1.1 Project context and objectives

The ultimate objective of project FAROS is to quantify and integrate the human error, which is found responsible for some 90% of maritime accidents, into risk-based ship design. Risk-based design is a design process supported by systematic risk assessment so that all significant design decisions are risk-informed. The project focuses on the concept design stage and adopts the system approach to the human error problem. The basic assumptions of the system approach are that the crew are fallible and errors are to be expected. Such errors are seen as consequences rather than causes, with their origins rooted in ship design on both meso (i.e. deck layout, arrangement of equipment and accessibility) and macro levels (i.e. hull and structural arrangement determining levels of ship motions, whole body vibration, and noise). Hence the broader operational aim of the project is to improve the conditions under which the crew works, thereby reducing the occurrence of human error and mitigating its consequences.

The following technical and non-technical objectives have been achieved in the first reporting period:

1. Synthesis of human performance failure: undertaking of extensive analysis and synthesis of existing knowledge (largely in the form of mathematical models and data repositories) about the effect of global design factors upon human performance and its failure.
2. Development of risk models incorporating human error: development of risk models that integrate and link the ship characteristics and the human performance to corresponding probabilistic figures, which are themselves essential components of the overall safety level (personal and ship/societal). These models will use data on Human Reliability from existing repositories, complemented and contextualised using experiments based on virtual reality technologies and use of observational instruments such as eye tracking.
3. Integration of Human Element into Risk-Based Design methodology: enhancement of the overall safety model with the developed human element aspects, integrating this into the overall Risk-Based Design methodology.
4. Development of parametric cargo ship models and quantification of uncertainty in design and operation parameters.
5. Dissemination and development of the draft exploitation plan: organisation of 1st public workshop, presentations at conferences and other public events.

1.2 Work performed and the main results achieved so far

The literature was extensively reviewed to quantify the causal link between global design factors (GDFs) and human performance. Considered GDFs were: ship motions, whole body vibration, noise, deck layout, equipment arrangement and its accessibility. However, no quantitative models were identified and a high-level, scientifically justified framework was proposed to bridge the knowledge gap. It considers the exposure to noise, vibration and ship motions to degrade the crew's attention management capability, which in turn may lead to human errors. The deck layout, arrangement of equipment and its accessibility were found to affect task demand.

The literature review found deficiencies in current design rules which prescribe maximum GDF limits for human performance. Although the violation of some limits was found to affect physiological functions, there is insufficient evidence to generalise this to all rules and no evidence at all to support the link to cognitive functions. As insufficiencies in cognitive functions were historically the primary causes of human errors behind serious maritime accidents, the current design standards may not provide for some safety critical tasks performed by the crew.

