# Is scientific learning effective enough in maritime risk analysis?

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## Introduction

Effective scientific learning is a key issue in maritime risk analysis. Accidents are not, luckily enough, very common, but their consequences are potentially huge, both in terms of lost lives, and large environmental damages. There, risk (probability x loss) can be considered high. Therefore, risk management must be effective, and based on the best possible scientific estimates. We argue, that there is an obvious need to learn from, as effectively as possible. End-users of information and society have a justified right to demand high quality and scientifically justified information, with realistic uncertainty estimates to enable risk averse decisions, i.e. decisions which are based on the tails of probability distributions.

Among the well-established statistical approaches, Bayesian statistics offers a systematic learning possibility due to the role of prior information. Prior probability distribution is assumed to include all such information, what the modeler and other knowledgeable experts argue consider to be relevant. The way to provide prior information may be meta-analysis, simulation models, additional raw data, all accidents, nearby cases, experiments, and expert judgements.. The last of these may be the only way to get systematic information for such decision alternatives, which have not been historically tested, and therefore empirical data does not exist. A decision not to use prior knowledge is the same as saying “no-one else has published any such information that could be relevant for the end users and society. Also, from the point of view of planning new experiments, it makes sense to first asses existing information, and focus the experiments on such uncertainties, which are in a key role in risk management decisions.

## Materials and methods

The material utilized in this paper comes from the published papers in maritime risk analysis. Especially, we will review papers which are focusing on environmental risk analysis, but also other relevant papers are examined. We mostly focus on the statistical and other methodological approaches applied, and consider their capacity to openly utilize existing information sources and to provide basis for cost effective learning.

## Implications on sustainable maritime operation

Bayesian models are quite common in environmental risk analysis of shipping. However, they are mostly Bayesian network models, which cannot, or are not used to, fully utilize all features of Bayesian analysis, especially those that are based on MCMC techniques to estimate parameters of simulation models. Most of published papers use calculus from causes to effects, and in this sense do not use the integrative possibilities of Bayesian models, i.e. summarize the evidence from effects back to potential causes, against the causal dependency described by arrows between the variables.

One of the key features of Bayesian networks is, that each observational data does not need to cover all variables of interest. This is in contrast with many multivariate methods, where missing data points lead to discarding of data. This feature of Bayesian inference means, in the case of maritime research, that also nearby cases can be utilized to decrease uncertainties related to risky behavior of the vessels. By definition, this leads to improve prediction capacity to identify risky situation, with lower research costs than approaches where priors and partially missing data are not used.

In maritime engineering experiments, often carried out by full size ships, are expensive. We argue that many of them are similar enough to utilize the experimental results by meta-analysis, with hierarchical Bayesian models. The hierarchies can consider the differences between experiments, but still help to decrease the uncertainties in a more cost-effective way than by sending yet another research vessel to the sea. In biology, hierarchical models are used to learn parameters between different species-.

Ideally, papers based on Bayesian methods could create learning chains between papers, as an posterior of one paper could be used as a prior in the next one. Such an approach would support decision makers to make well justified decisions under uncertainty, and safeguard human lives and good state of environment. This can be seen as the ethical duty of the maritime scientists.