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Quantifying the effect of noise, vibration and motion on human performance in ship collision and grounding risk assessment

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Agenda

Aim of the risk models presented here

Risk concept adopted

General structure of risk model

Human performance model

Results and benchmarking of collision and grounding risk models

Aim of the presented risk models

This paper presents two models that quantify the effect of performance-shaping factors (PSFs) pertained to ship design, a.k.a. as global design factors (GDF) on human performance and ultimately on ship collision and grounding risk.

GDFs are those PSFs that can be changed at the stage of ship design, addressing the risk level associated with a given ship design. The ship-related GDFs are as follows:

- ship noise,
- ship vibration,
- ship motions.

In the Risk-Based Ship Design methodology the assessment of the risk level of a new ship is conducted in the early design stage, where a design modification is easy and cost-effective. In this approach, risk is evaluated alongside conventional design performance measures like sufficient strength and stability, low resistance, cargo carrying capacity, propulsion and maneuvering capability. Risk is thus treated as a design objective rather than a constraint imposed by prescriptive safety rules.

Two models presented here allow comparative assessment of vessel designs based on risk level associated with various levels of the GDFs.

Aim of the presented risk models

Exclusions

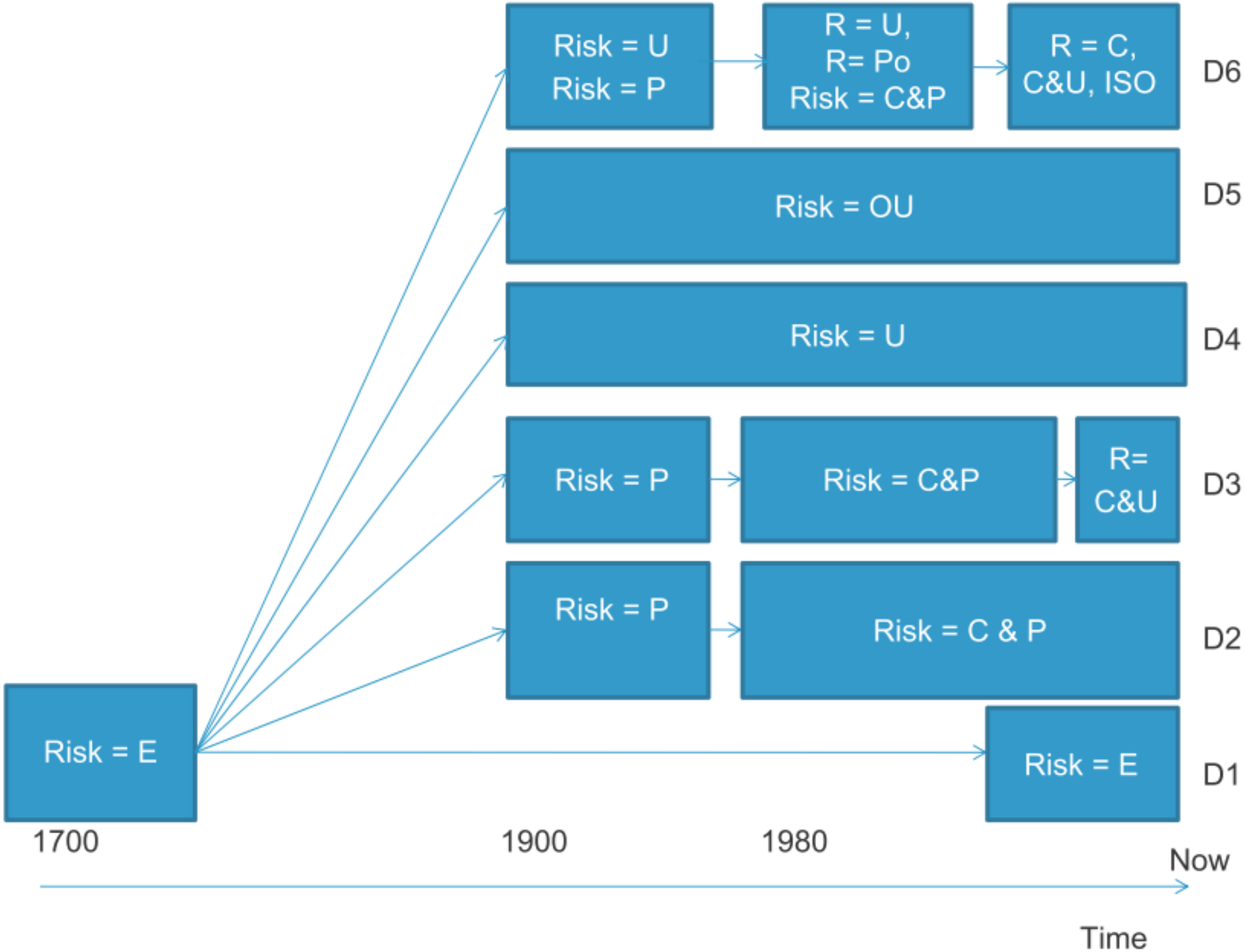
GDFs can be considered a type of performance shaping factor (PSF).

PSFs are an aspect of the human's individual characteristics, environment, organisation, or task that specifically decrements or improves human performance, thus increasing or decreasing the likelihood of human error respectively.

