EFFECTIVENESS OF MARITIME SAFETY POLICY INSTRUMENTS – CASE STUDY ON THE GULF OF FINLAND

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ABSTRACT

The aim of this paper is to evaluate maritime safety policy instruments with the focus on the Gulf of Finland. The Gulf of Finland is a shallow and ecologically vulnerable sea area with dense passenger and cargo traffic. The share of oil transports is over 50% of all cargo transports. The worst case scenario would be a collision of an oil tanker and a passenger ship, which could have devastating consequences both for human lives and for environment. New policies to prevent an accident from happening are developed and suggested in many maritime safety issues and at many levels (international, regional, national). Maritime safety is an issue concerned with multiple perspectives and disciplines, such as those dealing with technical, societal, economic, cultural and environmental aspects. It poses a challenge for society and decision makers: how to use limited resources so that the best benefit with the lowest costs is achieved? In addition, decision makers are typically faced with a flood of information, in which the comparability of results is poor and uncertainties high. The fact that we don't know how the future development of the global and regional economy, industries, infrastructure and environmental policies will proceed, brings even more challenges.

The purpose of this paper is to present both qualitative and a quantitative means to evaluate the effectiveness of policy instruments in order to give tools for decision makers: what kind of efforts would most likely minimize the risks at maritime traffic with reasonable costs? The paper includes the presentation of the qualitative criteria for effective policy instruments and a Bayesian network based model where cross-disciplinary information (social, technical, biological) is combined to evaluate the probability and biological consequences of an oil accident in the Gulf of Finland in the future and the effect of different management actions on them. In addition, one example of a management action (the Enhanced Navigation Support Information system), that is going to be tested in the SAFGOF meta-model, is presented. Because the meta-model is still being developed, this paper doesn't include yet the results of the model.

Because the amount of maritime safety regulation is large and new policies are suggested and regulated continuously, society must have tools to evaluate management actions against each other in order to be able to deploy the limited resources optimally. Our proposal is that both qualitative and quantitative evaluation methods should be used. For making a holistic and realistic comparison, we suggest cross-disciplinary, integrative decision models to be used, taking into account the uncertainties concerning both the future development and our knowledge on how the system reacts.

Keywords: maritime safety, policy instruments, Bayesian networks, evaluation, the Gulf of Finland

INTRODUCTION

Accidents at sea and increasing volumes of maritime traffic, especially the transportation of dangerous cargoes, have given rise to a growing awareness of the safety of maritime traffic. International maritime safety regulation has a long history and it is continuously revised and developed further in numerous maritime safety related issues.

In this paper different kinds of maritime safety policy instruments are presented, especially from the point of view of the Gulf of Finland. The Gulf of Finland (GoF), a large basin of the brackish Baltic Sea, is one of the world's most stressed sea areas with intensive maritime traffic that is predicted to strongly increase in the near future (see Klemola et al., 2009; Kuronen et al., 2008). The increasing amount of oil transport in addition to the increase of ships navigating in the GoF will inevitably lead to a raised probability of a large scale oil accident.

The concern about the possibility of a large scale oil accident in the GoF is wide, and besides existing policies different kinds of new management strategies have been suggested in order to prevent accident from happening. The crucial question, from the societal point of view, is what kind of policy instruments are the most (cost)-effective and how maritime safety in the Gulf of Finland could be enhanced best. In other words, what kind of efforts would most likely minimize the risks with the reasonable costs? Where should they take place?

As the maritime safety is an issue concerned with multiple perspectives and disciplines, such as those dealing with technical, societal, economic, cultural and environmental issues, the managers and decision-makers have a complicated task trying to assess the cost-effectiveness of different actions aiming for the minimization of the risks. Typically, they are faced with a flood of information, in which the comparability of results is poor and uncertainties high. The fact that we don't know how the future development of global or regional economy, industries, infrastructure and environmental policies will proceed, brings even more challenges.

