



**SAFEDOR**

design, operation and regulation  
for safety

Integrated Project 516278  
in the sixth framework programme of the European Commission

<http://www.safedor.org>

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***Editorial***

The SAFEDOR Consortium is pleased to welcome you as a reader of the 6<sup>th</sup> SAFEDOR Newsletter; it informs about the research activities and final results of the SAFEDOR Project. Further public domain information from the SAFEDOR project is available on-line (<http://www.safedor.org>).

The SAFEDOR series of newsletters address readers from the whole spectrum of the maritime industry: flag state and government administrations, classification societies, designers, operators, researchers, educators, and practitioners of risk-based design. The

present sixth issue of the SAFEDOR newsletters summarizes the main achievements of the project.

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***SAFEDOR research***

The integrated project SAFEDOR formally finishes its activities in April 2009; it commenced its work in February 2005 as the first large scale project developing the concept and elements of a risk-based regulatory framework for the maritime industry. A major part of the work was the integration of corresponding design tools to facilitate first principle approaches to safety, addressing the complexity of a fully comprehensive system. Strategic research objectives of the project, meeting the envisaged goals, were:

- Develop a risk-based and internationally accepted regulatory framework 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.

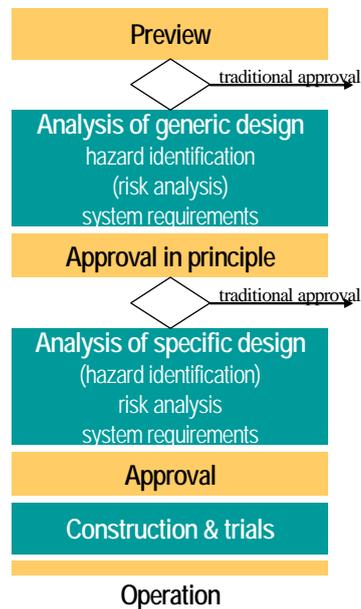
- Produce prototype designs for European safety-critical vessels to validate the proposed methodology and document its practicability.
- Transfer systematically knowledge to the wider maritime community and add a stimulus to the development of a safety culture.
- Improve training at universities and aptitudes of maritime industry staff in new technological, methodological and regulatory developments in order to attain more acceptances of these principles.

### **Regulatory framework**

Within the project SAFEDOR, elementary building blocks for a risk-based regulatory framework for shipping were developed. These comprise the approval processes for ships and ship systems, risk evaluation and acceptance criteria at ship and functional level and requirements for documentation and qualification. In addition, six formal safety assessment (FSA) studies were conducted; five of them already being submitted to IMO with an expected review in May 2009 during the meeting of the Maritime Safety Committee (MSC 86). Thus, work performed in SAFEDOR towards a modern and risk-based regulatory framework will eventually affect the way risk is managed within rule making at IMO level.

The approval processes for risk-based ship and ship systems both aim to provide a basis to be used by approval authorities to ensure that novel and risk-based designs are handled in a safe and efficient manner and to make the approval process these designs more transparent and reliable. The key element of the newly proposed approval processes is an intermediate

step called the “Preliminary Approval” which concludes the first phase of the process.



The preliminary approval allows 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. A summary of the novel approval process with all relevant details is being submitted to IMO (MSC 86).

High-level risk evaluation criteria for use within risk-based design and approval were also presented. These criteria include individual and societal risk acceptance criteria, a cost-effectiveness evaluation criterion related to life saving and appropriate background information to update the criteria. In addition, a new cost-effectiveness evaluation criterion related to environmental protection was developed: *Cost of Averting a Ton of Oil Spilt (CATS)*. This new criterion should primarily be used to assess design changes of oil tankers with respect to their cost effectiveness – under the assumption that risk

associated with oil transport by tankers is inside an ALARP area. Alternatively, one could use this criterion to enhance the cost-effectiveness evaluation related to life saving by subtracting expected difference in oil outflow times CATS from the differences in costs for a design option. The concept of CATS was intensely discussed and extensions relating to spill size and spill location were suggested. A correspondence group was established between recent Maritime Environmental Protection Committee (MEPC) meetings and the basic idea of CATS was recently agreed (IMO 2008). Continued discussions now focus on the correct value of CATS and whether an ALARP area would be needed for its application.