While there are many other PSFs that can affect human behaviour – for instance training, experience, competence, time available, workload, job design, manning, ergonomics of the equipment and procedures - these are excluded from the collision and grounding risk models as they are not affected by exposure to GDFs.

All the excluded PSFs are implicitly assumed to remain constant within the model.

Risk concepts



Aven, T. 2012. The risk concept – historical and recent development trends. Reliability Engineering and System Safety 99:33-44

Adopted risk concept and resulting perspective

In this paper we adopted an uncertainty-based perspective of risk:

R ~ C&U

This means that risk assessment is an expression of an assessor's uncertainty (U) about the occurrence of events and the associated consequences (C).

Following this perspective, risk assessment can always be performed, as **the risk model is seen as a tool to describe and convey uncertainties** rather than a tool to uncover the truth.

For this purpose, the risk description encompasses:

- **the events**
- **the consequences of the events**
- **the assessment of associated uncertainties**

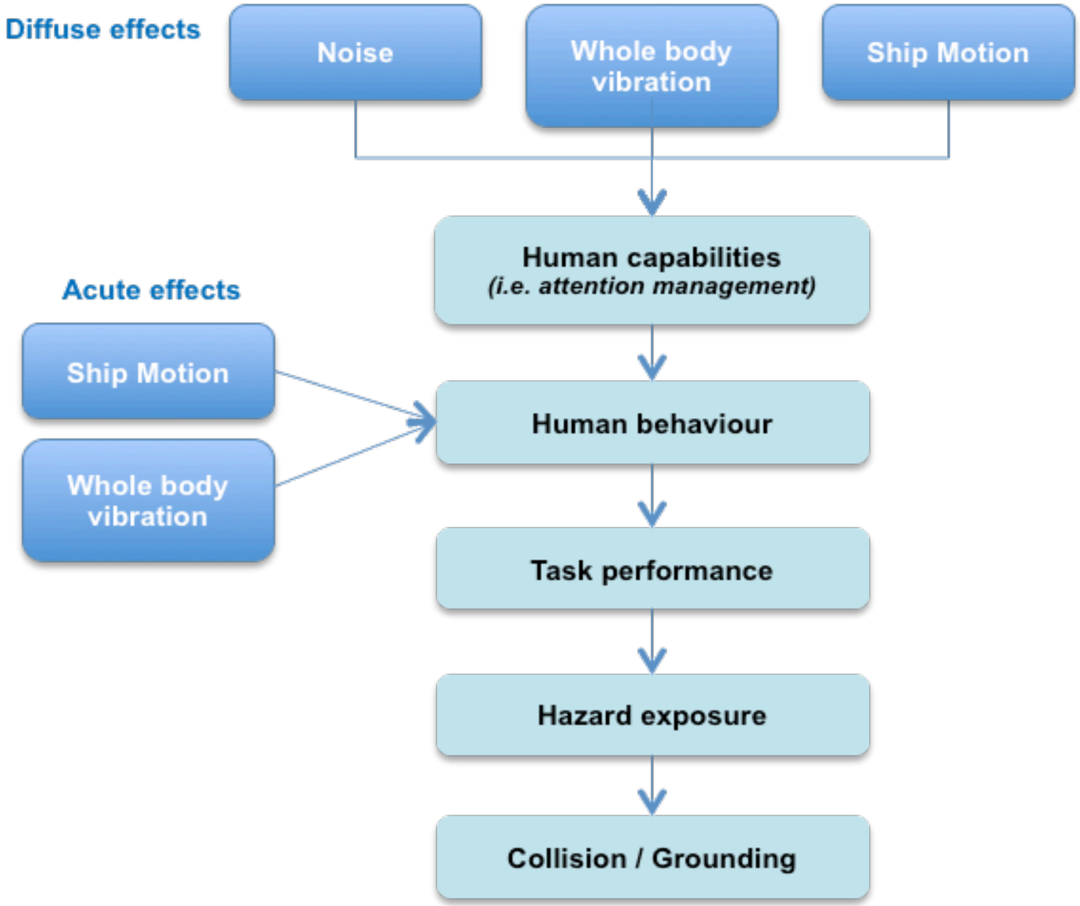
General structure of risk model

Path I

Exposure to Global Design Factors (GDFs) **act as a stressor** and can affect the capabilities of an individual (attention management), subsequently impairing the performance of the individual.