So far, the oil spill risk management work in the Baltic Sea and GoF has focused mainly on the minimization of the negative impacts through efficient oil recovery organization. In addition, it is still essential to assess alternative precautionary strategies. In this paper, qualitative criteria for effective policy instruments based on the literary sources and a new probabilistic modeling approach for evaluating and comparing them is presented. Commercial software Hugin Expert ® (Madsen et al., 2005) is used to build a probabilistic meta-model structure that integrates the latest maritime traffic statistics, predictions based on alternative growth scenarios, modern accident modelling techniques, ecosystem models and a spatial multi-criteria valuation tool for the evaluation of end results. The model presented is produced during the years 2008-2010 and is thus currently under construction.

The structure of this paper is as follows. First, as background information, different kinds of maritime safety policy instruments are gone through in general level. Then, the special features of the GoF and some examples of management actions, which have been or will be implemented in the area, are presented. After that comes the theoretical part, where the qualitative criteria of effective policy instruments and quantitative approach to decision analysis are presented. The paper ends with the presentation of the Bayesian "SAFGOF" meta-model.[1].

MARITIME SAFETY POLICY INSTRUMENTS

Policy instruments are often grouped into three categories: regulatory instruments (jurisdiction and law based decrees, restrictions, licences etc.), economic instruments (taxes, subsidies, fees etc.) and information-based guidance (information, voluntary education, certification, awards etc.). Policy instruments can be viewed from the perspective of the interests that they aim to protect: private goods (e.g. the competitiveness of companies) or public goods, which the market would otherwise neglect (e.g. the maintenance of safety and security in the shipping industry and protection of the environment from the harmful effects of shipping). Policy instruments can be either preventive measures, or sanctions and consequences. All the instruments are not necessarily based on jurisdiction. Private actors can also act in co-operation and promote maritime safety related goals, for example in P&I Clubs (Protection & Indemnity Clubs). (e.g. Klemmensen et al., 2007; Vieira et al., 2007)

Maritime safety includes the safety of people both on board and ashore and the safety of cargo transportation. The environmental safety includes operational discharges (automatic or intentional discharges of oil and other harmful substances, ballast water, antifouling

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substances, garbage and sewage) or accidental discharges of harmful substances (Roberts, 2007). Factors affecting maritime safety can be grouped into internal and external factors. Internal factors include the condition of a ship and its equipment and the competence of the personnel on board. External factors consist of the conditions of waterways and maritime safety devices, the quality of vessel traffic services, piloting, ice-breaker assistance and available information on weather conditions, ice and water level. The supervision of compliance with the regulations and compensation and liability questions are also important aspects of maritime safety (Greiner et al., 2000; Ministry of Transport and Communications Finland, 2009). All these issues are regulated in order to enhance the level of maritime safety.

Maritime safety is the most prominently legislated within the framework of the United Nations and the International Maritime Organisation (IMO). However, maritime safety is also regulated at supra-national, national and regional levels. In principle, these levels should work in a so-called nested hierarchy, where the international level is the outmost circle and other levels are within each other in a circle. The inner circles should be consistent with the outer levels of the circle in order to make the implementation of regulation effectual. In the real world, this has not always been the case, and the supra-national (e.g. European Union) and national (e.g. the United States) levels have taken steps to regulate the same issues as the IMO before the IMO has taken action, for example in case of double-hull tankers. (Roe, 2008) Some maritime safety issues belong to the sphere of national regulation, for example piloting. Besides the regulatory bodies of maritime safety, there are actors in the shipping industry who do not have legislative power, but who in some way or other influence maritime safety, for example classification societies or marine insurance companies. (Kuronen and Tapaninen, 2010)

Of different types of policy instruments regulatory instruments are the most widely used, also in the maritime world. Table 1 is a summary of how maritime safety is regulated by means of regulatory instruments and who is the main legislator or actor.

