Safety and risk assessment of autonomous shipping – challenges, solution proposals and research directions

Montewka J., Wróbel K., Heikkila E., Valdez Banda O., Goerlandt F., Haugen S.

Gdynia Maritime University, Poland
VTT Technical Research Centre of Finland Ltd, Tampere, Finland
Aalto University, Espoo, Finland
Dalhousie University, Halifax, Canada
Agenda

1. Introduction

2. Summary and discussion of the existing methods
   1. Risk-informed design (Formal Safety Assessment, Goal-based Standards)
   2. System theoretic process analysis
   3. Safety case approach

3. Conclusions
Background, aim and scope

• Safety of maritime transportation is governed by global and local codes and practices, and a distillation of past experience. It is a highly prescriptive world.

• Such approach suffices for standard ships, however for highly innovative solutions, like autonomous ships, another way of ensuring safe operations is needed.
Background, aim and scope

• Therefore in this presentation we discuss selected methods suitable for safety assessment and quantification of transportation systems including:
  • risk assessment,
  • system theoretic process analysis,
  • safety case approach.

• Challenges and opportunities of those approaches are highlighted and the recommendations are given regarding the application areas of the methods.
Methods: FSA, GBS

- International Maritime Organization offers solutions for proactive safety assessment and management called Formal Safety Assessment and Goal-based Standards.
- Therein safety is measured through a concept of risk.
- A system is considered safe as long as the calculated risk value falls within the acceptable risk limits.
- The need of quantitative risk estimates is challenging.
Methods: FSA, GBS

• The Guideliness for FSA defines risk as a follows: $R = P \times C$
• Interpreting risk simply as this combination, may lead to misconception, that the risk is just a number, divorced from the scenario of concern and available background knowledge.
• This in turn may lead to the loss of relevant information needed for risk management.
• It is not clear, how to express uncertainty and its effects on risk metrics and risk control options.
• Quantitative approach is strongly preferred, precise risk esitmates are sought.
• $P \times C$ definition of risk dominates the field, despite the existence of other, more flexible and broader definitions in other domains (e.g. oil and gas).
Methods: FSA, GBS

• In the context of GBS the concept of risk is used at the stage of verification of conformity (Tier III).

• The risk level of a given ship design is confronted with the allowed risk levels as anticipated by the rules (Tier IV).

• The tolerable, intolerable and ALARP risk levels are defined by the relevant stakeholders like IMO, authorities or classification societies.
Methods: FSA, GBS

• In many risk analyses, one sees that a lot of effort is put into producing as “accurate” risk numbers as possible. In fact, they are often only precise, but not accurate.

• However, it is futile to calculate high-precision values in the risk analysis if other parameters essentially are “guesstimates” made by the analyst.

• In the presence of structure uncertainty and alternative hypotheses how sure one can be about the obtained numbers?

• In the extreme cases, the numbers obtained from databases and analysis are considered “the ultimate truth” about the probability of an accident in the analysed area, without proper reflection of the context and background knowledge (only to mention the issue of underreporting).
Methods: FSA, GBS

- **Model of potential failure propagation** during the autonomous vessel’s accident allows for safety quantification in terms of risk.
- **Major challenge – lack of data.**
- Other (qualitative) methods may be better to elaborate on safety and the ways to control it.


Discussion – FSA, GBS

- A wider concept of risk should be introduced to the field.

- Various scientific approaches to risk exist, depending on the available background knowledge, utilizing the available sources of data and knowledge. These should be utilized.

- Recent shift in risk paradigm in oil&gas industry, from PxC towards U&C (uncertainty about the consequences) should be a sign for maritime.

Methods: STAMP / STPA

- **System-Theoretic Process Analysis (STPA)** is a method of assessing system’s safety by analysing the interactions between its components and the ways in which those can be unsafe.

- The nature of such interactions shall ensure that the system as a whole remains within safety limits.