Path II

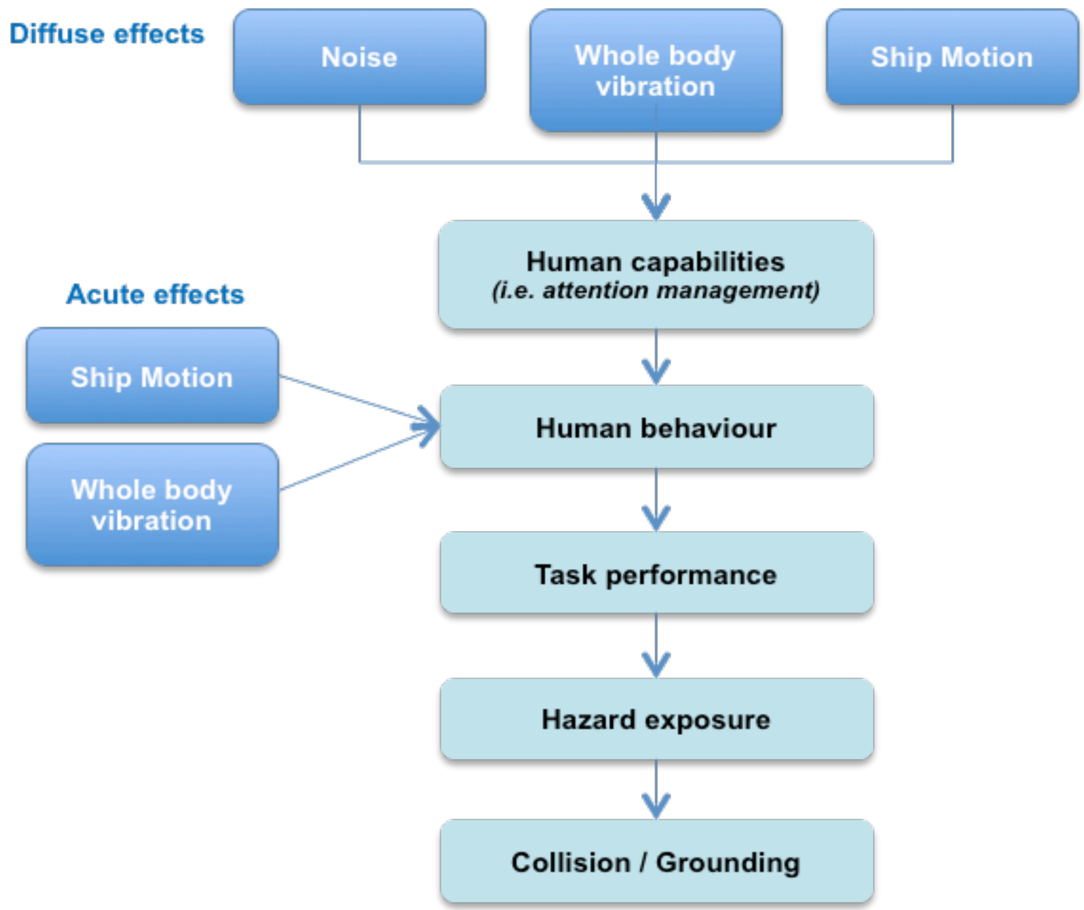
Exposure to GDFs can have specific and direct effect on the behavior produced.



General structure of risk model

Assumptions

- All individuals have the same basic set of capabilities (i.e. all individuals can manage their attention, irrespective of the extent of this capability).
- Human behaviour is influenced by diffuse and acute effects of GDF exposure.
- The crew perform safety critical tasks (SCT) related to collision and grounding.
- Tasks are appropriate, processes and procedures are optimised, and are undertaken by a competent operator.
- The interaction effects between GDFs within each pathway are likely to exist, however these are excluded from the model, as the literature does not provide any information describing this interaction.



Available background knowledge

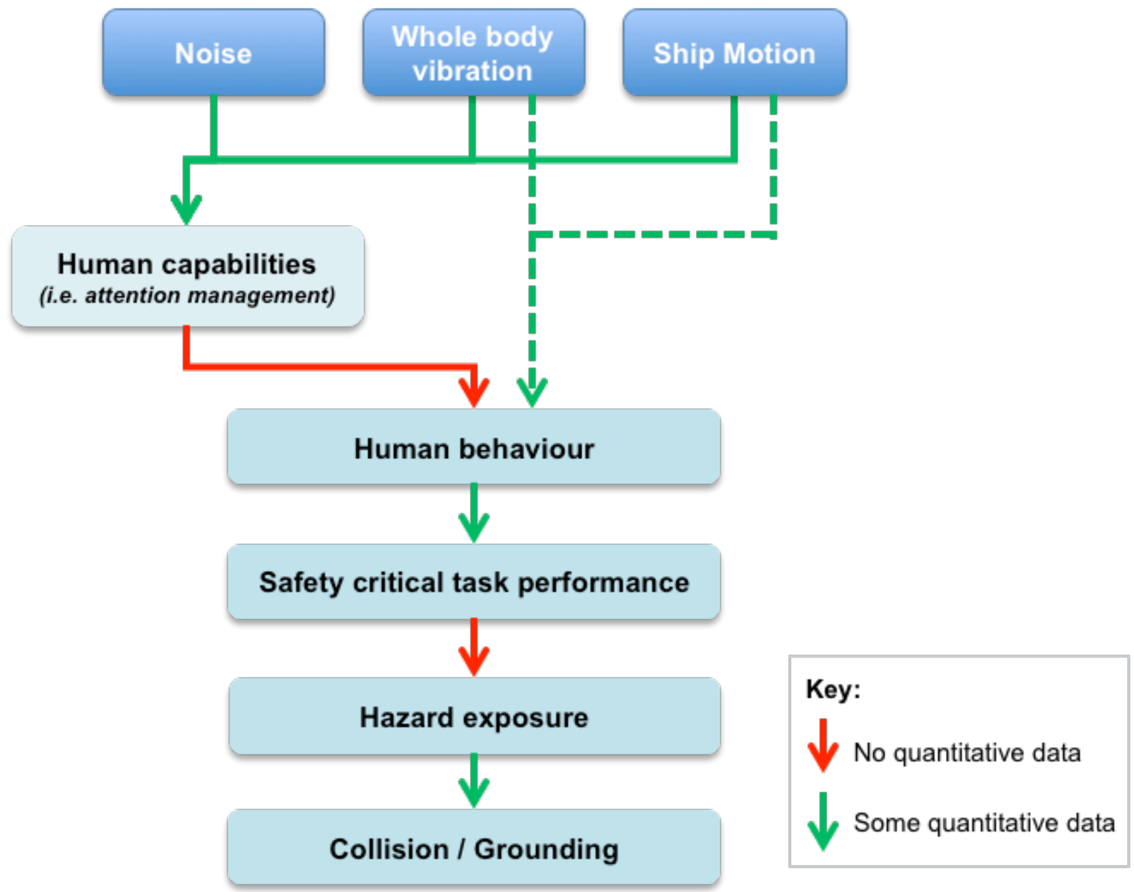
It was found that the data on the specific GDF effects of ship motion, noise, WBV on human performance are sparse and in many cases generated under very specific, often non-marine, conditions.