Table I – Maritime safety – regulatory instruments (Kuronen and Tapaninen, 2009)

Regulated sector		*Main legislator/actors*
Ship construction and equipment	• construction and subdivision • stability • equipment • stowage • navigation • handling of the cargo	→ IMO
Surveillance of ship conditions	• flag state control • port state control • host state control • classification societies • vetting inspections	→ IMO → IMO, PARIS MOU → EU → private companies → private companies
Mariners and safety management	• working conditions • employment conditions • manning of ships	→ IMO, ILO

	• safety and quality management	
Navigation	• VTS	→ IMO
	• ship reporting systems	→ IMO, regional co-operation
	• traffic separation schemes and routings	→ IMO, regional co-operation
	• traffic recommendations and restrictions	→ IMO, regional co-operation and nations
	• piloting	→ nations
	• waterway safety	→ IMO, IALA
	• nautical charts	→ IMO, IHO
	• information supply on weather, water level, ice situation etc.	→ IMO
	• towage services	→ nations, private companies

It is typical for shipping related economic instruments that they are mainly used to improve the competitiveness of the sector rather than to promote maritime safety related goals. It is also typical for economic instruments that they are adopted at the national level or used between private actors (see Table 2).

Table 2 – Maritime safety – economic instruments (Kuronen and Tapaninen, 2009)

Regulated sector	*Main legislator/actors*
Dues related to maintenance of waterways	→ nations
Port dues	→ nations, private companies
Marine insurance	→ private companies, IMO (obligatory insurances)
P&I Clubs	→ private companies
Liability and compensation (oil pollution)	→ IMO
Incentives, e.g. GreenAward Certification System	→ private companies, nations

Information guidance instruments are also used in maritime safety issues; for example, the IMO issues codes, guidelines or recommended practices on important matters not considered suitable for legally binding conventions. Voluntary education, voluntary certification systems and maritime safety related awards are other examples of information guidance instruments. The effect of information guidance is totally dependent on the voluntary interests of an actor and there are no formal consequences in the case of non-conformity. (Kuronen and Tapaninen, 2010)

Gulf of Finland and maritime safety

GoF is a narrow, shallow and ecologically vulnerable sea area and a part of the world's largest area of brackish water, the Baltic Sea. It is 400 km long, width varying between 60 and 135 km. Average depth of the gulf is 37 metres having the maximum of 60 metres. Coastal countries of the GoF are Finland, Russia and Estonia. The area is partially ice-covered, approximately from December to April, the ice being heaviest on the Russian side of the gulf. (Nikula and Tynkkynen, 2007)

Figure 1 – Major ports in the Gulf of Finland

Maritime traffic in the GoF has grown remarkably during the 2000's, which is mainly due to the strong economic growth and the increasing oil production and transportation activities of Russia. The expansion of oil exports has lead to a strong economic growth, which is also apparent in the growth of the other maritime transports in the area. Russia has been expanding its port activities in the GoF and is officially aiming to transport its own imports and exports - now being transported to great extend via Finnish, Estonian and other Baltic ports - through the ports of its own in the future. In addition, there is dense, intersecting passenger traffic line between the ports of Helsinki and Tallinn. (Kuronen et al., 2008) In 2008, about 253 M tonnes of cargo with 46 000 ship calls were transported by sea in the GoF. 56% of the cargo was oil (Särkijärvi et al., 2009).

