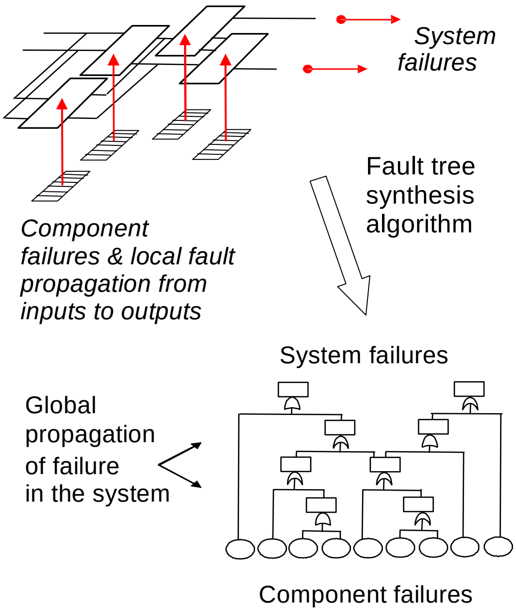

Figure 11: The Conversion of Fault Trees to FMEA's

In the next step a methodology for system safety assessment is developed. It integrates design with safety analysis and, with the aid of automation, enables fast iteration of analysis in the course of the design lifecycle. A computerised tool will generate fault trees and FMEA's from system designs developed in Simulation X, a modelling tool authored by ITI GmbH. The methodology is innovative, and there are no commercial tools with equivalent functionality. The potential benefits from application of this approach in industrial scale are substantial and include simplification of safety analysis, easing the assessment of the impact of design changes on safety and the provision of a rational, mathematical basis for making tradeoffs between long term system reliability and cost.

SP 3.2: Innovative concepts for safer navigation

The main objective of subproject 3.2 is to combine new technologies as used by the office industry (flat screen, wireless networks, integration of all controls) with new safety concepts for redundant workstation operation in such a way, that

- a clear and easy to overlook operator working place is achieved
- all workstations are working fully redundant
- every application respective every ship operation task can be performed from any workstation
- for the first time SOLAS RegV/A Reg15 principles for bridge design are applied and tested.

The main achievement in the first year is the collection of user requirements and identification of current practices for bridge design. Further on, drafts have been prepared for the specification of modules, for the preliminary bridge design guide and for the preliminary safe bridge architecture. Results so far are as follows:

Figure 12: Specification of Bridge Modules - Workstation

The specification of modules covers a new series of bridge consoles with flat screens and for integrated electronic units, as well as remotely connected electronic boxes. Further on, a concept for a new hand-held manoeuvring tablet has been developed. It receives main navigation data broadcasted via WLAN by a data server as part of the integrated bridge system. Various user configurable instruments are available. Based on this design a generic head-up display hanging down from the bridge house ceiling has been specified as well. It provides the user with a configurable set of instruments.

The work on preliminary bridge design provides a framework for the specification of new bridges with advanced technology. The functions of a bridge have been identified, classified and structured into an reference layer model. It starts from top with the bridge operational procedures like safe watch keeping schedule, followed by the overall man machine interface design and ends up with requirements for vibration, noise, lighting, temperature, on the lowest level.

The work on safe bridge architecture was focused on a preliminary report on applicable methods. It has been investigated which functions are involved in the safe completion of each phase of the passage (open sea, harbour, etc.) through a top-down analysis to identify the effects on the ship caused by each function's loss, in terms of safety (namely, the Functional Failure Analysis FFA). The results of the FFA are then integrated with any relevant considerations deriving from the hazard identification and analysis, especially concerning the effects of the unavailability of risk reduction or mitigation measures (e.g. such as a ship's fire detection and prevention). The final step of the preliminary safety analysis is to identify safety related functions.

SP 3.3: Innovative life saving for passenger ships

The principal aim of this subproject is to develop and validate, using risk-based methods, a matrix of Life Saving Appliances (LSA) solutions, also called risk control options, that are consistent with the type of vessel and operational envelope. This will allow designers to choose the most effective means to solve the LSA issues currently facing them. By considering all phases of the evacuation and abandonment, it takes a holistic approach to the area of life saving appliances, and will link the provision of LSA to the survivability of the vessel by considering LSA as a mitigating measure in the abandon ship process. It will look at a number of LSA solutions ('packages') and link the importance given to LSA to the likelihood that it will need to be used. This will be done by utilising risk assessment methods. It will look at the complete evacuation process from muster to recovery and will concentrate on solutions that incorporate and improve on aspects related to the human element. The specific objectives of this subproject are:

- To link LSA requirements to ship survivability
- To remove unintentional effects of LSA regulation that effectively limit the number of passengers / size of passenger vessels
- To challenge all European LSA manufacturers to suggest innovative solutions for abandonment of large passenger ships.

The main achievement in the first year is the draft of the global LSS analysis. It is divided into four parts as follows:

- In the first part, the review of the current regulatory framework, an overview of existing rules is given.
- In the second part, the review of the state-of-the-art, an overview is given on current research in LSA, main manufacturers, small innovative companies, market innovations, and recent valuable studies and reference centres. The main result is, that innovation and alternative approaches are present, but reserved to a small number of forward thinking major players.
- In the third part, a review of problems with current systems based on comprehensive historical data is given. According to this work, the release mechanism causes most of the accidents. It opens too early due to incorrect operation by crew members. Stringent training is the first choice.
- Finally, in the fourth part, a new survival formula for the evaluation of advanced risk-based designs is introduced. It has been derived from the survival timeframe by assessing each part of the evacuation process with a realistic time period. The sum of all parts gives an indication how quickly the vessel can be evacuated.

One further achievement, in the first year, is a concept for a new inflatable and partly rigid lifeboat design. During storage on-board, it can save up to 30% of space compared to conventional design. The work is still ongoing.

7.4 Anticipated End Results - Intentions for use and impact

The target of subproject 3.1 is the development of a methodology and computerised tools for safety and reliability analysis of innovative design proposals. The methodology has already been specified and it provides the foundation for the development of the supporting tools. The tool specification has been agreed and provides a basis for the development of the supporting tools in the reminder of the project.
Anticipated end results of SP 3.2 dealing with innovative concepts for safe navigation will lead to:

- Increased safety of operation with fail safe system configuration
- Increased safety of operation with user friendly system handling
- Reduced equipment costs with multipurpose workstations
- Reduced space requirements giving more design freedom in free view from all positions

whereas, the advantages for vessel operators are faster and more reliable information during critical passages.
Anticipated end results of SP 3.3 dealing with innovative LSA for passenger ships will lead to improved Life Saving for large Cruise Vessels, thus enable

  - 5000 passengers on a 330 m Vessel
  - Completely saved by Life Boats
  - Reduced Space for Live Saving Appliances
  - Increased Survival Rate and Direct Indoor Boarding

WP-4: Risk-based regulatory framework

7.5 Summary description of workpackage objectives

The objective of workpackage 4 is to establish an alternative new risk-based regulatory framework in shipping that allows linking performance optimization with risk minimisation as a means to providing solutions in order to increase the safety and security of waterborne transport cost-effectively. On this basis, WP4 aims to perform Formal safety Assessments (FSAs) for the selected ship types in SAFEDOR, to make explicit the current implicit safety levels in existing rules and regulations, to agree on and develop necessary documentation for a risk-based regulatory framework that could be implanted in shipping and to propose and promote the new regulatory framework at IMO and within IACS.

Thus, the first four subprojects, namely the FSAs, aim at documenting the risk level for the selected ship types, including all major accident scenarios, and to identify cost-effective risk control options related to design and operation.

7.6 Contractors involved

The WP-4 Leader is the Det Norske Veritas, DNV, www.dnv.com, represented by Dr Rolf Skjong Phone: +47.67.57.75.34, Fax: +47.67.57.75.20, Email: Rolf.Skjong@dnv.com

All the contractors involved in WP-4 are:

- SP 4.1: FSA for Cruise Ships
  DNV (SP-Leader), CAR
- SP 4.2: FSA for RoPax
  SSRC (SP-Leader), LMG, FSG, COLOR, DNV
- SP 4.3: FSA for Gas Tankers
  DNV (SP-Leader), LMG, NAVANTIA, IST
- SP 4.4: FSA for Containerships
  GL (SP-Leader), AMTW, Döhle, SSPA
- SP 4.5: Risk-Based Regulatory Framework
  DNV (SP-Leader), SSRC, GL, DMA

7.7 Work performed - Results achieved so far

SP4.1 FSA for Cruise Ships

The main objective of the SAFEDOR project is to propose a new, or improved, regulatory framework which will permit the approval of innovative ships that challenge today's prescriptive regime of rules and regulations. The FSA studies are carried out in order to establish the current safety level.

The SAFEDOR WP 4.1 – FSA for cruise ships – is divided into three subtasks:

- Task 4.1.1 – Hazard identification
- Task 4.1.2 – Risk analysis
- Task 4.1.3 – Cost benefit analysis and recommendations

Task 4.1.1 – Hazard identification

Two workshops were preformed by gathering a panel of different experts from the cruise industry to assess the risk exposure on cruise ships. One workshop dealt with the operation of the cruise vessel, and one looked at the design of the vessels. A total of 118 hazards related to operation and design were identified, of which 12 hazards were prioritized based on their consequences and the possibility for finding cost effective risk reducing measures. The second workshop focused on hazards with high consequences and low frequency rather than low consequences and high frequency identified in the first workshop, utilising experts from the shipbuilders (Fincantieri) and the regulators (MCA) in addition to the partners involved in the workpackage.

The five major collision, grounding & contact hazards identified:

- Officer on duty not watch-keeping
- Failure of critical navigational aids (in fog)
- Severe loss of functionality (e.g. loss of rudder/steering at full speed, failure of shaft bearings)
- Lack of knowledge of navigating procedures
- Misinterpretation of bridge information

The five major fire/explosion hazards identified:

- Arson - deliberate act resulting in a fire. Could be anywhere, anytime
- Galley - deep fat fryers/greasy cooking appliances catching fire (due to overheating)
- Engine room - flammable fluids on hot surfaces
- Laundry - lint from tumble driers catching fire
- Cabins - fire starts in cabin (cigarettes, candles, electrical equipment failure etc)

"High consequence hazards" have been identified that are relevant for design and operation of cruise vessels. Identified hazards cover potential high-consequence incidents, rather than low-consequence slips & fall hazards. Hazards have been identified, covering all aspects of operation from navigation, voyage planning, passenger movements, through to emergency operations.

Task 4.1.2 – Risk analysis

The risk modelling has been performed at high level in order to produce an overall risk picture for the generic cruise ship. However, in order for the FSA to provide value for an operator as a practical tool for decision-making under the design phase, more detailed risk models are necessary.

The study has been performed for a typical Post Panamax cruise vessel of 110.000 GRT that typically carries a total of four thousand (4000) people (passengers + crew). Due to the large number of people involved, only safety risk has been evaluated with consequence expressed through loss of life. Business and environmental risks are not considered.

Risk level for societal risk has been presented using a FN diagram; the risk level for individuals is presented as fatality frequencies. The results concern one specific ship chosen to represent the current cruise fleet and ships.

Almost half (46%) of reported accidents involving cruise ships are events other than the four modelled hazards (collision, grounding, contact, fire/explosion). However, the four modelled hazards accounts for 97% of the risk (fatalities). Collision and Grounding together amount to almost 95% of the risk (58% + 36%). Fourteen -14- fatalities per ship-year can be expected for the cruise fleet. Comparing to historical data, 2,4 fatalities have occurred per year in average for the 1990-2004 period (36 fatalities in 15 years).

Almost 90% (87,1) of the risk lies within the large-scale accident category of 2,000 fatalities. Smaller accidents with 2 or 5 fatalities can be expected every 5-7 fleet years. This corresponds well to historical data from LRFP. However, the large-scale accidents are the main risk driver.

The risk level for identified accident scenarios is within the ALARP region, i.e. RCO's should be identified. Collision and grounding account for 95 % of the risk (fatalities). Catastrophic accidents with large number of fatalities account for 90% of the risk, although the frequency for such events is very remote.

Task 4.1.3 – Cost benefit analysis and recommendations

This task will focus on identifying RCO's for large-scale collision and grounding accidents. However, the risk level is within the ALARP area meaning that only cost beneficial RCO's should be recommended for further studies/implementation. This task is to be completed. Clear recommendations and proposal for further work/studies will be included.