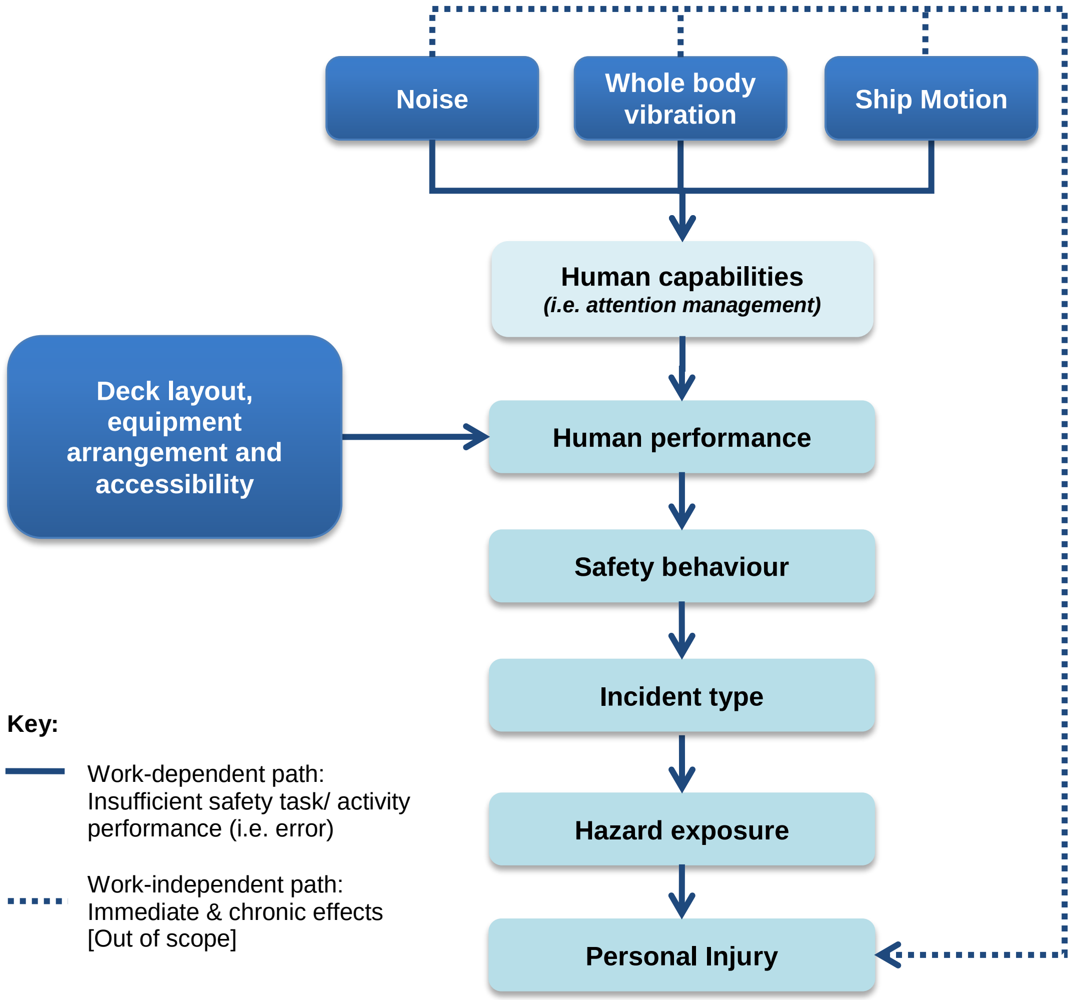
Virtual Reality experiments in RoPax machinery spaces were conducted with 12 engineers involved. It was observed that propensity to keep watertight doors open, which notoriously compromises watertight integrity of the vessel, may be directly proportional to the frequency of passing through them. It was also noticed that a bigger engine room may be safer because the crew would utilise extra space to keep further away from hazardous objects. However, both observations were inconclusive.

Engineer in CAVE performing WTD scenario (courtesy of University of Strathclyde)

The negative effect of GDFs was also studied on tanker and RoPax bridge simulators. The experiments were aimed to test the effects of noise and ship motion on collision/grounding avoidance. Whilst the mariners in almost all cases violated the safe navigation distance of 1nm, no evidence of an influence of GDFs on navigation performance emerged. However, there were clear findings of the effect of sleep restriction in RoPax scenarios. Mariners, when sleep restricted, were found to steer courses significantly further away from target vessels than did fully rested mariners. This pattern was interpreted as reflecting effort to compensate for tiredness.