Data shows that there is certainly evidence for GDFs having some effect on human performance.

- Impact of GDFs on specific human capabilities.
- Impact of GDFs on specific human behaviours.
- Impact of errors on task performance.

However, there is very little data about the link between the following components:

- Degraded human capabilities and collision or grounding related human performance.
- Degraded task performance and exposure to the collision / grounding hazard.



Human performance modelling

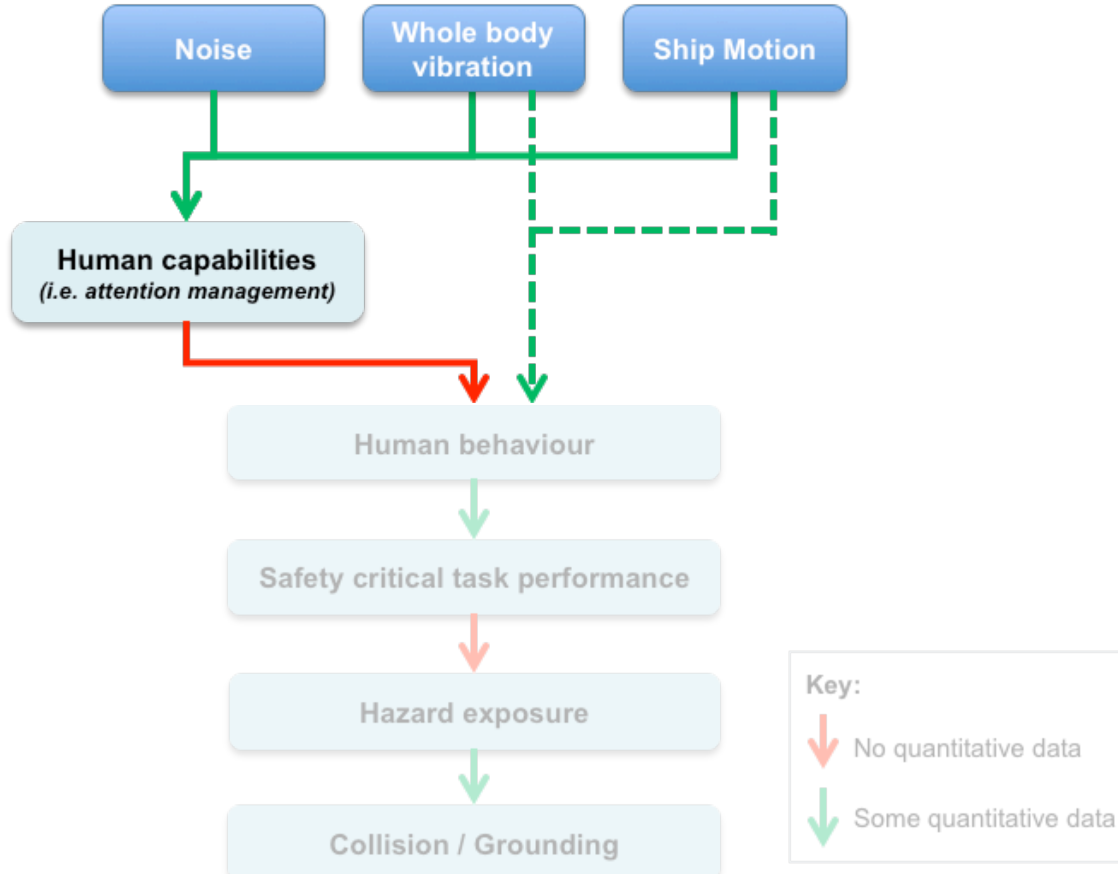
The approach taken here to describe a mechanism that accounts for the impact of stressors on human performance, has been based on the principles of **attention management**.

It combines the principles from three theoretical models:

- Dynamic Adaptability Model (DAM).
- Cognitive Control Model (CMM).
- Malleable Attentional Resources Theory (MART)

Adoption of attention management concept allows us representation of the effect of GDF exposure as a stressor that sits either above or below the threshold of attentional capacity for any given task.

If the stressor exceeds the attentional capacity then a negative effect is expected.