SP4.2 FSA for RoPax

Subproject 4.2 aims at conducting a high-level FSA study for RoPax vessels with main technical objective to assess the current/existing level of safety and make recommendations for future improvements. Results will be formatted such that a submission at IMO is possible (standard reporting format specified in MSC Circ.1023/MEPC Circ.392).

The activities of the sub-project are organised in the following three tasks:

- Task 4.2.1: Hazard identification (HAZID)
- Task 4.2.2: Risk analysis
- Task 4.2.3: Cost-Benefit Analysis and Recommendations

Task 4.2.1 – Hazard identification

A HAZID report on RoPax vessels has been produced based on a HAZID meeting (held in Sandefjord, Norway at the Color Line Marine AS offices on 13 and 14 of June 2005, with the participation of all SP 4.2 partners and an external representative from the UK Maritime and Coastguard Agency).

The risk register developed during the HAZID meeting contains a total of 62 hazards. 58 hazards have been evaluated for probabilities and consequences (four ordinary hazards were also identified, but no evaluation was carried out), based on an 8 × 5 Risk Matrix, which is an extension of the standard 7 × 4 Risk Matrix contained in the IMO FSA Guidelines. 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)

The added value of the HAZID work is that it facilitates a more focused risk analysis and cost-benefit assessment through pinpointing the challenges regarding design/operation of a RoPax vessel.

Task 4.2.2 – Risk Analysis

Casualty data obtained from the Lloyd's Marine Information Unit (LMIU) for the period 1994 to 2004 have been used to carry out the risk analysis for RoPax. This period was selected for the following two reasons:

- A comprehensive QRA study on North West European RoPax has been reported on October 1996, as part of the activities of the NWE Project on the Safety of RoPax in North West Europe, covering the period 1978 to 1994 (partly extended to 1996 to include major accidents), i.e. the whole period that casualty data were available at that time.
- The period from 1994 onwards has been a period of development of a significant number of important new rules and regulations; hence this FSA study could provide estimates on the improvement of RoPax safety level in relation to previous historical data.

World-wide casualty experience has been utilised for the purposes of this study. RoPax vessels have been categorised in two GRT groups, one at the range of 1,000 to 4,000 GRT (small RoPax) and the second including all RoPax vessels of 4,000 GRT and above.

The analysis is carried out on the basis of 285 incidents of RoPax vessels between 1,000 to 4,000 GRT and 766 incidents of RoPax vessels of 4,000 GRT and above. Tables 3 and 4 give some of the details of the data analysed. Further detail, regarding non-fatal incidents, is available but not included here.

Work is currently being carried out on developing a risk model for RoPax vessels, on the basis of the data above, further analysis and also use of expert judgement. The risk model will in turn provide input to the cost-benefit analysis for RoPax vessels.

Task 4.2.3 – Cost benefit analysis and recommendations

Based on the ALARP principle, risk-control options will be drawn up. Risk-control options for hazards with a high contribution to the total risk should be emphasized. In this task, the market is to be surveyed for new and existing equipment. Cost-Effectiveness Analysis will assess every measure. In this analysis, the benefit from each measure will be converted to monetary value by using recognised methods. The estimated value will be compared to the cost of implementing the measure. Favourable measures will be the measures where the cost of implementing are less than the benefit the measure will supply. The total costs of implementing measures will be based on life-cycle costs. This task is to be completed in the beginning of the second year.

SP4.3 FSA for Gas Tankers

The principal objective of this FSA is to document the risk level for the LNG carriers, including all major accident scenarios, and to identify cost-effective risk control options related to design and operation.

The FSA for LNG also provides a valuable input to the risk-based design process to be conducted in WP-6 (SP6.7) for a short-sea LNG vessel, in terms of highlighting focus areas in the design process.

During the first year, the three tasks described below were active.

Task 4.3.1 – HAZID for LNG Tankers

This task focused on the first step – Hazard Identification – in a high-level, generic FSA study on ocean going LNG carriers involved in international trade. The HAZID has been conducted based on a membrane-type 138.000 m3 LNG carrier.

A structured approach to identify hazards has been utilized based on studying the various operational phases of the tankers through: identifying hazards, describing their failure modes, outlining risk reducing measures that can prevent or mitigate each hazard and analyzing their frequencies and consequences, thus ranking the hazards.

The main findings from the HAZID session are that no separate hazard forms an immediate threat to the operation of LNG vessels. However, summarising the various risk contributions may indicate that there are a number of scenarios that should be further evaluated in the risk analysis. The preliminary conclusion on ranking of scenarios seems to indicate that the scenarios "collision", "grounding" and "occupational accidents" should be prioritised in the risk analysis work.

The HAZID session was attended by a team being representative for the maritime industry that is involved with design/building/operation of LNG tankers. A HAZID report on LNG tankers has been developed based on a HAZID meeting, the resulting risk register from the meeting and the consequent follow-up work and discussions.

Task 4.3.2 – Risk Analysis of LNG Tankers

This task focused on the second step – the risk analysis – in a high-level, generic FSA study on ocean going LNG carriers involved in international trade.

This task is the first high level FSA that has been carried out for LNG carriers and the main aims of this study are:

1. To identify high risk areas where further attention can be focused, e.g. by identifying and evaluating risk control options
2. To develop a baseline risk level for the world fleet of conventional LNG carriers, to be utilized in comparison with risk-based design of innovative solutions for LNG carriers.
3. To demonstrate the feasibility of generic FSA studies

The scope of task 4.3.2 is limited to embrace safety issues and loss of lives. Thus, risks to the environment and property are regarded out of scope, as are security risks. This risk analysis only covers the operational phase of an LNG carrier's life cycle. Furthermore, only the shipping stage in the LNG value chain will be considered. Regarding third party risks, only risks to LNG crew and to crew and passengers onboard other vessels that might be exposed to additional risks from LNG shipping will be considered.

A review of selected previously published literature on LNG safety has been performed as well as a thorough review of historic accidents involving LNG carriers. In the risk assessment carried out for each of the selected accident scenarios, actual accident frequencies from the history of LNG shipping were adopted in the frequency assessment, whereas an approach utilizing event trees was exploited for the consequence assessment.

This task concluded that both the individual and the societal risk associated with LNG carriers are within the ALARP area. This means that risks should be made ALARP and that cost effective risk control options should be implemented. Therefore, further studies on identifying and evaluating prospective measures are recommended.

Task 4.3.3 – Cost benefit analysis and recommendations

From the Risk Analysis, it was concluded that three generic accident scenarios together are responsible for about 90% of the total risk, i.e. collision, grounding and contact accidents. Thus, this task, which is still ongoing, is focused towards these. In particular, this tasks focuses on found measures (RCO) related to Navigational Safety, Manoeuvrability, Collision and Grounding Avoidance, Cargo Protection, Damage Stability and Evacuation Arrangements.

SP4.4 FSA for Container Ships

The objective of SAFEDOR project SP4.4 was to perform a high-level Formal Safety Assessment (FSA) in order to establish the current safety level for generic container ships. The activities of this project are organised according to the following task structure directly reflecting the steps of an FSA:

- Task 4.4.1 – Hazard Identification (HAZID),
- Task 4.4.2 – Risk Analysis,
- Task 4.4.3. – Cost-Benefit Analysis & Recommendations

Task 4.4.1 - Hazard Identification

In accordance with the IMO guidelines for FSA, a HAZID for container ships was conducted to identify and analyse conceivable and relevant hazards and to establish a comprehensive list of hazards associated with the operation of container ships. Failure modes, causes and effects were identified using the Failure Mode and Effect Analysis (FMEA) technique. Existing constructions, as well as new designs, were considered. Special attention was paid to open top constructions where appropriate.

Three (3) moderated expert meetings were organised, each of them associated to a phase of operation. The following phases were considered most relevant for a high-level analysis:

- Operation in port, loading and unloading
- Restricted waters and costal passage
- Open seas voyage

Sixteen -16- experts from 6 companies with background in design, operation and regulation of container ships participated. In total, 91 hazards in 22 scenarios were identified. Some of the scenarios are covered more than once, when the different contexts suggested different results with respect to the consequence. Risks to human life, for the environment, for cargo, and for the ship have been considered.

Based on the list of identified hazards, an evaluation of severity and frequency took place using tables standardized across WP 4. Participants estimated frequencies and consequences individually. Based on their feedback, a consolidated table was compiled. Risk indices for all risk types listed above were calculated as arithmetic mean. The range between minimum and maximum risk index was used as quality measure. Afterwards, a Delphi-like method was successfully applied to streamline the assessments. The number of large deviations was reduced significantly.

Hazards with a risk level higher than a defined threshold value were listed, resulting in four lists with 5 (five) hazards for human safety, 13 (thirteen) hazards for environment, 13 (thirteen) hazards for cargo and 11 (eleven) hazards for ship.

The scenarios “Large Ship Motions”, “Lashing”, “Contact”, “Human Error”, “Collision”, “Fire & Explosion”, “Structural failure”, and “Unlawful act” have been identified and suggested for later analysis.

For a “high-level” FSA many experts needed to be involved. However, experience shows that the availability of experts is a limiting factor, not only in this project, but also in general. Another lesson learned is, that an onsite assessment by the team should be preferred over distributed assessment since estimates of frequency and severity are heavily based on a common understanding of the hazards and scenarios.

Task 4.4.2 - Risk Analysis

The results from the HAZID were used as major input for the risk analysis. A number of significant scenarios were chosen to be modelled in details. These scenarios are general scenarios like collision, grounding, fire & explosion, but also some specific to container ships like loading/unloading including lashing and water ingress into container hold. A risk-model was developed describing the safety level of current container ships. Both potential loss of life and environmental impacts were considered.

The total frequency figures and total expected number of fatalities were combined to derive key safety indicators such as PLL (Potential Loss of Life) per ship year for each scenario. Cumulative figures for the expected number of crew fatalities for each scenario sequence were compiled and presented in FN diagrams.

An extensive analysis of casualty data for containerships was conducted based on database provided by Lloyd Maritime Investigation Unit in order

- to characterise the historic risk level in terms of fatalities (FN-curves), and
- to derive probabilities for the initiating events in the scenarios.

A high-level model, including event trees and also partial fault trees, was developed including contributions for all major scenarios. The estimated risk level based on historical data (LMIU data base), statistical analysis and expert judgement indicates that the collision scenario is the dominant risk. Compared with previously presented FN curves (IMO MSC72) for container vessels, the curve derived in this study shows higher figures in particular in the area with low number of fatalities. It can further be noted that the FN curve derived in this study only reflects a selected number of accident scenarios, but the water ingress scenario also include incidents registered as hull damage and foundering in the casualty statistics.

Important contributing factors, such as human error aspects and influence from heavy weather, are also integrated in the scenarios.

Though the FN curve developed in this study indicates a slightly higher risk level than previously statistically derived level, the presented curve still fits within the acceptance range (ALARP area) of the proposed acceptance criteria. For risk levels in this range, it is well motivated to consider additional risk control measures and to use cost benefit analysis to rank and compare different options.
It is believed that the event trees developed to estimate the presented FN curves will be an effective part in the process for identification and evaluation of risk control options in the nest FSA step.
A statistical report was provided as annex to the deliverable.

Task 4.4.3 - Cost-Benefit Analysis & Recommendations

The aim of this task is to quantify costs and benefits associated to selected Risk Control Options (RCO). Some RCOs have already been identified during HAZID and risk analysis, but no quantification of cost-benefit was done yet. Typical cost structures have been analysed.

SP4.5: Risk-Based Regulatory Framework

SAFEDOR will constitute a large activity on developing risk-based (probabilistic) methods and tools (WP2), innovative safety-critical technologies (WP3), risk based design environment (WP5) and innovative ship designs (WP6). All these activities constitute a broad experience base for developing the necessary risk based regulatory framework.

The objectives of Subproject 4.5 are:

- To develop relevant documentation that together defines the new alternative regime
- To promote the regime
- To educate the regulator

Task 4.5.1: Approval Process for Novel and Risk-based design

The objective of this task is to develop a high-level description of the whole approval process in cases of risk based design.

The approval process is developed based on relevant literature and the results of a number of interviews with approval engineers and consultants within DNV (carried out in the period September-October 2005). Focus is on the approval authority (which includes flag administrations, classification societies, and other organisations doing approval of ship design) and the interaction with the client.