Risk evaluation criteria at ship system and function level are presently not publicly available. An unpublished report from SAFEDOR lists such criteria and proposes a general procedure to derive lower-level risk evaluation criteria. This procedure builds upon a risk model for the considered system or function and uses high-level cost-effectiveness criteria to derive target reliabilities, availabilities or failure probabilities. The procedure was successfully applied to hull girders in intact and damaged condition and a fuel oil system.

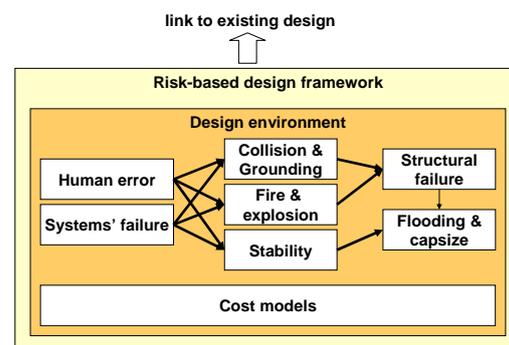
The FSA studies were performed to deliver high-level risk models, identify risk control options and to document the current level of risk per ship type and followed the FSA guidelines (IMO 2002 and IMO 2007). At the moment of writing, five FSA studies have been submitted to IMO addressing container vessels, LNG tankers, oil tankers, cruise vessels and RoPax ferries. One FSA study on dangerous goods on open-top container vessels is currently

being finalized. The submitted FSA studies show that all the societal risk profiles of considered ship types are in the ALARP area and, therefore, cost-effective risk control options should be implemented. The FSA studies for the oil tanker, the cruise and RoPax vessels list a number of such measures for consideration by rule makers.

### *Designer's toolbox*

Risk-based design is an extension of the traditional design process in that it integrates assessment of the safety performance into the design process. Prevention and / or reduction of risk (to life, the environment and property) are embedded as a design objective, alongside conventional design objectives (such as speed, capacity, etc). SAFEDOR developed this design framework offering an enhanced decision-making to balance traditional objectives – performance and cost – with the new objective – minimize risk.

An overview of the elements of the risk-based design framework and the principal linkage between safety performance predictions tools addressing main accident categories is presented in the figure below.



Within SAFEDOR, several engineering tools to predict the safety performance of a vessel in extreme and accidental conditions were newly developed or refined. These tools

address the main accident categories, as shown in figure above. The following developments were performed to date:

- A Bayesian network was extended to evaluate changes in the causation factor driving from enhanced training and advanced bridge equipment for collision and grounding.
- A new Bayesian network was established to predict the probability of propulsion and maneuvering systems' failure. However, lack of sufficiently validated data on components limited validation.
- A new technique to create fault trees and FMEA tables from system descriptions inside a standard system simulation package was developed. Enhancements include entering annotations to systems and components related to failure modes.
- A new approach to assess fire in cargo holds was applied by introducing a Bayesian network to evaluate probabilities and consequences of container fires.
- A methodology to assess fire safety for passenger ships was developed which offers a probabilistic approach to fire safety similar to the probabilistic approach to damage stability.
- A structural reliability analysis of a damaged ship structure showed that the damaged condition – following a collision – is not a dimensioning case for the hull girder of a tanker.
- The probability for intact capsizes was predicted with two newly developed algorithms. A validation of the new methods using dedicated experimental data is ongoing.
- A new method was developed to predict the probability density function for the time to capsize for RoPax ferries. The new method is extremely fast – which allows integration into a design environment - and is still

considered to be sufficiently accurate. Validation is ongoing.

### *Ships and their systems*

Eight design teams started developing innovative ship concepts when SAFEDOR began. Concepts addressed technological, economical and safety aspects for two cruise vessels, a fast full displacement RoPax ferry, a hybrid RoRo/RoPax vessel, a lightweight composite sandwich superstructure for a RoPax ferry, a short-sea LNG tanker, an open-top container vessel and an oil tanker. A formal selection of the best designs by a panel resulted in two winning designs which were given additional resources to refine their concepts and prepare for preliminary approval.