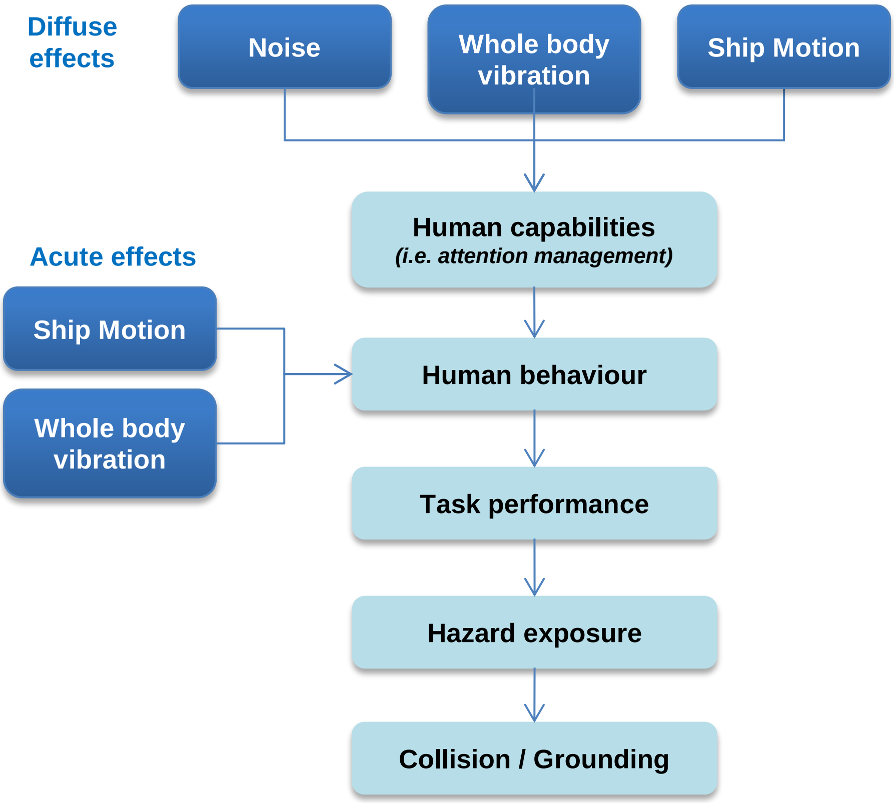
Deck officer wearing the Dikablis wireless mobile eye-tracking system (courtesy of University of Strathclyde)

The accumulated knowledge about the factors affecting crew performance allowed developing risk models, for RoPax and tanker ships, with the human error in mind. The personal risk model linked GDFs with probabilities of injury and death. The model focuses on such incident types as slips, trips, falls, falls from height, and hit by moving objects, and considers unsafe behaviour as the main antecedent condition of accidents.



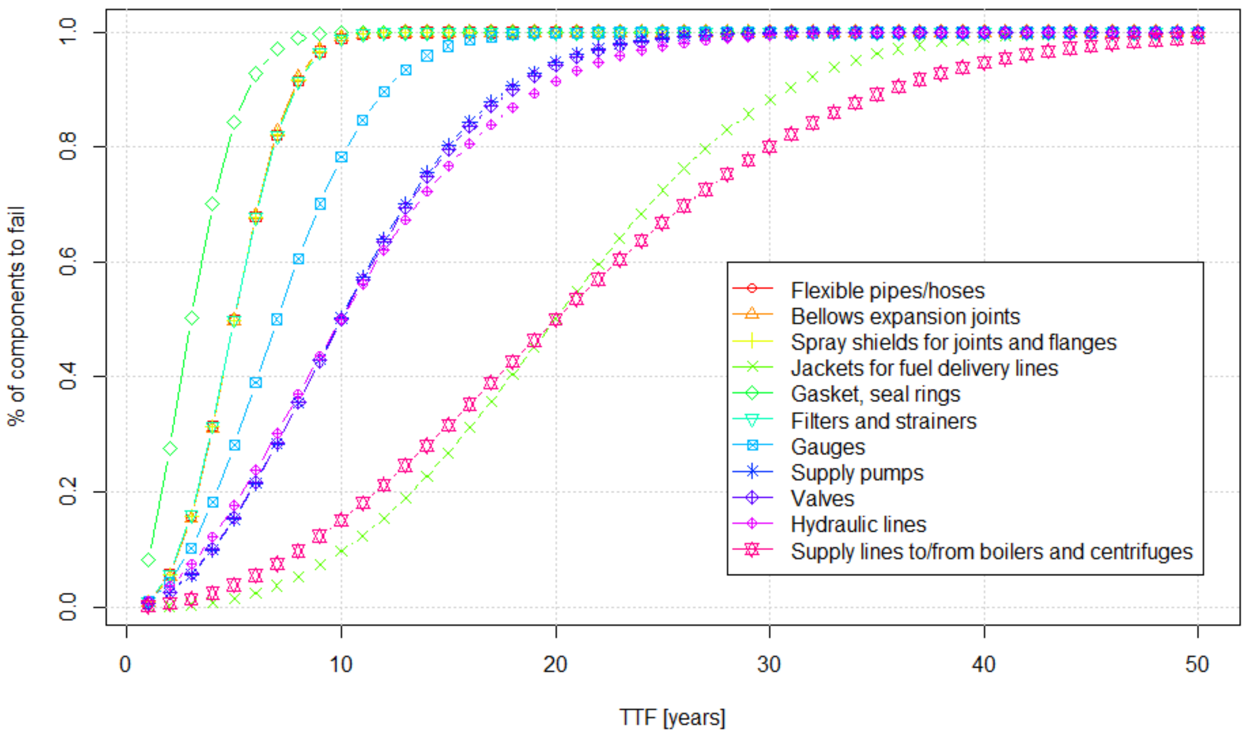
Considered work-dependent and work-independent causal paths describing the effect of Global Design Factors on human performance, safety behaviour, and the occurrence of personal injury (Courtesy of Lloyd's Register).