At this stage, only a preliminary version of the overall approval process is presented. It includes overall descriptions of use of risk acceptance criteria, methods, tools and required documentation. The preliminary version is to be distributed to the SAFEDOR project participants to communicate what will be the requirements to approval of novel and risk-based designs, and thereby influencing the direction of the developments in the subprojects (i.e WP3 and WP6). The process, as well as this report, will be detailed, revised and updated towards the end of the SAFEDOR project, based on the feedback and learning from the different subprojects. The final document will form the basic high level reference document for all parties involved in approval of novel and risk-based designs – from the project concept stage through maintaining approval during operation. The end-result will meet the overall purpose of SAFEDOR SP4.5 of defining and documenting an alternative approval regime for risk-based design.

The approval process, illustrated in the next figure, describes the overall procedure for obtaining and maintaining approval for designs that are novel or risk-based. As seen from the figure, the process, which covers concept development through operation, includes the following milestones:

- Preliminary Approval (if requested by the Client)
- Approval

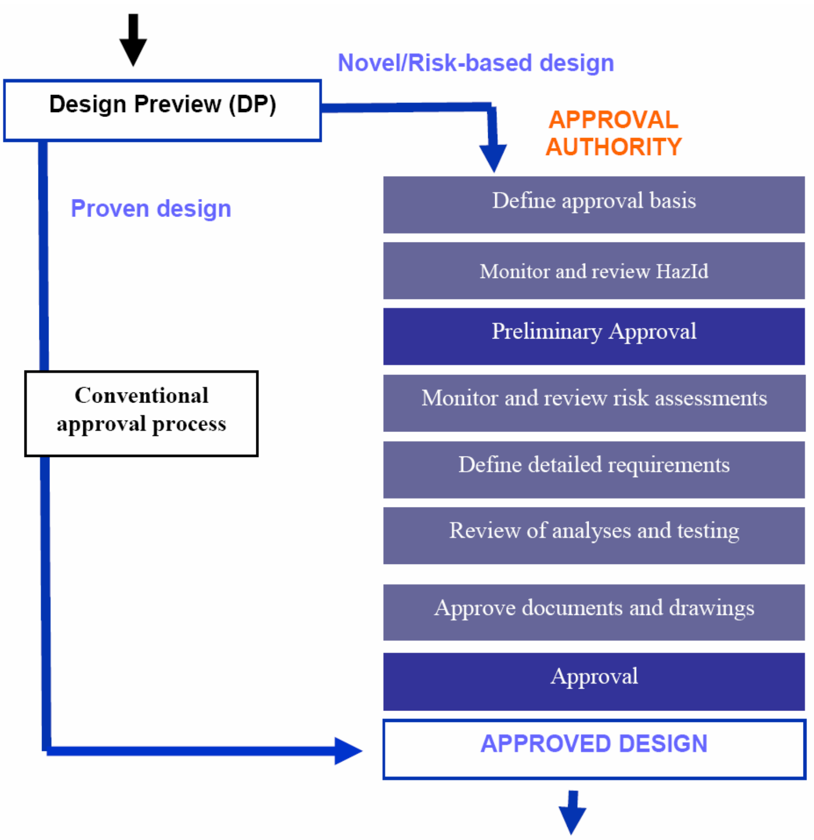

Figure 13: High-level approval process for novel and risk-based design

As a first step in the approval process, the client should be invited to a Design Preview meeting in order to discuss the concept, the novel or risk-based features, relevant rules/guides/codes/standards, as well as the further steps involved in the approval process. Following the Design Preview meeting, the next step is for the Approval Authority to define the approval basis. The client and the Approval Authority should also discuss plans for risk assessments (including decision of which acceptance criteria to utilise) and plans for testing and analyses. All novel or risk-based designs should be subject to a HAZID requirement. Thus, the client will be required to arrange a HAZID (or similar such as HazOp, SWIFT, etc.), and is required to invite an Approval Authority representative to attend the HAZID.

Typically, the client will seek an early indication of approval, which may be given through a Preliminary Approval (PA). The Preliminary Approval enables the client to demonstrate that an independent third party attests to the novel or risk-based design, which may be useful with respect to project partners, financial institutions and regulatory agencies. This may also assist the client in staying focused on the most important issues and ensure that the money is spent wisely.

The work performed related to risk assessments should be documented and submitted, in order for the Approval Authority to stay informed of the processes and to intervene if necessary. Eventually, the risk assessments will be included as the basis for approval. As the level of understanding of the concept increases, following the clients detailed design phase and the risk assessment phase, the Preliminary Approval conditions may be revised. That is, the requirements to be met in order to achieve final approval will be described in more detail. The engineering analyses and test are used to verify that the design is feasible with respect to intentions and overall safety in all phases of operation. The Approval Authority needs to review both the manner in which the analyses and tests are performed and the result itself. All documents and drawings required submitted by the client should be verified by the Approval Authority. This process is the same as for traditional ship design approval processes. For novel or risk-based features, the documents and drawings are to be approved based on requirements defined in the Preliminary Approval and the “detailed requirement” phases. The Approval phase will cover typical approval submittals, such as drawings, specifications, and support documentation, in addition to the submissions specified at the time of achieving PA. At the time of approval, all potential hazards and failure modes for the novel or risk-based design will have been assessed versus acceptance criteria, to a level of confidence necessary to grant approval.

Approval will in most cases of novel and risk-based design involve conditions related to in-service surveys, inspections, monitoring, and possibly testing. (These conditions will be fairly fixed already during the design phase.) The periodic surveys may be expanded with respect to scope and frequency, in order to maintain and review the class certificate. As experience accumulates and confidence in the novel or risk-based design is gained, these additional conditions and requirements may be relaxed.

The approval team should include approval professionals covering all disciplines involved in the novel or risk-based design. The team should have the combined necessary competence with respect to design, structures, systems, equipment, construction, operation, human factors, safety issues and legislation as necessary for the specific novel or risk-based concept. The level of expertise that individuals should have to participate in the team may vary depending on the complexity of the novel or risk-based design.

Task 4.5.2 Risk Evaluation Criteria

This task intends to describe a general philosophy for deriving criteria for tolerable/ALARP/intolerable regions of risk, and the R (“Reasonable” in ALARP), as well as deriving criteria for the most common ship types. The D-4.5.2 report [5] discusses various risk evaluation criteria with relevance to shipping and ship design. In particular, risk acceptance criteria for safety and environmental damage are considered. The report contains a review of existing criteria and discusses current practice within IMO. In addition, new proposals are presented in areas where risk evaluation criteria have not been commonly used, e.g. in cost effectiveness criteria for risk control options related to environmental risk.

The D-4.5.2 report on Risk Evaluation Criteria [5] consists of three major chapters, namely chapter 2, 3 and 4:

- Chapter 2 contains a description of general principles on how risk evaluation criteria may be derived. Of particular relevance to risk-based design and the work within SAFEDOR are the ALARP principle and the principle of equivalency. Various risk acceptance criteria are generally needed in order to assess an activity in terms of risk. First, limits for when the risk is intolerable should be established. It would also be useful to define a limit for when risks are regarded as negligible. Then, cost effectiveness criteria should be decided upon, in order to evaluate whether risks are ALARP if in the ALARP area. The principles discussed in chapter 2 are applied to safety in chapter 3 and to accidental environmental releases in chapter 4.
- Chapter 3 largely relies on work done prior to SAFEDOR, and was reported in e.g. an INTERSHIP II-2 report in 2004 [8]. This part has only been subjects to some updates, accounting for recently published papers and results.
  The chapter discusses various risk acceptance criteria related to safety for individual risk and societal risk. The main focus is on fatality risk, but also the risk of non-fatal injuries and ill health is covered. Furthermore, cost effectiveness criteria in terms of the value of preventing a fatality are considered. A review of actual cost effectiveness in previous life saving interventions is also carried out.
- The major new research reported is in Chapter 4, containing the risk evaluation criteria for accidental releases to the environment. Whilst there has been some general agreement on risk evaluation criteria for safety, no review or proposal has been presented for general use in IMO FSA studies, or in risk-based designs relating to environmental risk. This issue was in the terms of reference of the IMO FSA working group at MSC 80 (May 2005), and the work with this chapter therefore started after MSC 80. However, as no proposal was submitted to IMO, this topic was not debated in any detail and was put on the terms of reference of the correspondence group FSA working intersessionally between MSC 80 and 81 (May 2006). This deliverable was therefore made available to the IMO correspondence group, which reviewed and included an extract in the report to MSC 81, including references to the full report.

Task 4.5.3 Acceptance criteria for main ship functions/systems

The objective of this task is to develop a methodology for setting acceptance criteria at main function/system level. This is needed to facilitate approval of innovative ship designs with limited deviations from prescriptive designs, with the aim to minimise the amount of work and documentation required for a safe, transparent and consistent approval process.

The relevant report is planned to include three sections:

- Use of implicit criteria stated in reviewed FSAs for approval of innovative design
- Use of acceptance criteria for main ship functions for approval of innovative design
- Suggested format for Acceptance criteria for main ship functions

The first two sections will describe two approaches or methodologies to setting acceptance criteria. The third section will outline what the criteria will look like. Work on the two first sections has been initiated, and an initial draft has been produced for section two. A possible definition of main ship functions has been identified.

7.8 Anticipated End Results - Intentions for use and impact

Further to the work conducted in the first project year, as described above, the following tasks are also to be completed throughout the SAFEDOR duration, under this workpackage:

- Target reliabilities in structural reliability
- Assessment and approval process for risk-based ship system design
- Methods and techniques in support of ship system safety analysis
- Requirements to documentation and verification
- Requirements to key personnel involved in the assessment and approval process
- Risk-based design philosophy

8 WP-5: Risk-based design framework

8.1 Summary description of workpackage objectives

Workpackage 5 aims at providing the necessary conceptual and practical developments to facilitate the implementation of risk-based design. In terms of the conceptual developments, the main objective is:

- to consolidate a high-level understanding of risk-based design as a process in the light of current ship design practice.

In terms of the practical developments, two objectives are pursued:

- to develop performance-earning-cost-risk parametric models specific ship types (cruise, ropax, gas tankers and containerships) and to propose a generic formulation for use in ship design optimisation
- to develop a specification for an integrated ship design platform, incorporating the elements of risk-based design and implement and demonstrate its applicability with an IT platform incorporating the developments of SAFEDOR (safety-performance evaluation and risk analysis tools)

8.2 Contractors involved

The WP-5 Leader is the Universities of Glasgow & Strathclyde, the Ship Stability Research Centre (SSRC), www.na-me.ac.uk, represented by Dr Luis Guarin, Phone: +44 141 5725571, Fax +44 141 572 5590 , email: Luis.guarin@na-me.ac.uk

All the contractors involved in WP-5 are:

Key Partners: SSRC, DNV, GL, CAR

- SP 5.1: Risk-Based Design Concept
  SSRC (SP Leader), GL, DNV, DMA, FSG, NAVANTIA, CAR, NTUA, DTU, CAT, COLOR, FIN, Döhle, AMTW, LHC, BMT, AVEVA, DM, VSHIPS, DAPP, LMG, NAPA, SIR, MEY
- SP 5.2: Generic Risk-Cost-Earnings-Performance Model
  SSRC (SP Leader), GL, DNV, DMA, NAVANTIA, CAR, NTUA, DTU, CAT, COLOR, FIN, Döhle, AMTW, LHC, BMT, AVEVA, DM, VSHIPS, DAPP, LMG, NAPA, MEY
- SP 5.3: Integrated Design Environment
  SSRC (SP Leader), GL, DNV, DMA, NAVANTIA, CAR, NTUA, DTU, CAT, COLOR, FIN, Döhle, AMTW, LHC, BMT, AVEVA, DM, VSHIPS, DAPP, LMG, NAPA, SIR, MEY

8.3 Work performed - Results achieved so far

WP 5 is structured in three sub projects (SP) as follows:

- SP 5.1: risk-based design concept
- SP 5.2: global risk-cost-earnings-performance model
- SP 5.3: integrated design environment

The activities of WP 5 during the first year were focused on consolidating a high-level working concept of risk-based ship design with a view to set the course for the developments expected during other SAFEDOR key tasks and providing preliminary guidance for its implementation in the design projects in WP6. These activities were approached by conducting a series of brainstorming "plenary" meetings with the majority of the partners of the project, aimed at consolidating basic notions related to current ship design practice and with a view to understanding the role, the impact and the limitations of using prescriptive regulations in ship design as a way to achieve safety design goals.