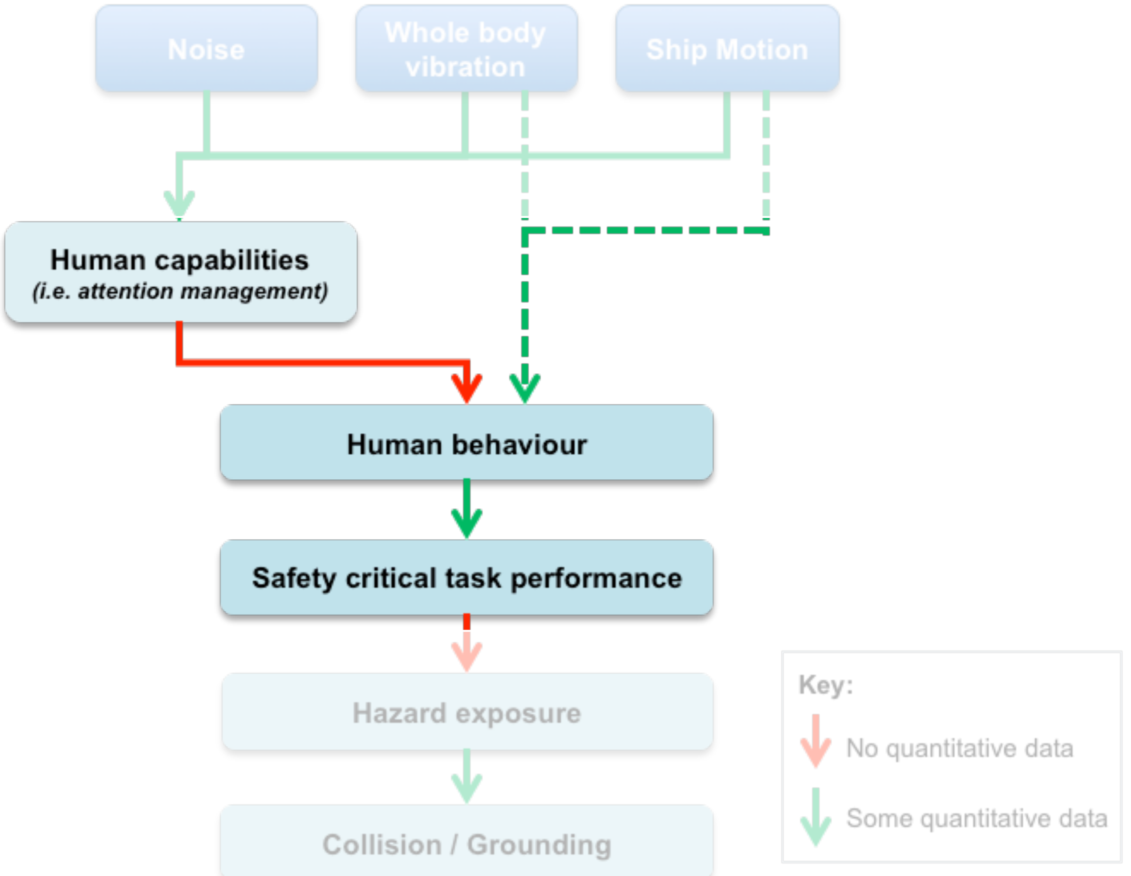


Integration of HRA in the risk model

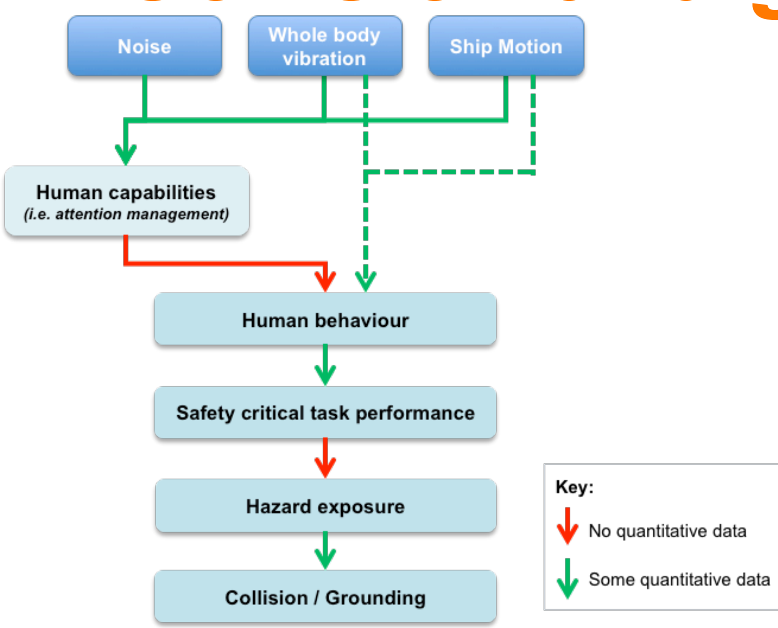
Due to the limitations in data on the effects of GDF exposure on human performance, one cannot find precise values in the scientific literature.
A solution was found in **Human Reliability Analysis (HRA)** techniques.

While HRA techniques do not typically cover the specific GDFs or the maritime environment, the human error probabilities (HEPs) generated by HRA allow sensible bounds to be determined.

The HRA method **Nuclear Action Reliability Assessment (NARA)** was selected to provide the HEPs associated within collision and grounding model.