The collision and grounding risk model comprises probability of collision/grounding event and its consequences. The model is based on the most recent casualty statistics and expert estimates of incident encounters on preselected routes. The consequence part of the model is underpinned by recent research work on damage stability.



Considered causal chain describing the relationship between crew exposure to Global Design Factors and the unwanted outcome of collision or grounding (probability of collision per encounter) (Courtesy of AALTO University)

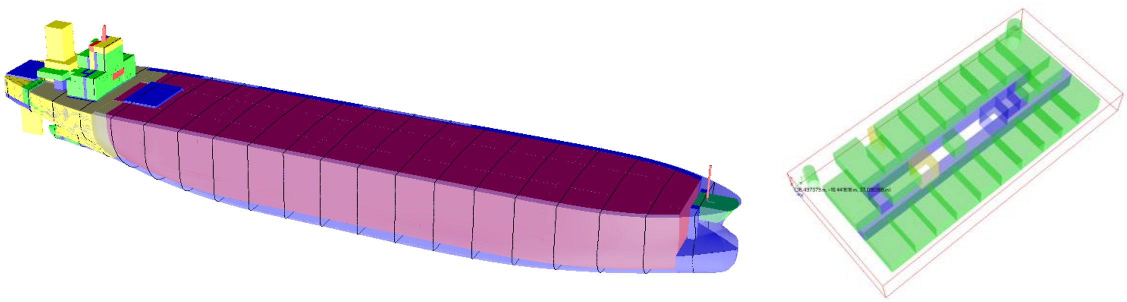
The work on the fire risk model was focused on fire inception probability in different onboard spaces. The development was based on causality statistics, fire accident investigation reports, empirical data elicited from marine engineers, etc. The work resulted in probabilistic ignition models for engine rooms, galley, cabins, electrical fault caused ignitions, etc.



Cumulative probability distributions of Time to Fail (TTF), i.e. time to leak, for machinery components liable to leaking flammable oil in the RoPax engine room (Courtesy of Brookes Bell LLP)

The risk models were then integrated into the overall risk model that deals hazards emerging in both normal and emergency situations. This makes the risk assessment comprehensive and useful at the concept design stage where distinct design alternatives are assessed on the ship level.

RoPax and oil tanker designs were parameterised to undertake optimisation studies. For this purpose, design and design evaluation tools were integrated into automated processes of multi-disciplinary performance assessment.



Parametric VLCC model (courtesy of UCL)

1.3 Expected final results and their potential impacts and use

In the second project period project FAROS will explore new areas of human factors (HF) integration into ship design. From the standpoint of methodological development, the project will demonstrate how the HF metrics and risk models developed in the project can be applied in a practical design optimisation process. The project will generate ship designs that are measurably better in terms of HF-related risk than the conventional designs, and demonstrate technical solutions as well as methodological developments to achieve them.

In total, four ship concepts of tanker (AFRAMAX and VLCC) and RoPax ships (140m and 200m in length) will be optimised with respect to the overall risk, commercial viability, and energy efficiency. Improvements in hull, propulsion, and general arrangement are envisaged.

As the current findings can already be used to enhance training of crew members, upgrade internal safety procedures (as a part of continuous improvement under the International Safety Management Code), implement revisions and changes to plan approval processes, and improve ship design practices, the new project results are expected to further strengthen the understanding of how human error can be mitigated by design.