In this respect, a high-level and generic description of what constitutes current ship design practice (illustrated in Figure 14) was consolidated and used as a point of reference for subsequent discussions. On this basis it would appear fair to conclude that although modern design methods are capable of producing very good designs, these, are unlikely to be optimal for two reasons: (i) the design solution is constrained within the prescriptive regulation envelope, and (ii) design optimisation is not done systematically and is largely based on the designer's competence alone. Moreover, without being able to recognise the effects of slight modifications on the design at once, designers may adversely affect other design requirements while concentrating on a particular design aspect. Ship design is a juggling act of many factors including safe operation, technical performance, cost, logistics, feasibility, aesthetics, etc. In this list, safety is not considered later or less important than everything else, it is however limited to rule compliance and hence it is treated as a design constraint – not as a design objective. In this sense, it can be stated that a designer is deprived from exploring the complete design solution space and hence achieving a well balanced and optimal design solution is left to chance. The implications of this are twofold:

- The safety of the vessel may not achieve expectations or be at the right level as a result of complying with prescriptive regulations, the level of safety of which is largely unknown (explicitly),
- The safety of the vessel might have caused more cost than it should; the right trade-offs might have taken place, but this in turn might have led to reduced earnings and to a less competitive design.

This is particularly true for new design concepts, or design concepts incorporating innovative features for which operational experience is very limited or does not exist at all. Indeed, the fundamental advance of risk-based design in relation to current ship design practice is the explicit, rational and cost-effective treatment of safety, and this is based on the following principles:

a) A consistent measure of safety must be employed and a formalised procedure of its quantification adopted (risk analysis). For this to be workable, considering the complexity of what constitutes safety, a clear focus on key safety "drivers" is necessary (major accident categories). A number of formalised procedures for risk quantification, risk assessment and risk management exist in various contexts, for instance Formal Safety Assessment (FSA) for rule-making, Safety Case addressing for specific design/operational concepts, among others. Adding to these, a risk assessment framework for use in ship design has also been proposed and described in this report.

b) Such procedure must be integrated in the design process to allow for trade-offs between safety and other design factors by utilising overlaps between performance, life-cycle cost considerations, functionality and safety at parameter level. A high-level framework for this integration is illustrated in Figure 15. Consequently, additional information on safety performance and risk will be available for design decision-making and design optimisation. However,

c) Considering the level of computations that might be necessary to address all pertinent safety concerns and the effect of safety-related design changes on functionality and other performance factors, a different handling is required; namely, the use of parametric models to facilitate trade-offs and access to fast and accurate first-principles tools. The design optimisation process becomes thus a typical case of multi-objective, multi-criteria optimisation problem. A common ship design model managed within an integrated design environment (software platform) will also be required for this process to be conducted efficiently. illustrates the elements to be integrated in such design environment.

In relation to (a), it ought to be highlighted that risk analysis requires the availability or development of risk models (see for instance Figure 17); the probabilistic quantification of such models requires safety-performance evaluation tools, which can consist of first-principle models, methods and when necessary numerical tools (adequately verified and validated) coupled with engineering judgement and necessary experiential knowledge as available (see Figure 18). Most of such tools and methods are well established and some are already commonly used in ship design. Examples of tools are those based on Finite Element Methods (FEM) or CFD (Computational Fluids Dynamics). The tools themselves would not – of course – generate the required probabilities, but their outcome can be used in a probabilistic manner (also using common sense and engineering judgment for interpretation of the results) to estimate risk.

In relation to (b) and (c), in addition to safety performance evaluation tools, risk-based design necessitates the development of the so-called knowledge models: these are parametric relationships derived on the basis of first-principles (model tests and/or numerical simulation), existing knowledge and data. Examples of Performance-related knowledge models include for instance the Holtrop-Mennen method for resistance, linking key hull form parameters to resistance; the Static Equivalence Method (SEM) for evaluating survivability of ro-ro ferries, linking survivability performance (limiting sea state, expected time to flood) with key design and environmental parameters (freeboard, car-deck arrangement, loading).

Similar models for Risk (derived from risk analysis, see for instance Figure 19), Cost and Earning potential (PERC models) would provide the designer with means to rapidly and reasonably accurately obtain quantitative information on the baseline design, and support a more rational design decision-making. Obviously, not all necessary such models would be available in all cases; however, the implied availability of a global parametric description of the baseline design solution would facilitate the use of explicit performance and safety-performance (first-principles) evaluation tools and would allow formal (numerical) optimisation techniques in ship design to be used effectively. A concept of this "common-model approach is illustrated in Figure 20.

It is worth emphasising again that the possibility of optimising ship performance without regulatory constrains is what would make a significant difference in ship design decision-making as the best design solution (from all relevant perspectives) may lie outside the regulatory envelope (see Figure 21). Established optimisation tools and techniques can help the designer to explore a much wider design solution envelope within the time scale available during early design concept development and beyond. For this to be practical, an integrated design environment is needed.

The high-level concept of risk-based design described above, as reported in D 5.1.1 and D 5.1.2 reflects the knowledge and experience in terms of current ship design practice and the understanding of risk-based design of the partners contributing in these discussions. It must be said that the synthesis provided in D 5.1.1 was a very challenging task due to the fact that operators, ship owners, building yards, equipment manufacturer, class societies, administrations, researchers, etc, all seemed to have a different understanding of risk and the associated notions. Although there was a more or less consolidated view of ship design as a process, there were quite diverging views as to what a risk-based design approach for ship design entails. Equally diverging were the expectations from the so called risk-based design process. Consequently, it is fair to state that it is too early to expect that, even within the SAFEDOR consortium, total 100% agreement on a consolidated concept of risk-based design can be achieved. There is a more or less consolidated understanding of risk-based design at a very high-level (explicitly among key partners) but that agreement and clarity does not exist at a lower – more practical, designer level. This is nonetheless to be expected, as it is through the application and implementation of these ideas that a clear concept can be achieved.

Thus, it is anticipated that during the developments undertaken by other WPs and during the development of the design concepts, the ideas presented here will be further elucidated, nurtured, refined and evolved.