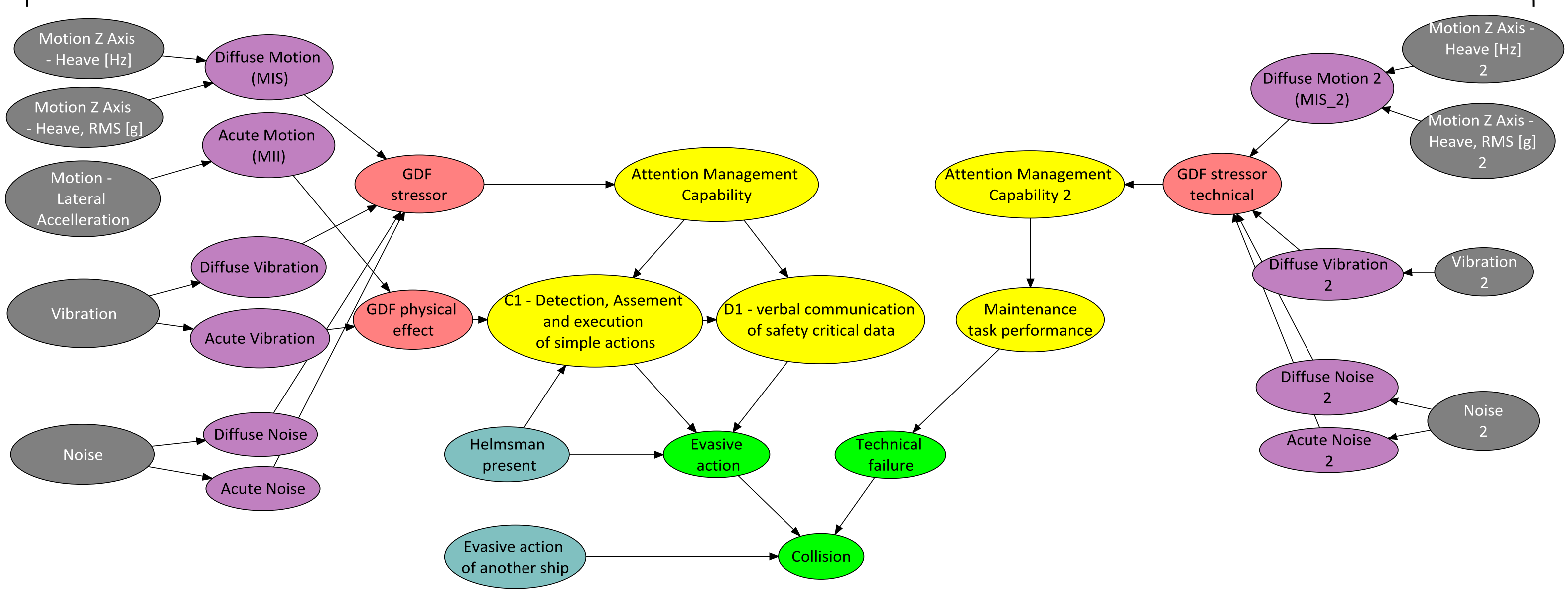
Collision and grounding risk models



Translation of general structure into a workable model using **Bayesian Belief Network (BBN)**.

BBN allows for:

- probabilistic and causal representation of the background knowledge on the analysed domain,
- reasoning in the presence of uncertainty,
- assessment of the effect of the uncertainties on the outcome of the model.