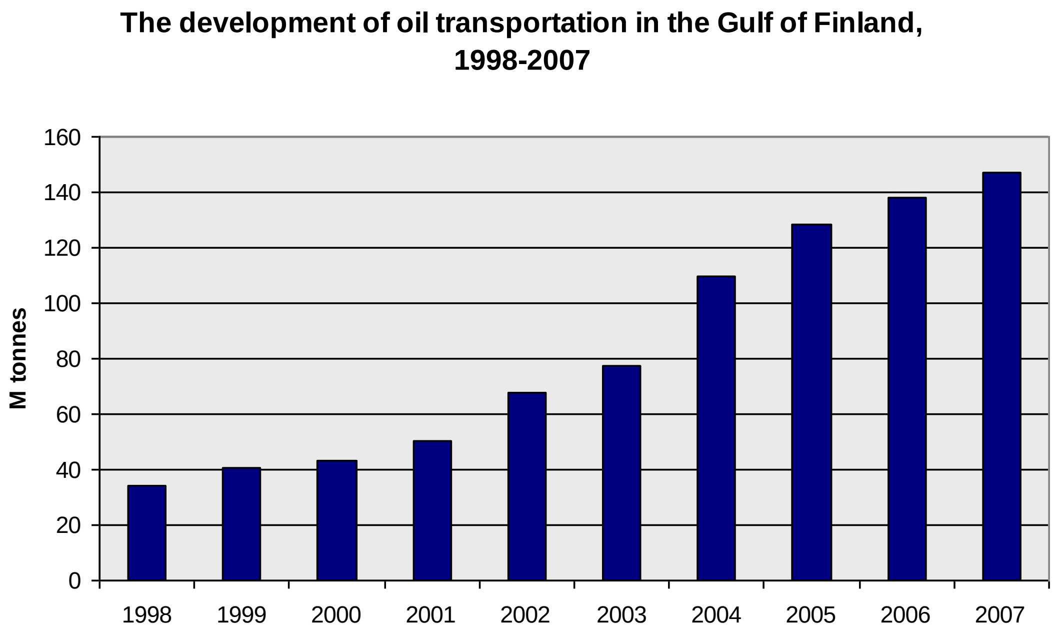

Figure 2 – The development of oil transportation in the Gulf of Finland, 1998-2007 (Finland's environmental administration 2008)

Maritime safety policy in the Gulf of Finland

IMO has designated the Baltic Sea, including the GoF, as a Particular Sensitive Sea Area (PSSA) needing special protection. PSSA status gives coastal states the opportunity to take additional protective measures to minimize the risks caused by shipping. The designation of PSSA is not a regulation in itself, but it serves as a basis for the proposal for additional protective measures. (Roberts, 2007) Associated protective measures for PSSAs are limited to actions that are to be, or have been, approved and adopted by IMO. Additional protective measures can include routing systems such as an area to be avoided, ship reporting systems and discharge and emission control systems. (International Maritime Organisation, 2006)

Helsinki Commission (HELCOM) aims for the protection of the Baltic Sea marine environment and is thus also dealing with the maritime traffic issues. It is the governing body of the Helsinki Convention (1992) meant to promote the intergovernmental co-operation between the coastal states of the Baltic Sea and the European Community. It gives recommendations for its members to implement although they are not legally obliged to do so. Recently HELCOM has focused in maritime issues for example on the development of vessel traffic control services and the safety of winter navigation. (HELCOM, 2010)

In the GoF, in order to tackle with maritime safety risks, Russia Finland and Estonia have agreed on a Mandatory Ship Reporting System (GOFREP), which has IMO approval. There are also six traffic separation schemes and one deep water (DW) route in the GoF. (Ministry of Transport and Communications Finland, 2009) Finland, Estonia and Russia have decided to submit a proposal to IMO on the improvement of traffic separation schemes in the Gulf of

Finland. The proposal includes, for example widening the traffic lanes and establishing a new security zone in the area. (Finnish Maritime Administration, 2009)

Ice conditions are one of the special features of the GoF. Finland, Russia and Estonia organize ice-breaking assistance services. States also impose traffic restrictions based on DWT and ice class. During the ice-covered season, ships can also be routed to sea areas with easier conditions.

The European Union has defined future goals for maritime issues in its Strategy for the Baltic Sea Region (Commission of the European Communities 2009). The Baltic Sea should become a leading region in maritime safety and security in Europe. Key means to enhance maritime system are seen to be the improvements of traffic organization measures, such as the more efficient surveillance of traffic and routing system, and addressing of human-driven errors. (Commission of the European Communities, 2009)

Also in the national level maritime safety issues in the Baltic Sea and in the GoF are high on the agenda. Finland for example is developing a system that automatically follows the movements of ships and gives automatic warnings in case of potential dangerous situations. (Finnish Maritime Administration, 2009)

In regard to existing regulations and those under development, it can be concluded that maritime safety risks are taken seriously and a great amount of work is done to ensure safe shipping, both worldwide but in this case especially in the Gulf of Finland. But what kind of policy instruments and management actions are effective and how to decide which actions to take? These issues are dealt with in the following chapters.