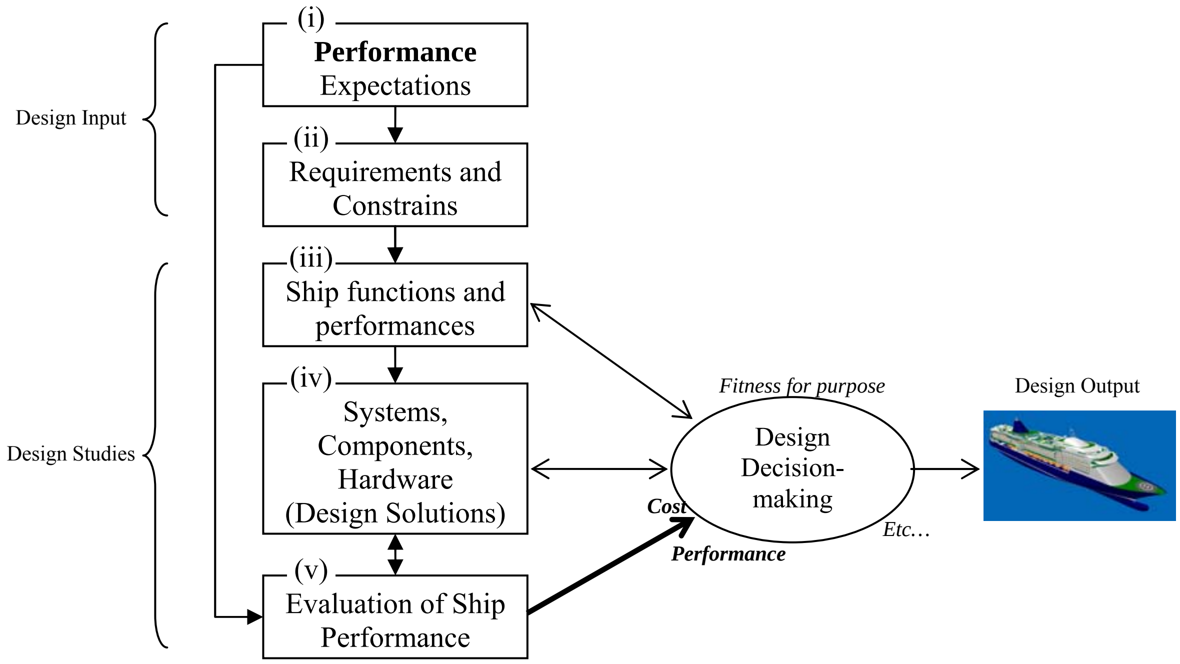

Figure 14: High-level *conventional* design process

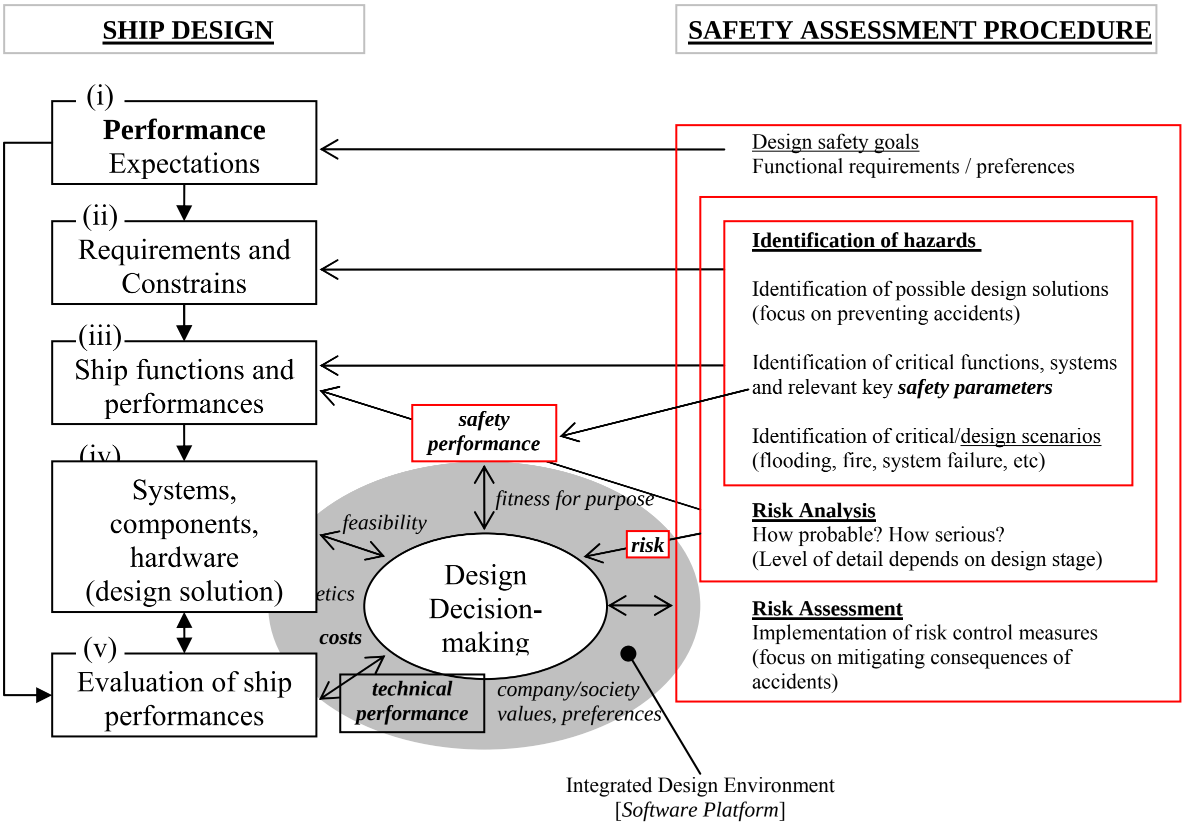

Figure 15: A high-level framework for risk-based design implementation

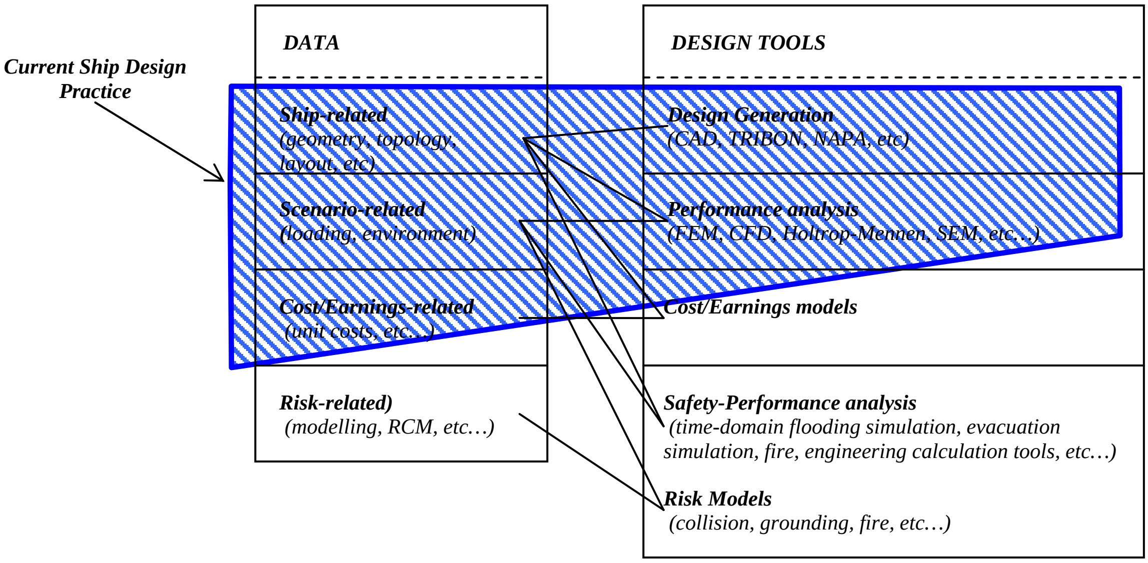

Figure 16: Design elements to be integrated within a risk-based design platform

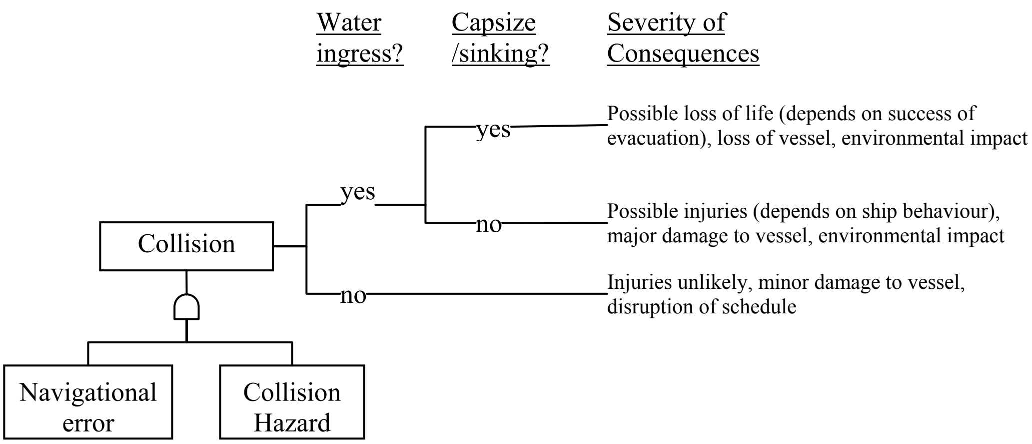

Figure 17: Example of a basic risk contribution tree (risk model) for collision

<u>Scenario:</u> *(including definition of environment, loading conditions, etc.)*

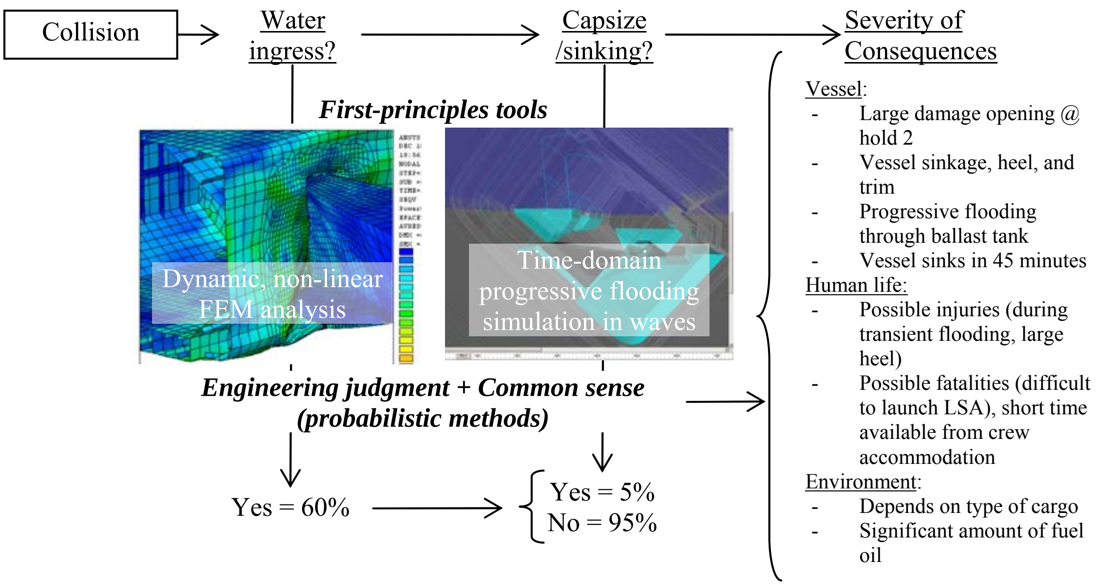

Figure 18: Role of “*first-principle tools*” in risk analysis

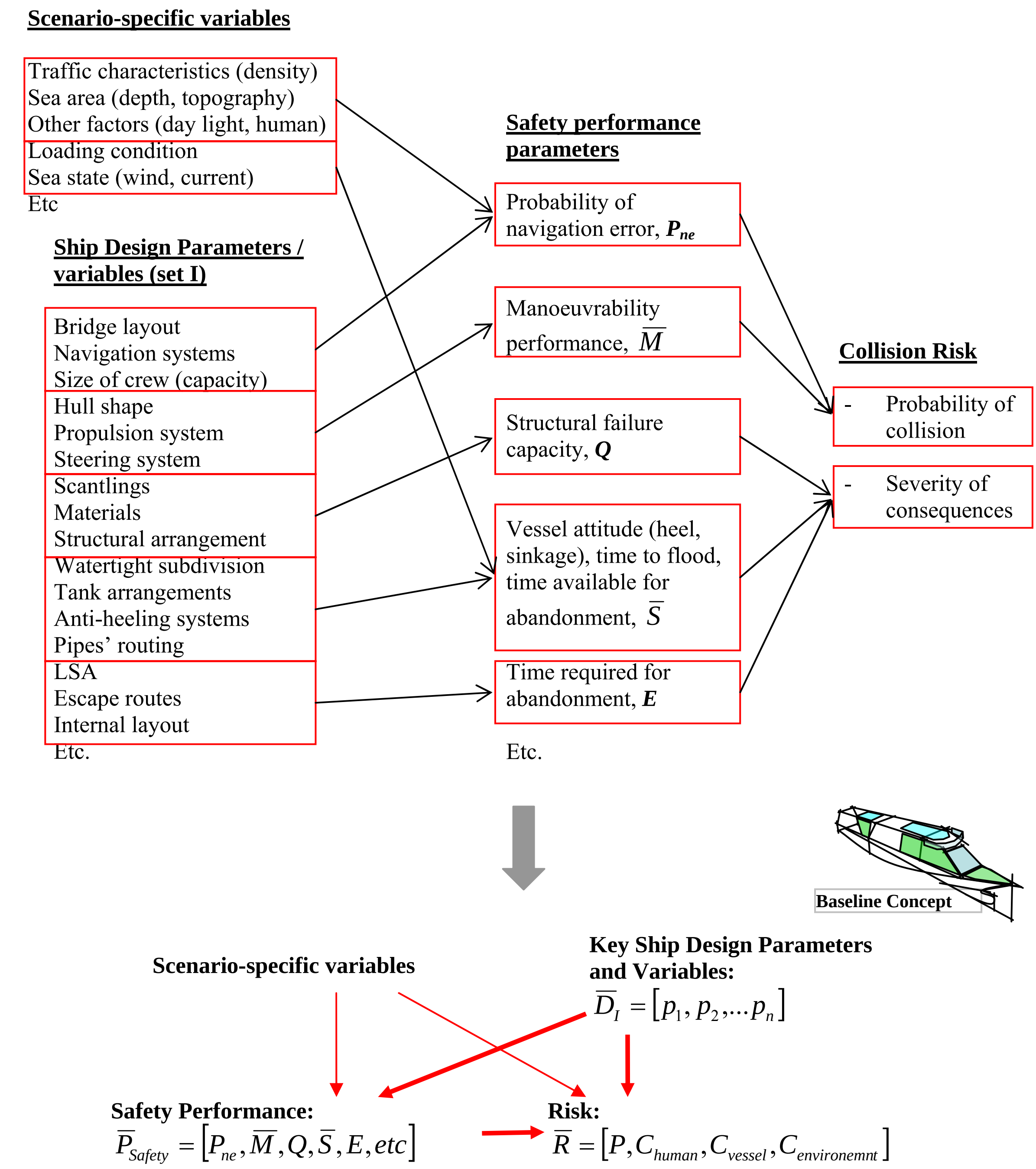

Figure 19: *Risk-knowledge model* of collision

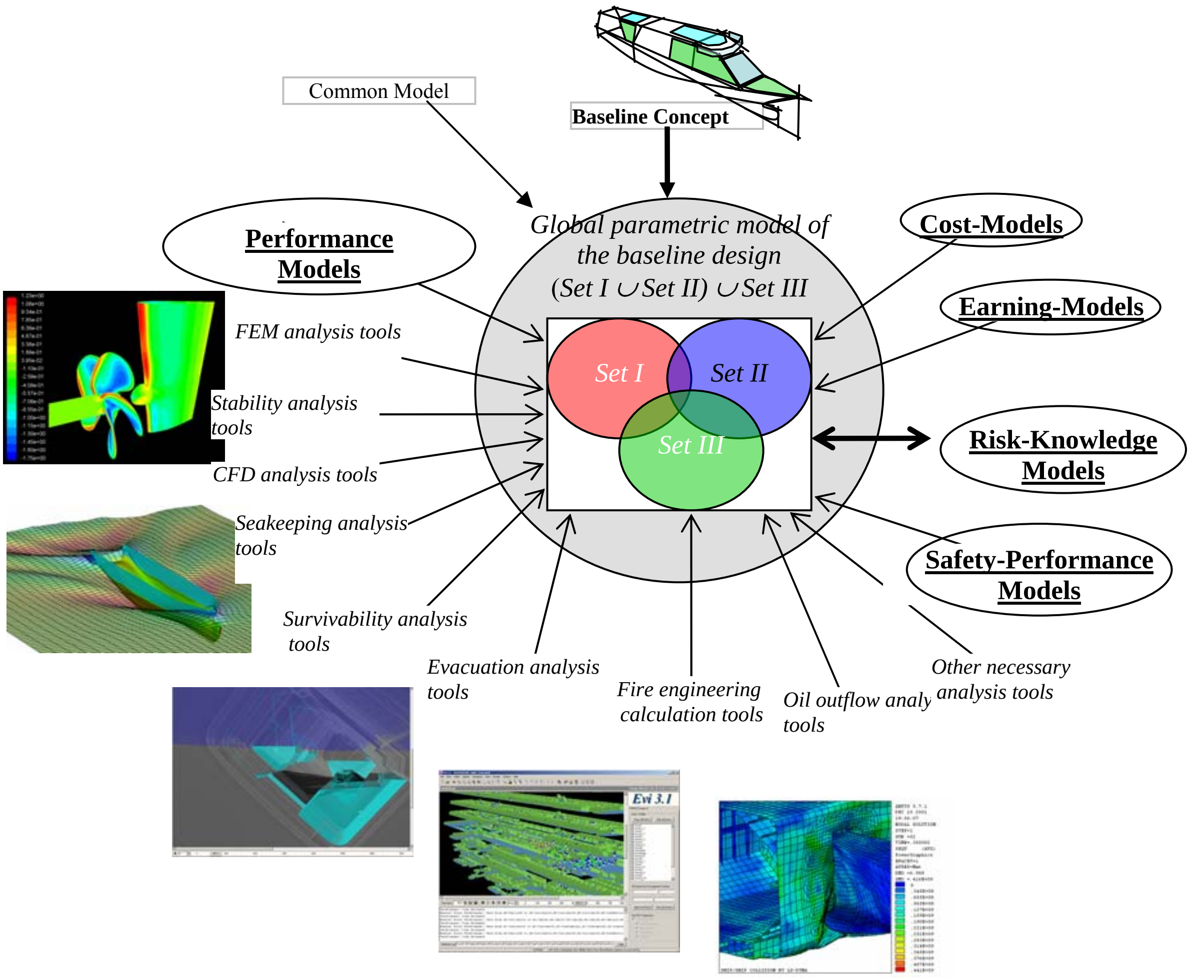

Figure 20: Concept for integration of *PERC knowledge models* [key parameters + prediction models] with performance and safety-performance analysis tools within a ship design optimisation environment