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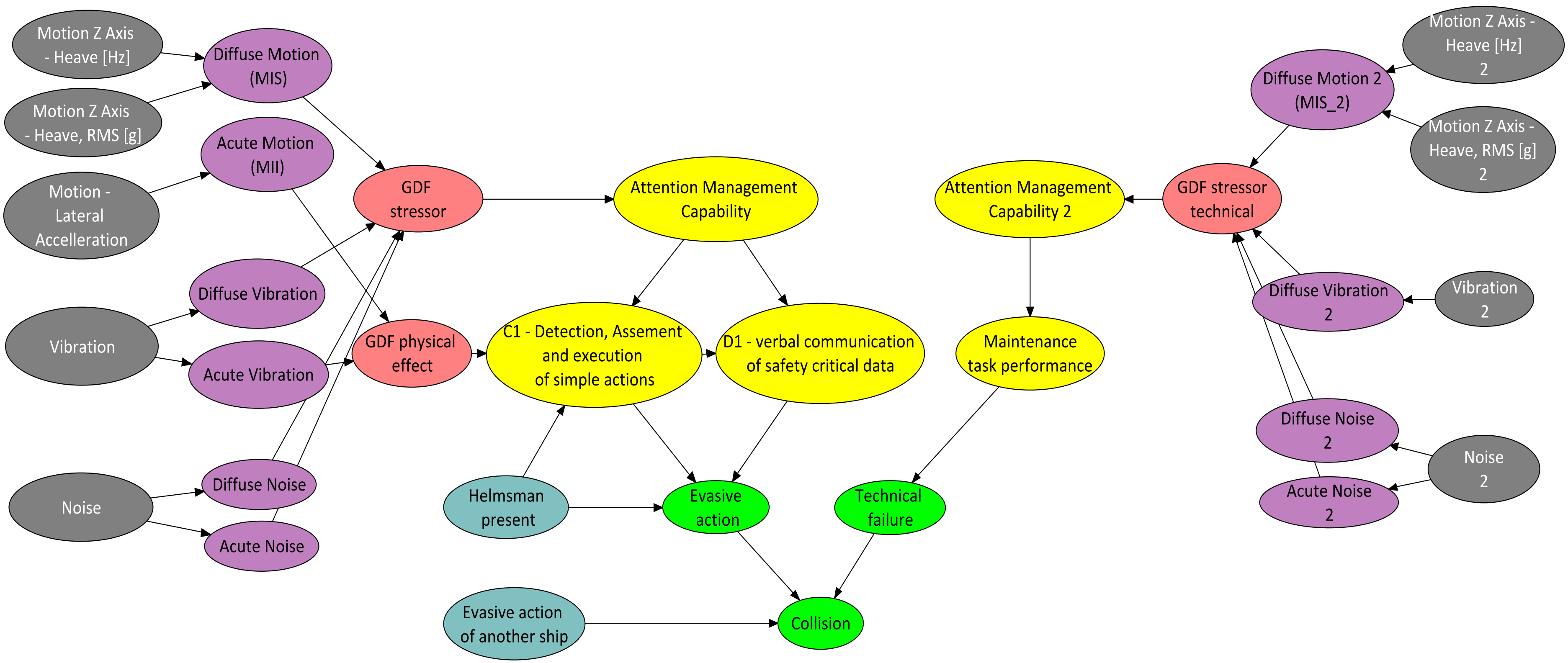
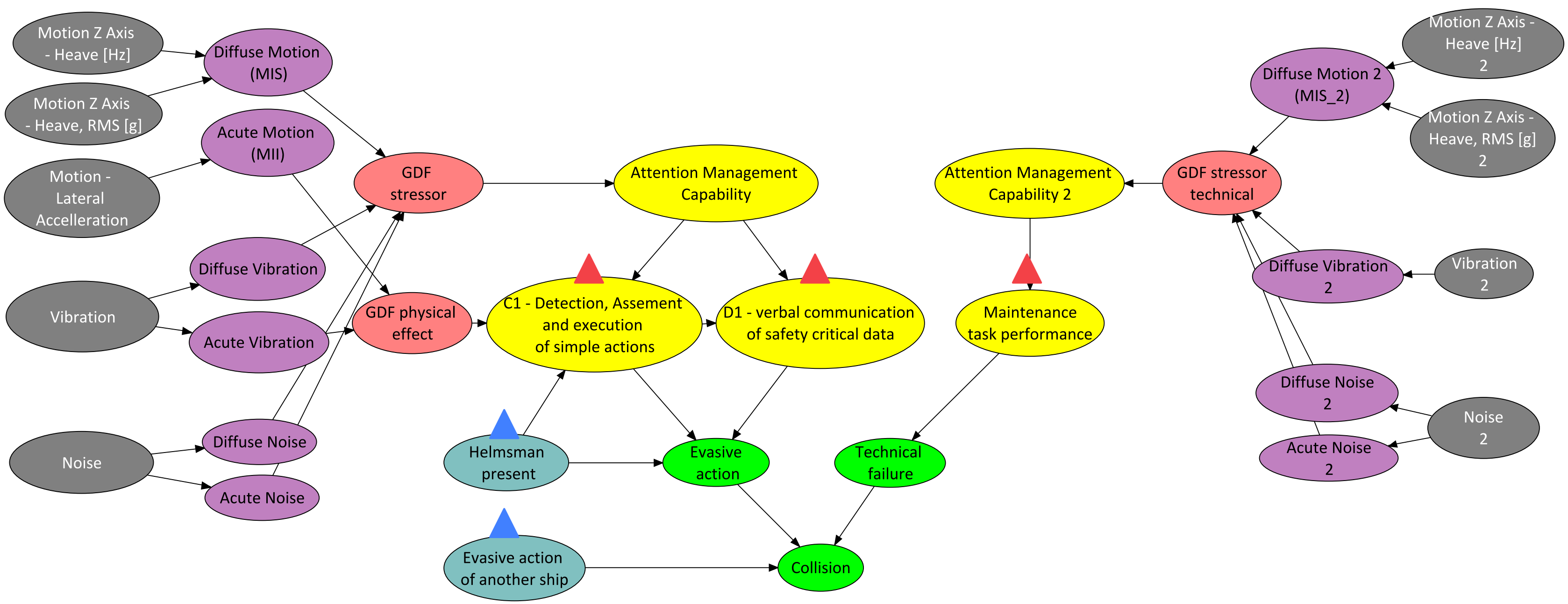
Collision and grounding risk models