CRITERIA FOR EFFECTIVE POLICY INSTRUMENTS AND DECISION ANALYSIS SYSTEMS

This chapter includes two parts. First, qualitative criteria for effective policy instruments are presented. The criteria have been mainly formed basing on two articles on policy instruments (Greiner et al., 2000; Vieira et al., 2007). Then, decision analysis and decision support systems are presented (e.g. Burgman, 2005; Power and McCarty 2000; 2005). These form the theoretical background to our study.

Criteria for effective policy instruments

Vieira et al. (2007) have developed a system for assessing transport policy instruments where the set of policies are evaluated against certain criteria and in relation to each other. Greiner et al. (2000) have also used very similar criteria for transport policy evaluation. Below, we have amalgamated criteria for the effective policy from these two articles.

Table 3 – Criteria for effective policy instruments

Criterion	*Explanation*

Effectiveness and appropriateness	Effectiveness and appropriateness refers to the potential improvement in the thing that an effort is made to change. It relates to whether an instrument is appropriate and technically suitable for achieving a goal. (Greiner et al., 2000; Vieira et al., 2007)
Acceptability	Acceptability refers to the stakeholders' level of agreement on a new policy instrument, and to the political and community acceptability of an instrument. Acceptability is a necessary condition for the durability of the policy. (Greiner et al., 2000; Vieira et al., 2007)
Economic efficiency	Economic efficiency relates to effectiveness in terms of implementation costs of an instrument and the economic efficiency of an instrument in a collective sense, assessing the total benefits of the associated change in risk minimizing against its total costs. (Greiner et al., 2000; Vieira et al., 2007)
Enforcement	Enforcement indicates how effectively a policy instrument can be implemented. Some instruments can be difficult to implement, even though they would probably be effective. Vieira et al. (2007) present the following types of barriers for implementation: legal and institutional (legal or regulatory conflicts, legal powers are spread through various institutions or organizations), resource or financial (lack of financial or physical resources to implement an instrument), political and cultural (some groups oppose policy) and technological (e.g. lack of suitable technology). (Greiner et al., 2000; Vieira et al., 2007)

Decision analysis and decision support systems

Decision-makers are typically faced with a flood of information, in which the comparability of results is poor and uncertainties high. An optimal solution based on the point estimates of the state of nature may not be the safest one when compared with an optimal solution based on the best expected utility, taking total uncertainty into account. The expected utilities of various options are uncertain; thus, choosing the "best" action is not self-evident (Burgman, 2005). Often, a "one-answer" scenario is not enough, and a conclusion based on "many answers" derived from a series of decision support models is more realistic (Power and McCarty, 2000).

Decision analyses and decision support systems are terms for methods that provide a quantitative means to study alternative decisions in the presence of multiple aims (e.g. Clemen, 1996). They ease the work of decision-makers by helping them to make consistent and justifiable choices (Power and McCarty, 2000). The evaluation of the nature and extent of uncertainty should always be included in these tools for making the process transparent and to give the decision-makers a realistic picture of the uncertainty and range of the possible outcomes of the management actions (Burgman, 2005; Power and McCarty, 2006).

Modeling aims at finding out optimal decisions; when and where policy instruments on the future state of maritime safety are the most effective?