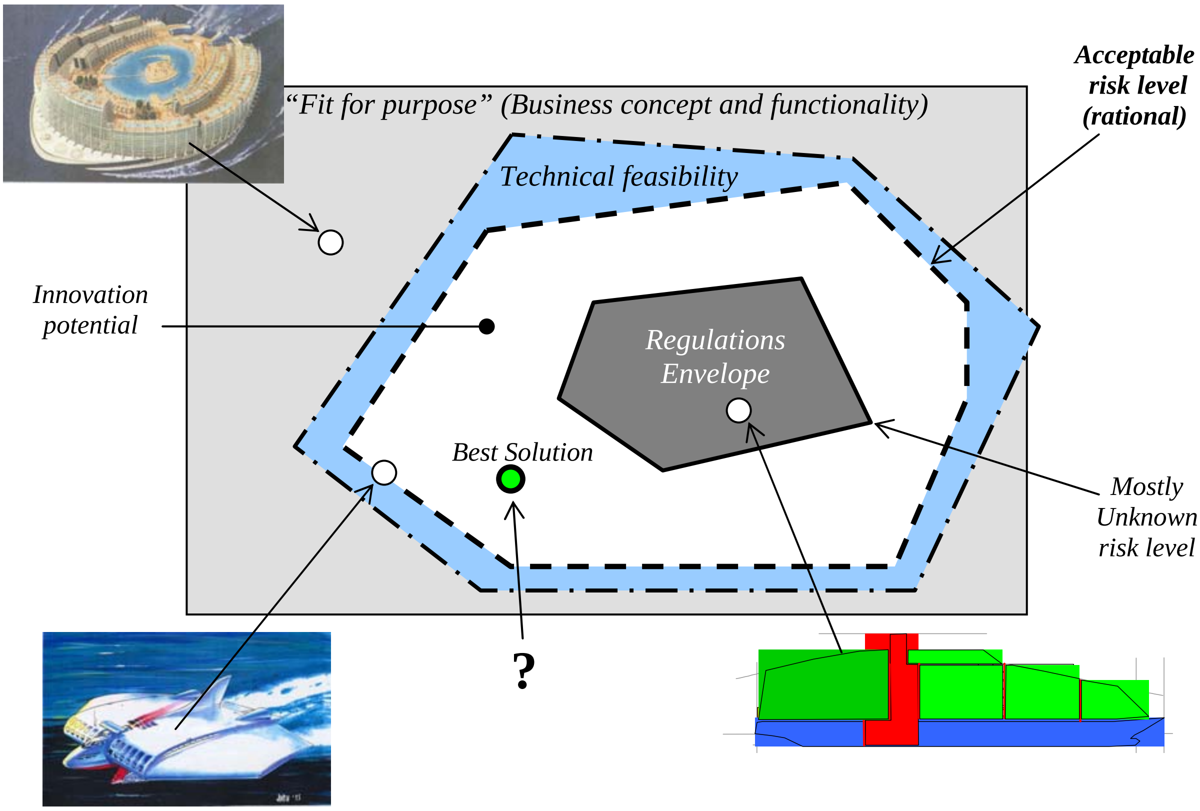

Figure 21: Possible design solution envelopes

8.4 Anticipated End results – Intentions for use and impact

Future activities of workpackage 5 and anticipated end results, with intentions for use and their impact, are as following:

- SP 5.1 aims at consolidating the concept of risk-based design. Hence, it should be the point of reference for all activities in SAFEDOR.
- SP5.2 aims at developing cost/earning models for specific ship types to be consolidated into a generic cost/earning model for passenger and cargo vessels. In this SP, the probabilistic methods developed in WP2 (tool development) will be “convoluted” with cost-earning models. Hence, its outcome will be used in WP6 (conceptual risk-based ship design projects) for cost-effectiveness analysis.
- SP5.3 aims at defining and implementing an integrated ship design platform in which risk-based design can be demonstrated. Hence, its outcome will be used in WP6 in years 2 and 4 of the project.

9 WP-6: Validation and implementation for innovative ship designs

9.1 Summary description of workpackage objectives

The principal objective of WP6 is to focus on innovative ship designs that are expected to be as safe as today (with reduced building costs and / or improved earning potential), or safer than current ships, but for formal reasons cannot be approved under the current rules, class and/or flag regulations.

WP-6, by the use of the new developed methods and tools, aims to:

- test the practicability of the proposed risk-based design approach,
- challenge some regulations that restrain innovation,
- develop a common understanding for risk-based approaches by implementing it,
- gain experience that can be used to refine the documentation of risk-based regulatory framework and for the training, and
- eventually sustain competitiveness of European maritime industry by producing prototype designs

9.2 Contractors involved

The WP-6 Leader is the NAVANTIA S.A., Phone: +34 91 335 84 00, Fax: +34 91 335 86 52, http://www.navantia.es. , represented by D. Francisco del Castillo, Direct: +34 91 335 85 11, Fax: +34 91 335 86 53, e-mail: fcastillo@navantia.es.

All the contractors involved in WP-6 are:

- SP6.1 – INNOVATIVE CRUISE SHIPS – POST-PANAMA SIZE
  FIN (SP Leader), SAS, RINA, CAR, CET, SAM
- SP6.2 – CRUISE VESSEL
  ASD (SP Leader), H&W, LR, RCL, SAS
- SP6.3 – FAST FULL DISPLACEMENT FERRY
  DM (SP Leader), SAS, MEY, COLOR, DNV
- SP6.4 – THE 13th PASSENGER
  FSG (SP Leader), DFDS, GL, SAM, DMA
- SP6.5 – LIGHTWEIGHT COMPOSITE SANDWICH SUPERSTRUCTURE
  DNV (SP Leader), FSG, BRAA, FRC, STENA
- SP6.7 – RISK BASED DESIGN FOR SHORTSEA LNG VESSEL
  LMG (SP Leader), NAVANTIA, SNECMA, IST
- SP6.8 – INNOVATIVE OPEN TOP CONTAINER VESSEL
  AMTW (SP Leader), Döhle, HSUED, GL
- SP6.9 – SAFE AND OIL TANKER – AFRAMAX SIZE
  NAVANTIA (SP Leader), SSRC, NTUA, LR, ASME
- SP6.10- FINAL DESIGN AND APPROVAL IN PRINCIPLE OF INNOVATIVE SHIP 1
  GL
- SP6.11- FINAL DESIGN AND APPROVAL IN PRINCIPLE OF INNOVATIVE SHIP 2
  GL

9.3 Work performed - Results achieved so far

SAFEDOR has identified a series of eight (8) innovative ship designs that are expected to meet with above-mentioned objectives.
For each innovative design, the work to be conducted has been divided into 3 phases:

- Design Concept
- Design studies (Project Definition)
- Functional design phase.

During the first year of SAFEDOR, only the Design Concept (Phase 1) has been carried out for the innovative designs. Eight nascent concept ship designs have already been established. The defining feature is their attempt to overcome a specific safety related design goal, which for formal reasons could not be approved under current rules. These proposals will be whittled down at the project's midpoint (only two designs will be selected) for approval in principle by class societies.
At the moment, for each one of the eight (8) innovative designs, an identification of the design problem, rules that need to be challenged and the means of overcoming rule constraints to offer an acceptable level of safety cost-effectively have been developed.
A more detailed description of the progress of each subproject is given in the following.

Subproject SP6.1 – INNOVATIVE CRUISE SHIPS – POST-PANAMA SIZE

Design Problem

Post-Panama ships are very large and technologically complex vessels – continuously growing in size, very profitable and with high economic value for the European Industry.

The opportunity for adopting a goal-based design on this shiptype has not been systematically explored. A performance-based design approach may play an important role in this process.

Of course, ship designers may still take advantage of some SOLAS regulations offering the explicitly opportunity of proposing "equivalent" design solutions, but the difficulty in this approach is that safety levels and the required performances should be determined and agreed before assessing the equivalent level of safety of any alternative design.

In order to treat safety as a design objective, it is necessary to establish a performance-based regulatory framework.

Design Focus

Using a Post-Panama cruise ship as reference (130,000 GRT), the focus is to design, through performance based methodology, a new Post-Panama Cruise vessel with design solutions looking for a better client satisfaction and an adequate safety level referred to the design goals.

At the same time, the focus is to assess if a performance based design is more effective than a conventional design, based upon prescriptive rules and regulations, and if there is a sensible cost variation which may influence the decision.

Design Concept

The progress towards the design concept of this subproject could be summarized in the following:

- Definition of main commercial goals: range of operation, speed, payload, use of public spaces, operational flexibility, logistics etc..
- Definition of main safety goals: Stability (based upon a "platform optimisation" concept and the possible use of side sponsons), Fire prevention (innovative lay-out of large public spaces and stairway

enclosures), Evacuation and Abandonment (including compatibility with innovative Life Saving Appliances), Bridge design and equipment to prevent collisions.
- Analysis of regulatory framework.
- Setting of vessel functional requirements to meet the defined goals.
- Identification of Alternative Design and Performance Criteria to meet these goals.
- Preliminary Cost-Benefit analysis.
- Development of vessel specific design features, to be assessed by means of performance-based criteria.

Innovations Aspects

Specific intentions of this design concept are to introduce among other things:

- At least a public space exceeding the current size limits required by SOLAS
- Reconsideration of the prescriptive limits for fire load and material certification in public spaces.
- Type, arrangement, position and configuration of LSA.
- Use of stairway enclosures as assembly stations (Safe areas)
- Platform optimisation, based upon the new probabilistic damage requirements and escape requirements from flooded compartments
- Improved navigation / bridge equipment to prevent collisions.

Subproject SP6.2 – CRUISE VESSEL

Design Problem

At present, the safety of any vessel is defined with reference to strict prescriptive rules, all derived and created over many years with a constant feedback from incidents and accidents. However, the rules have primarily been written for passenger liners and not for actual tourist cruise ships, which are designed for a higher number of people onboard.

The increase of size required to introduce amended rules to SOLAS imposing further restrictions to the design and layout of future cruise ships: Fire-Zone length, Position and types of lifesaving appliances, Type of fire doors, Margin Line.

In addition, nowadays it is necessary to address new risks as:

- Terrorist attacks
- Pollution of the environment in case of fire, grounding or collision.

Design Focus

The focus is to design a Cruise Liner with Risk-Based tools and methods which will be safer than existing ones, in terms of passenger safety and which shall be designed with reduced incidental damages to the environment in case of grounding and collision comparing with existing vessels; And at the same time, to design a cruise vessel more attractive to the cruise industry with maximum exterior cabins, very large public rooms, which can be used as its own lifeboat.

Design Concept

The progress towards the design concept of this subproject could be summarized in the:

- Selection of a benchmark vessel
- Selection of a novel concept design.

From the start, the goal has been to create a vessel, which in all respects will be safer than the present ones, and the results of the first phase seems to be indicative that this goal can be fulfilled.

The development of the Concept Vessel has required a certain input from the industry. This has led to a very thorough investigation and testing of extremely large mobile fire barriers.

Innovations Aspects

Specific intentions of this design concept are to introduce among other things:

- Innovative and novel layout with very large fire-curtains, fire zones and watertight compartments
- balconies in all passenger cabins
- an upper structure working as a lifebelt in case of very large damages
- Transversal and longitudinal Cross flooding through valve operate trunks
- Novel machinery location, etc.

Subproject SP6.3 – FAST FULL DISPLACEMENT FERRY

Design Problem

Present prescriptive regulation: SOLAS 95, Stockholm Agreement, MSC 194 (80), Fire Safety and Evacuation requirements do not allow for design optimisation, from a point of view of safety, lightweight, payload, cargo capacity, etc.

Specific intentions of this design concept are:

- increased MFZ length beyond present SOLAS
- novel watertight compartment arrangement
- Novel machinery location / protection of vital systems
- Fully replacement of life boats with MES.

Design Focus

This subproject focus on taking state of the art reference vessel to develop an equivalent safe or safer fast full-displacement vessel through challenging the current rules and making it more attractive by:

- increasing payload,
- improving survivability,
- Incorporating IMO “safe haven concept”, and
- Increasing protection of the vital systems against various damage and fire scenarios.

It is aimed to provide an innovative platform for testing the risk-based approach for a concept design.