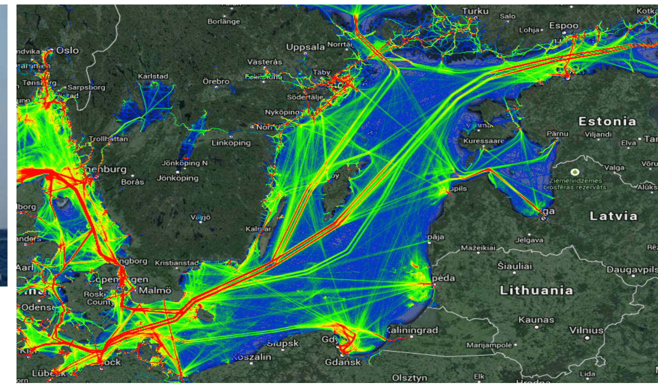
Collision and grounding risk models

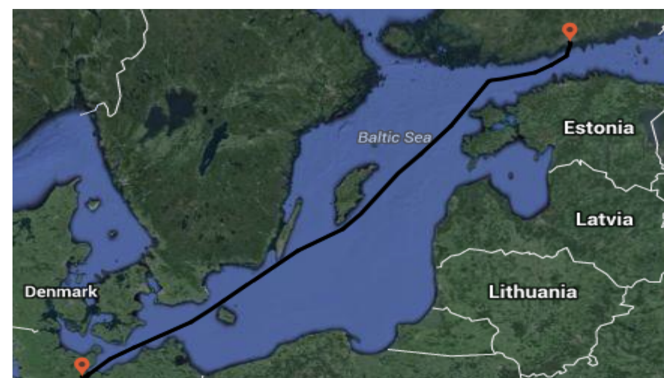


Model parameter	*Evidential uncertainty score*	*Sensitivity score*	*Importance score*
Maintenance Task Performance	Moderate	High	High
C1 - Detection, Assessment and execution of simple actions	Moderate	High	High
D1 - verbal communication of safety critical data	Moderate	High	High
Evasive action of another ship	Moderate	Moderate	Moderate
Helmsman present	Moderate	Moderate	Moderate

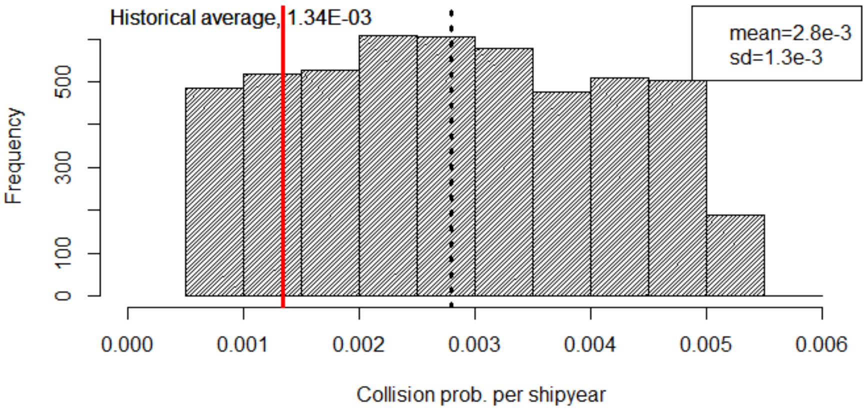
Collision and grounding risk models - benchmarking

Risk for collision and grounding for a RoPax operating on a route between Helsinki (Finland) and Rostock (Germany).



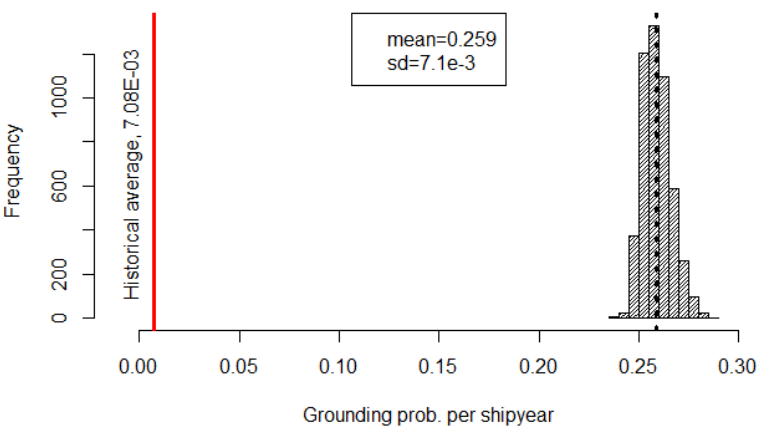


Collision and grounding risk models - benchmarking



Collision risk model for RoPax

- The collision risk model for RoPax ships delivered mainly acceptable results when compared to historical averages.
- More specifically, the risk results are of the same order of magnitude as the historical averages.
- This study does not give rise to corrections to the risk model for RoPax.



Grounding risk model for RoPax

- The grounding risk model did not deliver acceptable results when compared to historical averages.
- More specifically, the risk results are of up to three orders of magnitude higher than the corresponding historical averages.
- Corrections are necessary so the cost benefit analysis, when such performed, delivers reasonable results.

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Conclusions

- The causal mechanism represented within the model that describes occurrence of an accident as the result of insufficient performance of an individual when exposed to hazardous situation offers a flexible modelling framework.

- Modelling improper performance in critical situations is compatible with the general conceptualisation of human error within the Human Factors (HF) domain and its relationship to task performance.

- As expected, the paucity of data on GDF effects presented a particular challenge. However, attention management theory successfully provided a means to represent the mechanism by which ship motion, noise and WBV affect cognitive performance.

- The application of BBNs as a modelling tools, allows for clear representation of the modelled problem and comprehensive distribution of all the recognised uncertainties.

- Finally, comparative assessment of vessel designs based on manipulation of the GDF input nodes is possible in principle.

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