The first winning design was the lightweight composite sandwich superstructure for a RoPax ferry which exemplifies the use of risk-based approaches to demonstrate safety compliance. The risk model incorporated results from full scale fire tests and advanced computer simulations to show that the risk level for passengers is smaller than for passengers on conventional ferries when appropriate risk control options are implemented. The second winning design was the fast full displacement RoPax ferry which exemplifies the optimization potential for risk-based design and demonstrated the potential of a newly developed tool to predict flooding. The risk assessment of a novel subdivision concept also introduced blisters (inflatable buoyancy units above design waterline) as potential powerful risk control options.

Work within SAFEDOR also addressed development of innovative



systems focusing on area with high impact on safety, such as an innovative bridge layout, a novel system to distribute electrical power and several new concepts for life saving appliances.

The novel system to distribute electrical power (primary power bus) was integrated into a RoPax ferry design and analyzed with respect to its safety compliance.

The final step following an accident may be life saving and rescue if the vessel needs to be abandoned. SAFEDOR developed three novel life saving appliances, each focusing on a different scenario and related different survival ranges. The long-range solution focused on a novel launching system to facilitate safe embarkation. The medium-range solution considered a novel onboard stowage to reduce space allocation. The short-range solution addressed safe access and stowage for a complementary life saving system – similar to life rafts.

### ***Qualified Engineers***

A number of dissemination and training measures were planned from the beginning of SAFEDOR to enhance knowledge on risk-based approaches within the maritime industry and to add stimulus towards developing a new safety culture. SAFEDOR attracted a large number of people for the annual public conferences. In addition, annual public reports and presentations were provided together with fact sheets for main stakeholders. Two training courses were organised with one focusing on regulators and the second one on PhD students and young professionals from all the industry. To complement the material for students and experienced engineers alike, besides the offered training course

material, a handbook on risk-based ship design was published, which is being offered commercially by SPRINGER Publishers.

### ***Outlook***

With the regulatory framework for shipping changing towards a more goal-based style and new regulations addressing fire safety, damage stability and - in the near future - life saving appliances advanced by IMO, the design solution space available to the ship designer is expanded. Ship designers have now available increasingly sophisticated methods and tools supporting advanced and risk-based ship design and including safety as additional objective into the design process. Risk evaluation criteria are eventually becoming explicit and accepted also at maritime administrations and enable a holistic decision-making. Taken together, all necessary elements and the frame are now available to produce innovative ships with enhanced economics and increased safety.

Although the further development of the Goal-based Standards (GBS) at IMO using the risk-based Safety-level Approach (SLA) is not progressing fast, a clear trend is seen towards using risk analysis in design, approval and rule-making. In this respect, the planned review of the FSA studies conducted by SAFEDOR at IMO (MSC 86 in May 2009) is seen as a large step towards documenting risk levels for shipping at IMO. In parallel, industry has started using the risk-based approach developed in SAFEDOR in a number of new commercial and research projects. And the European maritime industry has identified the implementation of risk-

based frameworks as key priority towards 2020.

Risk-based ships are sailing today and their operational aspects are aligned with the current regulatory framework treating risk-based elements as equivalents. Details and reasons for the acceptance of the equivalent are to be communicated to IMO and circulated to IMO Member States. With the advent of more design aspects of a ship becoming risk-based, there is a clear need to ensure complete documentation of all risk-based elements of a ship together with the process and criteria of acceptance should be carried onboard. In addition, a proper summary addressing the concerns of surveyors and port state control officers should be drafted.

### ***SAFEDOR Book on Risk based Ship Design***

A book on Risk Based Ship Design was published by Springer-Verlag in

February 2009. The book, which is co-authored by renowned experts from the SAFEDOR consortium, facilitates the transfer of knowledge emanating from the research conducted within the SAFEDOR project to the wider maritime community and nurtures inculcation upon scientific approaches dealing with risk-based design and ship safety.

Formal reference: “Risk based Ship Design – Methods, Tools and Applications”, A. D. Papanikolaou (Ed.), Springer-Verlag, ISBN 978-3-540-89041-6.

### ***SAFEDOR final conference***

The final and public conference of SAFEDOR will take place on 27&28 April 2009 at IMO, London, UK. More information can be found at [www.safedor.org](http://www.safedor.org).

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