Design Concept

The progress towards the design concept of this subproject could be split in the following phases:

- Existing design selected as “state of art ” reference
- Existing design compared to lately built vessels
- Tracing the existing rules, which may restrain innovation
- Assessment of Damage stability according to new probabilistic rules
- Developing the possible design concepts
- Selection of a Design concept for next phase

In the development of the design concept, the potential for improving safety was considered by challenging the existing rules, which tend to limit the implementation new innovative solutions.

In addition to functional requirements, the developed design concept introduces a new way of thinking on watertight compartment arrangement, which could be described as “onion structure”.

9.3.1 Subproject SP6.4 – THE 13th PASSENGER

Design Problem

Existing rules and regulations do not explicitly reflect the risks, which a ship or its passengers are exposed to. In the case of damage stability and fire safety, most rules apply if more than 12 passengers are to be transported. No matter whether the vessel is designed for 13 or 2500 passengers, the requirements are more or less the same.
Consequently, the transport of a small number of passengers is economically of limited interests.

Specific intentions of this project are to identify in qualitative terms the safety level of present vessels with 12 passengers and to design an innovative one as safe as the SOLAS vessel but more cost- efficient.

Design Focus

The focus is to design a RoPax ferry for about 50 passenger, using risk-based principles and not-SOLAS requirements, which will be as safe as a design using SOLAS but more cost-efficient. In addition, to introduce high tensile steels and a power-bus for supply with electrical energy.

The main aim addressed in this subproject during Task 6.4.1 is to develop a design concept for a RoPAX vessel carrying more than twelve, but not more than fifty passengers, based on an existing modern RoRo ship.

Design Concept

To fulfil the aims without the constraints of prescriptive SOLAS and Class Rules, a risk-based approach is chosen. The major tasks addressed during the concept design definition are:

- Selection of a reference design.
- Issuing a specification for the modification of the reference vessel
- Making an initial cost estimate for a vessel according to the rules
- Identification of relevant rules and their intention
- Identification of hazards, which are threatening the safety of passengers,
- Identification, in qualitative terms, of the safety level of a vessel of 12 passengers according to rules and regulations.
- Identification of differences in risk between reference vessel and modified vessel using a qualitative, risk-based approach
- Identification of main risk contributors for the modified vessel.

Subproject SP6.5 – LIGHTWEIGHT COMPOSITE SANDWICH SUPERSTRUCTURE

Design Concept

The aim of SP6.5 is to provide documentation of the risks and benefits of a composite superstructure in a passenger ship. The design goal is to develop a commercially attractive design solution that exploits the advantages offered by lightweight composite structures. To achieve this, it is necessary to demonstrate that the composite design is safe.

The progress towards the design concept of this subproject could be summarized in the following tasks:

- Definition of goals
- Analysis of SOLAS safety objectives and functional requirements
- Identification of rules challenged by new design
- Adoption of a pragmatic approach to reach the objective

- Identification of hazards and critical fire scenarios
- Development of fire risk model
- Selection of an Application case
- Establishment of a Electronic geometry model of superstructure (identical to existing steel design)
- Extraction of FE model of composite module in progress
- Definition of Composite materials and scantlings in progress**Design Problem**

The state of the art prior to this project is that economic lightweight design solutions and fire protection systems are suitable for HSC and Naval Ships. However, merchant ships (except HSC) have to satisfy requirements of SOLAS convention that prevent the use of composites.

Specific intentions of this project are to carry out a risk based design approach in order to allow introduction of lightweight composite structures in superstructures of merchant ships and to provide benchmark examples for application of fire safety engineering and methods.

Design Focus

The focus is to develop an economic lightweight composite sandwich design concept for a superstructure on a passenger ship through developing a fire risk model and to provide a quantitative measure of the fire risks associated with the new design concept and the economic benefits expected from using it.

Subproject SP6.6 – INNOVATIVE DESIGN SOLUTION FOR GAS TANKERS

This subproject was cancelled in the course of year 1 of the project. The partners behind SP 6.6 soon realized that the ideas developed in this project were commercially attractive. Therefore, they withdrew the project from SAFEDOR and financed a Joint Industry Project that could develop the concept quicker and with much more resources than could be provided by SAFEDOR. This activity may therefore result in the first risk-based ship design resulting from the SAFDOR initiative, but fully financed by industry.

Subproject SP6.7 – RISK-BASED DESIGN FOR SHORTSEA LNG VESSEL

Design Problem

There is a growing market for small-scale LNG distribution in Europe (and Asia). Small LNG carriers may be economical with two cylindrical cargo tanks (type C). That permits the transport of LNG pressurised.

The LNG vessel is developed in order to transport LNG for short distances from small-scale LNG factories/storage tanks to small-scale end-customers, in such way boil-off reliquification is not required. Instead, a thermal oxidiser could be installed.

This scenario permit to challenge some rules in particular:

- Structural Solutions – IGC rules using the new CNG (Compressed Natural Gas Carriers) class rules which permit to used equivalent bottom solutions if they can be shown by calculations or tests to offer the same protection to the cargo tank against indentations and the same energy absorption capabilities as conventional double bottom design.
- Gas combustion unit – No code exist for small vessels
- Machinery Solutions – ICG Code: gas dangerous areas

Design Focus

The focus is to develop a short sea LNG vessel which can distribute gas to small scale customers with a structural solution optimised using the principia of safety equivalency establish in the CNG rules; and to test the implementation of new LNG equipments as power connector, gas combustion units, medium pressure pneumatic cargo valve actuators, argon, since a safety and economic point of view.

Design Concept

The progress towards the design concept of this subproject could be split in following phases:

- Knowledge Exchange between the partners.
- Analysis of state of the art.
- Development of a preliminary business case to identify market drivers and constraints. Requirement profile
- Selection of a reference vessel.
- Analysis of present rules and regulations.
- Identification of innovations which could be integrated and tested out within the framework of the basic design including their economic profitability.
- Identification of rules challenged by new design.
- Establishment of design concept: Development of a short sea LNG vessel which can distribute gas to small scale customers with a structural solution optimised using the principia of safety equivalency established in the CNG rules.

Innovations Aspects

This design incorporate the following innovations

- Power connector – ICG Code: no rules at all
- Medium pressure pneumatic cargo valve actuators
- Use of Argon as inert gas

Subproject SP6.8 – INNOVATIVE OPEN TOP CONTAINER VESSEL

Design Problem

Open top feeder ships are potentially regarded as an effective transport means for short sea shipping service where cargo-handling times are the crucial driving forces. But open top container ships are still the exception. The reason for this is likely that these vessels have quite significant rule-based economic disadvantages: A bigger tonnage and therefore higher operation costs.

Design Focus:

The focus is on the creation of a low gross tonnage, highly competitive and equivalent safe open-top container vessel through challenging current rules where necessary to make it more competitive.

Design Concept

The aim of Subproject 6.8 is to design and promote an innovative open top feeder containership. These ship designs will have the same or higher overall safety level as existing standard ships, although they do infringe certain mandatory (safety) rules and / or regulations.

The progress towards the design concept of this subproject could be summarized in the following tasks:

- Knowledge exchange on open top container vessels: Design implications, identification of market drivers and constraints, market prospects
- The legal environment: Existing rules and regulations, guidelines, specific requirements

- Identification of market entry barriers and ways to overcome these, respectively which rules and/or regulations will be addressed (and challenged) to achieve a competitive advantage.
- Design outline of the innovative open top container design

Subproject SP6.9 – SAFE AND OIL TANKER – AFRAMAX SIZE

Design Problem

The transportation of oil by tankers involves a very high risk since the consequences in case of accidents can be catastrophic.

Although the frequency of accidents has been substantially reduced in the post-90 period, there is not reduction in spilled tonnes rates (by ship year) in the same period.

A series of IMO regulations concerning the prevention of incidents and accidents have contributed to this improvement, however the state of affairs is yet not satisfactory. Public have zero tolerance for oil spill and associated pollution.

DH design is not the only improvement taken place in improving safety of tankers. Many others have into force during last 26 years, but not all regulations are cost effective.

Using a risk assessment methodology, regulations can be justifiably introduced to improve the safety of tanker designs and operation.

The intention of this subproject is, taking as reference (state of art vessel) a DH tanker, to challenge some rules of the MARPOL 73/78 and SOLAS II-2 Part b, relative to general layout of the vessel, cargo tank size, tank length limitation, capacity of the segregated ballast tanks, and, among others:

- to get a greater overall oil outflow performance
- to increase cargo capacity
- to improve cargo handling

Design Focus:

To evolve a Double Hull concept, as it is publicly and politically set to be the norm, with the following safety goals:

- Reduction of potential of medium to large amount oil spills significantly
- Eliminate small size oil spills due to operational incidents/accidents
- Significantly reduced ballast water exchange and their effects

Design Concept

This task discusses the background of AFRAMAX tankers and proposes a highly competitive oil tanker design concept challenging some requirements of current regulation.

- More cost-effective to build and operate,
- In line with modern safety expectations.

In order to develop an oil tanker design in concept level, having the above key objectives in mind, the following activities were carried out:

- Identification of basic functionality and performance requirements
- Identification and reporting of basic safety expectations
- Identification of rules that govern tanker design: overview of rules and regulations, in particular rules concerning tank configurations.
- Development of design specification: design objectives, functional requirements and design criteria.

9.4 Anticipated End Results - Intentions for use and impact

As mentioned above, the work to be conducted for each innovative design has been divided into 3 phases: Design Concept (already completed), Design Studies (Project Definition) and Functional Design phase.

In the Design Studies phase, which will be carried out for each innovative design during the second year of SAFEDOR, the developed concept designs will be refined. Then, all necessary documents required to evaluate each design regarding the achievement of conceptual targets will be produced including feasibility, reliability, economic studies and risk and safety assessments.

At the end of the second phase, the developed design studies within WP-6 will undergo a peer evaluation and selection process. This evaluation procedure should serve the improvement of the design quality, as well as an intermediate evaluation of the obtained results. It is noted that a similar selection procedure was applied to identify the best proposals initially received for this workpackage.

The evaluation criteria (equal weighting) for selecting the best design studies will be:

- Economic impact
- Environmental impact
- Safety impact
- Feasibility
- Rule challenge

The evaluation will be carried out by a Peer Evaluation Panel, composed by:

- Members of the Steering Committee
- Nominated experts representing Owners, Yards, Equipment Manufacturers, Classification Societies and the SAFEDOR Advisory Board.

The Evaluation Panel will conclude the ranking of the designs according to the obtained qualifications and the two (2) top scored designs will continue in phase 3.

In this last phase, for the two selected designs, the documentation for approval will be prepared and considered by the Classification Society for "approval in principle" using the criteria developed in SP4.5 [5]. This phase will be carried out during the third and fourth year of SAFEDOR and the Design teams in this task will benefit from methods and tools developed in other WPs of SAFEDOR.

10 WP-7: Knowledge Management, Dissemination and Training

10.1 Summary description of workpackage objectives

Future competitiveness of the European maritime industry depends on proper management of acquired innovative knowledge and the availability of qualified employees. For the risk-based design approach to be successfully implemented in practice, in the future, a proper training of professionals has to be performed to enable their familiarisation with introduced new design methods, tools and assessment procedures. Furthermore, research results of SAFEDOR should be widely disseminated. Finally, the quality of obtained results should be checked and benchmarking studies will be performed to quantify the impact of the conducted research.

Therefore, the main objectives of WP7 are:

- Knowledge transfer from the research conducted within the SAFEDOR IP in a systematic manner to the wider maritime community and to promote the application and implementation of the work undertaken
- Training improvement at universities and aptitudes of maritime industry staff in new technological/methodological and regulatory developments
- Effective dissemination of SAFEDOR IP results
- Benchmark studies performance for selected topics
- Rational assessment of SAFEDOR IP results

To meet the outlined objectives, three subprojects have been defined as follows:

- SP7.1 Training, including the development and delivery of postgraduate training modular course
- SP7.2 Dissemination Activities
- SP7.3 Assessment and Exploitation of Project Results and Benchmarking

10.2 Contractors involved

The WP-7 Leader is the National Technical University of Athens – Ship Design Laboratory (http://www.naval.ntua.gr/sdl), represented by Prof. A.D. Papanikolaou (tel. +30 210 772 1416, Fax: +30 210 772 1408, email: papa@deslab.ntua.gr

All the contractors involved in WP7 are:

- SP 7.1: Training Activities
  NTUA (SP-Leader), SSRC, DTU, IST, GL, DNV, DMA
- SP 7.2: Dissemination Activities
  NTUA (SP-Leader), SSRC, DTU, IST, GL, DNV
- SP 7.3: Assessment & Exploitation of Project Results and Benchmarking
  GL (SP-Leader), BMT, DNV, NTUA

10.3 Work performed - Results achieved so far

In the first year of the project, dissemination and plans for the exploitation of results was attained via the completion of the following activities:

- The 1st Open Workshop was held on 14th February 2006, at the headquarters of the International Maritime Organisation (IMO) in London. The Workshop was jointly organised by the SAFEDOR consortium and the Royal Institution of Naval Architects (RINA), subcontracted by the SAFEDOR WP7 Leader (NTUA). It addressed the wide range of latest developments on risk-based ship design, operation and regulation and updated the public about first year research activities of the project. It was attended by a large number of more than 150 professionals from the whole spectrum of the maritime industry, both from within and outside the SAFEDOR consortium, the European Commission and mass information media. It was, by all means, a very successful dissemination event, as it attracted a fully satisfactory critical mass of participants and besides the pure dissemination of valuable information in the forefront of developments in risk-based design, it triggered the active response and debate of the conducted research by workshop participants representing the whole maritime industry.