- The aim is **not to quantify the safety** (mainly due to lack of data) **but to ensure that it is controlled in proper manner**.
Methods: STAMP / STPA


discussion - STPA

- Uncertainties pertaining to the outcome of the study come as a result of the unmanned shipping technology being in its infancy. No empirical data or reliable models of such ships’ safety performance is available.
- The subjective uncertainty assessment, borrowed from the risk analysis, and applied in system-theoretic approach tends to reflect the analyst’s level of background knowledge.
- Prioritization of control actions. Where to put money first?

**Uncertainty magnitude**

<table>
<thead>
<tr>
<th>Category</th>
<th>Phenomena</th>
<th>Uncertainty level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>Low level or no understanding</td>
<td>Significant</td>
</tr>
<tr>
<td></td>
<td>Some basis for models, level of</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td>simplifications adopted varies</td>
<td></td>
</tr>
<tr>
<td></td>
<td>across the model; alternative</td>
<td></td>
</tr>
<tr>
<td></td>
<td>hypotheses exist</td>
<td></td>
</tr>
<tr>
<td>Assumptions</td>
<td>Poor justifications for the</td>
<td>Significant</td>
</tr>
<tr>
<td></td>
<td>assumptions made, oversimplifying</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td>the analysed phenomena</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reasonable justifications for</td>
<td>Minor</td>
</tr>
<tr>
<td></td>
<td>the assumptions made, although</td>
<td></td>
</tr>
<tr>
<td></td>
<td>simplifying the analysed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>phenomena</td>
<td></td>
</tr>
<tr>
<td>Data</td>
<td>Not available or reliable</td>
<td>Significant</td>
</tr>
<tr>
<td></td>
<td>Data of varying quality is</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td>available</td>
<td></td>
</tr>
<tr>
<td>Consensus</td>
<td>Lack of consensus</td>
<td>Minor</td>
</tr>
<tr>
<td></td>
<td>Various views exist among</td>
<td></td>
</tr>
<tr>
<td></td>
<td>experts</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Broad agreement among experts</td>
<td></td>
</tr>
</tbody>
</table>


The goal-based safety case approach is a proposed extension to the regular safety qualification methodologies to help in structuring the results of qualification activities and especially in enabling communication between the different stakeholders involved in the safety design and qualification processes.

In this approach, the safety requirements (represented as goals) and safety evidence (data created in the actual qualification activities) are presented together in a visual manner as a structured safety case. This provides a link showing which evidence items are provided to demonstrate the fulfillment of each of the safety goals.

The structure of safety goals is a living documentation that is updated throughout the design and qualification processes.
Methods: goal-based safety case approach

A safety qualification procedure, resulting in safety argumentation documented as structured safety case.

A simplified example of how the safety goals and evidence can be represented in the case of an autonomous ship sensor system.

Discussion – safety case

• The major advantages of the method are in the communicative power of the visual representation of safety goals and evidence, making the link between these easily comprehensible.

• This enables efficient communication regarding safety between the different stakeholders, and enables a faster approval of new technologies for autonomous shipping.

• The methodology is mainly designed with the communicational aspect in mind, and thus provides no direct tools for prioritizing the safety goals based on their safety impact.

• Neither does it directly provide tools for assessing the probabilities or uncertainties regarding the fulfillment of the goals.

• The methodology, however, is new to the maritime sector and further case applications are needed to fully consider its benefits.
Conclusions

• Goals-based and risk-informed approaches give flexibility in development of novel solutions, at the same time as retaining consistent and acceptable risk levels also for new technology.

• However a more flexible perspective on risk is needed, where in particular the aspect of background knowledge/uncertainty is incorporated, to give to decision-makers better basis for making sound decisions.

• New safety and risk analysis methods are better suited for analysing increasingly complex systems, with increased use of sensors, software, communication between ships and between ship and shore, very different demands on the humans involved etc.

• Both method development and more guidance on choice of methods and combinations of methods is required.
Thank you for your attention.
For more information, please contact:

Jakub Montewka, DSc (Tech.)
Associate professor
Dept. of Transport and Logistics
Gdynia Maritime University
POLAND

Tel. +48 732666078
E-mail j.montewka@wn.umg.edu.pl
www https://www.researchgate.net/profile/Jakub_Montewka