- The 1st year Public Report and the 1st year Newsletter were issued and are to be annually updated. They both can be downloaded from the SAFEDOR website (http://www.safedor.org/). Through their annual update, both these dissemination activities will effectively contribute to the dissemination of acquired knowledge in the SAFEDOR project in the public domain and to the promotion of SAFEDOR concept.

- Furthermore, the Dissemination and Communication Plan year 1 has been issued at the early start of the project, outlining the planned dissemination and communication activities in the 1st year of the project. This plan will be also annually updated at the beginning of subsequent years of the project.

- Finally, the first part of the SAFEDOR Exploitation Plan has been prepared. The objectives of the Exploitation Plan are to map out the way the Consortium can derive commercial benefits during and after the project from the work conducted under SAFEDOR and to define the way the remainder of the technical work should be conducted in order to maximise commercial benefits. The SAFEDOR exploitation plan (part I) has been prepared by BMT, with contributions from GL and DNV. It represents the first step in building an Exploitation Plan for SAFEDOR. The bulk of the exploitation plan is taken with the analysis of market trends and defines a first set of issues that the final Exploitation Plan must cover. The relevant analysis conducted so far concerns cruise ship, RoPax, Gas and oil tankers and containership segments, on which SAFEDOR mainly concentrates. The analysis carried out in the first year for these ship types, points to a market that is favourable to a strong SAFEDOR commercial action. In the first place, the market is buoyant and is set to remain at a healthy level. Secondly, ships are set to grow in size and complexity, pointing to new and innovative solutions that are hard to reach with the strict confines of present approval methods. Therefore it is obvious that, at no point in the recent past have the conditions been better for SAFEDOR to become a commercial success. It now depends on the project being able to devise the right mechanisms to bring its products to the market and plan its commercial actions before the end of the research project.

  The exploitation plan constitutes a live document throughout the duration of SAFEDOR and, which is even more important, beyond SAFEDOR. It will be updated at yearly intervals. By the end of the project, it will constitute a blueprint for commercial activities that will take place after the research, development, demonstration and training work of the project.

10.4 Anticipated End results - Intentions for use and impact

The 1st year open workshop of SAFEDOR inaugurated a series of follow-up SAFEDOR dissemination events, namely:

- The SAFEDOR Midterm Conference, in spring 2007
- The 2nd Open Workshop of SAFEDOR, in spring 2008
- The SAFEDOR postgraduate training course on risk-based design, operation and regulations, in spring-summer 2008
- The SAFEDOR Final Conference, in spring 2009.

The SAFEDOR postgraduate training course on Risk-Based Design, Operation and Regulations will be delivered in spring-summer 2008. The course will address maritime industry professionals; specifically academic personnel, class society personnel and regulatory administrators, as well as other professionals related to naval architecture. It is anticipated to attract the interest of a large number of professionals and academic staff/ postgraduate students.

The training course modules shall include both elements of risk-based design, operation and regulation, such as formal safety assessment, acceptance criteria, risk analysis, equivalent design and approaches as well as their integration within the process of ship design and operation. Eventually, a translation / transformation of source material into a coherent lecture material, accompanied by tutorials, application examples and design case studies, is planned and will be edited and printed.

Furthermore, the planned edition of a Handbook of Risk-based Design will be widely disseminated and is expected to be very appealing to a wide range of professionals and challenge many interested readers to study it and enable them to be updated on developments in the Integrated Risk-Based Ship Design, Operation and Regulation.

All planned for the future training, dissemination and knowledge management activities of SAFEDOR are outlined in the following:

Year 2
- Midterm conference
- Public report and newsletter 2
- Dissemination and communication plan for year 2
- Assessment of results part 1
- Exploitation plan part 2

Year 3
- Seminar Year 3
- Public report and newsletter 3
- Dissemination and communication plan for year 3
- Assessment of results part 2
- Exploitation plan part 3

Year 4
- Final conference
- Public report and 4
- Handbook on risk-based design
- Dissemination and communication plan for year 4
- Assessment of results part 3
- Benchmarking study
- Exploitation plan part 4

11 Conclusions

The SAFEDOR project approaches a series of major scientific and technological challenges in the risk-based approach to ship design, operation and regulations.

During its first year of activities, SAFEDOR contributed to the following:

- The development and enhancement of design tools to predict the safety performance of ships in extreme and accidental conditions. As a start, focused hazard identifications have been performed and requirements for tools predicting the probability of accidents and their immediate consequences were specified. Five topics are dealt with in this concern: fast and accurate flooding prediction of complex compartment configurations, prediction of failure of hull structure, prediction of capsize probability in intact and damage condition, prediction of collision and grounding probability taking into account system and human failures, and prediction of fire events for cargo and passenger ships.

- Safety-critical technologies such as electrical power distribution system, navigation and life saving. First steps were related to the specification of a new tool to automatically generate fault trees for rapid safety assessment of complex systems. A novel bridge layout has been specified taking into account available state-of-the-art work station equipment including wireless connections. A range of innovative life saving concepts was studied, taking into account the vessel size, service and operating area.

- Formal Safety Assessment studies were carried out on four different ship types. If appropriate recommendations can be identified, these studies will be submitted to IMO for consideration. In addition, a blueprint for a modernized regulatory framework was initiated. Already now SAFEDOR has drafted a high-level approval process for risk-based ships including top level acceptance criteria related to life and environment. The report on "Risk Evaluation Criteria" was posted on the web and also circulated to all members of the IMO correspondence group on FSA. The chairman of the group, therefore, included an extract of this report to MSC 81 (MSC 81/18). The recommendations from the report were used by IACS in MSC81/INF.6 (on Hull Girder Strength of Tankers, available at http://research.dnv.com/skj/GBSPAPERS/Papers.doc), and by Denmark and Norway in MSC81/23/13, MSC 81/24/5 and MSC81/INF.9 in a FSA on Electronic Chart Display and Information System (ECDIS). All FSA/ECDIS reports are available at http://research.dnv.com/skj/FSA-ECDIS/ECDIS.htm. This work has, therefore, already been put to good use by the maritime industry and international regulatory bodies.

- Development of a concept for risk-based ship design. This concept includes a high-level process description and decision-making approaches. One of the pre-conclusions of the task is a recommendation to use cost-effectiveness as criterion to assess design changes with respect to safety performance. A survey is ongoing to identify available and needed tools to enable full risk-based design.

- Development of eight innovative ship designs: two cruise vessels, three RoPax, one gas tanker, one oil tanker and one container ship. Focus is on ship designs that are believed to be safer, but for some formal reason, cannot be approved today. Alternatively, innovative ships may be as safe as today with reduced building costs and/or improved earning potential. All eight concepts are completed and will now be refined into design studies. These design studies will make use of full risk analyses to perform the evaluated risks and to assess risk-control options.

- Effective dissemination of project results and knowledge management; Organisation of public workshop at the headquarters of the International Maritime Organisation (IMO) with good participation of professionals and all stakeholders of the maritime industry; Issuance of a year 1 public report and newsletter, dissemination and communication plan and part 1 of the SAFEDOR exploitation plan.

SAFEDOR is already well-known to all stakeholders of maritime safety, and has acquired an excellent reputation over the wider maritime and industrial community.

SAFEDOR's momentum will continue and as progress is made, it is anticipated to gain more and more key findings, contributing to the full implementation of Risk-Based Design. Simultaneously, end-products will advance into a more mature stage enabling demonstrations to a wide audience.

12 References

[1] IP SAFEDOR FP6-516278, Sixth Framework Programme Priority 1.6.2, Sustainable Surface Transport, Contract for Integrated Project, Annex I - "Description of Work".

[2] Pierre C. Sames, Hans Christensen, Rolf Skjong, Wilfried Hensel, Tom Strang, Antonio Perez de Lucas, Dracos Vassalos, 2005, "SAFEDOR- risk-based ship design, operation and regulation", Proc. 12th Int. Congress of the Int. Maritime Association of the Mediterranean, IMAM 05, Lisbon, September 2005.

[3] IMO MSC 80/INF.8, 2005, "Formal Safety Assessment, SAFEDOR – Risk-based Design, Operation and Regulation of ships", submitted by Denmark, 80th session, Agenda item 7.

[4] SAFEDOR-Q-01.00.00-2005-02-21-GL-project-manual-rev-1, 2005, Project Manual.

[5] SAFEDOR-D-04.05.02-2005-10-21-DNV, 2005, "Risk Evaluation Criteria" available on-line: http://www.safedor.org/resources/SAFEDOR-D-04.05.02-2005-10-21-DNV-RiskEvaluationCriteria-rev-

[6] SAFEDOR 1st Open Workshop, 14th February 2006, IMO, London, Set of Presentations, available on-line: http://www.safedor.org/news/SAFEDOR-2006-02-14_open-workshop-at_IMO.pdf

[7] SAFEDOR-SC-2005-06-20-GL-public-presentation, 2005 Public Presentation, available online: http://www.safedor.org/press/SAFEDOR-SC-2005-06-20-GL-public-presentation.pdf

[8] Intership, 2004, "Review of Existing Risk Evaluation Criteria", Rolf Skjong, Erik Vanem, "Intership subproject II-2 report: T03-01-2004-09-15-REP-DNV-V2", 2004.

[9] SAFEDOR status submission to MSC81, 2006, "Formal Safety Assessment, SAFEDOR – Risk-based Design, Operation and Regulation of ships", submitted by Denmark, 81st session, Agenda item 18.

13 List of SAFEDOR Publications in Year 1

[1] Christensen Hans, Hensel Wilfried, Perez de Lucas Antonio, Sames Pierre C, Skjong Rolf, Strang Tom, Vassalos Dracos, 2005, “SAFEDOR- Risk-Based Ship Design, Operation and Regulation”, Proc. 12th Int. Congress of the Int. Maritime Association of the Mediterranean, IMAM 05, Lisbon, September 2005.

[2] Christensen Hans, Hensel Wilfried, Perez de Lucas Antonio, Sames Pierre C, Skjong Rolf, Strang Tom, Vassalos Dracos, 2005, “SAFEDOR- Risiko-basierter Entwurf, Betrieb und Genehmigung von Schiffen”, Proc. Schiffbautechnische Gesellschaft (STG), Berlin, November 2005.

[3] Papadopoulos Y., Grante C., Grunske L., Kaiser B., 2005, "Continuous assessment of evolving desings & re-use of analyses in a model-based technique for semi-automatic Fault Tree and FMEA analysis of complex systems", Proc. of 16th IFAC World Congress, Int'l Federation of Automatic Control, Prague, July 4-8, 2005.

[4] Papadopoulos Y., Parker D., Walker M., Petersen U., Hamann R., Wu. Q., Uhlig A., 2005, "Automated Failure Modes and Effects Analysis of systems on board ship", ICMRT'05, Proc. Of Int'l Conf. On Marine Research and Transportation, Ischia/Naples, September 19-21, 2005.

[5] Petersen U., Hamann R., Wu Q., Uhlig A., Papadopoulos Y., 2005, "Integration von Simulation und Zuverlässigkeitsanalyse für komplexe Systeme", Proc. Of TTZ 2005, 22.Tagung Technische Zuverlässigkeit, Annual VDI Conf., Stuttgart, 7-8 April, 2005.

[6] Spanos D., Papanikolaou A., 2005, “Numerical Simulation of a Fishing Vessel in Parametric Roll in Head Seas”, Proc. 8th International Workshop on Stability and Operational Safety of Ships, Istanbul, Turkey, October 6-7, 2005.