We aim at developing a new kind of risk- and decision analysis system to help in the evaluation of alternative instruments for minimizing the oil accident risks in the area of GoF. We wanted to compare the alternative steering actions or strategies taking holistically into account different sources of uncertainties. That is to say, to define - from a certain selection - the most reasonable alternative in the light of our current knowledge and also the understanding on what we do not know yet. In practice we are developing a meta-model which will draw together qualitative information and predictions on the future development with the latest technical accident models. For this, we are using hierarchical Bayesian influence diagrams, which are well suited for this kind of probabilistic decision analysis. In the current version, the evaluation will happen through the minimization of ecological (biodiversity and legislative point of view) risk that is spatially heterogeneously distributed within the area. Thus - at this stage - this tool is developed for the assessment of the effectiveness and appropriateness criterion (table 3), but in the future it can be further developed to include other criteria aspects as well.

Bayesian Belief Networks (BBN) and Influence Diagrams (BID)

Bayesian belief networks (BBN) are models for reasoning under uncertainty through computing our updated beliefs about (unobserved) events given observations on other events (Kjærulff and Madsen, 2005). They were originally developed as a formal means of choosing optimal decision strategies under uncertainty (Pearl, 1986). Since then, BBNs have been successfully exploited e.g. in modeling complex environmental questions and interactions containing significant uncertainties (Borsuk et al., 2004; Marcot et al., 2001; Reckhow, 1999) as well as in decision analysis under uncertainty (e.g. Kuikka and Varis, 1997; Uusitalo et al., 2005; Varis et al., 1990).

A BBN is a probabilistic model where each variable has a particular number of mutually exclusionary states of outcome and where its relation to the other variables is defined with links (Jensen, 2001; Kjærulff and Madsen, 2005). Each random variable having incoming links has a conditional probability table (CPT). A CPT contains the information on conditional probability distributions specifying a probability of a variable being in a certain state depending on the configuration of its parents. Unconditional variables (without parents), in turn, have only one prior distribution describing the relative credibilities of the states. Divergent ways to produce these probability distributions can be used, from simulations and data analyses (e.g. Gilks et al., 1994; Mäntyniemi, 2006) to interviews of one or more experts (e.g. O'Hagan et al. 2006; Uusitalo et al. 2005).

BBNs augmented with decision variables including alternative actions to take, and utility functions specifying our preferences concerning the output, are called Bayesian Influence Diagrams (BID) (Kjærulff and Madsen, 2005). The objective of a BID is to identify the action that produces the highest expected utility given the prevailing overall uncertainty.

BBNs and BIDs enable the combination of data sets of different forms and with different precision to a single analysis, and the assessment of the origin, type and magnitude of the uncertainties related to the cause-effect relationships and decisions. They provide a possibility to integrate qualitative knowledge with quantitative data, which makes them extremely useful in multidisciplinary questions. BBNs and BIDs enable the incorporation of social values, expert assessments, and pure numerical data or statistics into the same analysis (Bromley et al., 2005; Klemola et al., 2009; Marcot et al., 2001). Afterwards, the network can be used to evaluate the functioning of the system by manipulating the state of some variables and calculating the effects on the others.

THE SAFGOF RISK-ASSESSMENT AND DECISION ANALYSIS META-MODEL

This chapter describes how maritime safety policy instruments, or in other words individual management actions or steering methods, and their effectiveness can be modelled together with the ship accident probabilities and environmental effects of an oil accident. It shows how probabilistic Bayesian networks can be used as helpful tools when integrating different types of models and knowledge. The need for comprehensive, sub-regional risk assessment tools and evaluation methodology targeting the minimization of the oil accident probability and their negative effects in the Baltic Sea is commonly recognized (e.g. HELCOM, 2007; Steiner, 2004). Such tools would be of great aid in trying to reach the international consensus of the best ways to manage the risks.

Model structure and idea

Current approach is a BID that describes how different future oil transportation growth scenarios affect the biological risks, i.e. the probability and severity of an accident in the Gulf of Finland and how well the risks can be controlled by different management actions, given the growth scenario (Fig. 3). The model integrates several, uncertain future scenarios on maritime traffic with advanced accident models for spatial collision and grounding probabilities, all of which can be manipulated through a selection of management actions. The biological risk is evaluated by linking the BBN to existing nature value software OILECO, developed for the purposes of coastal oil combating prioritization (Kokkonen et al., 2010).

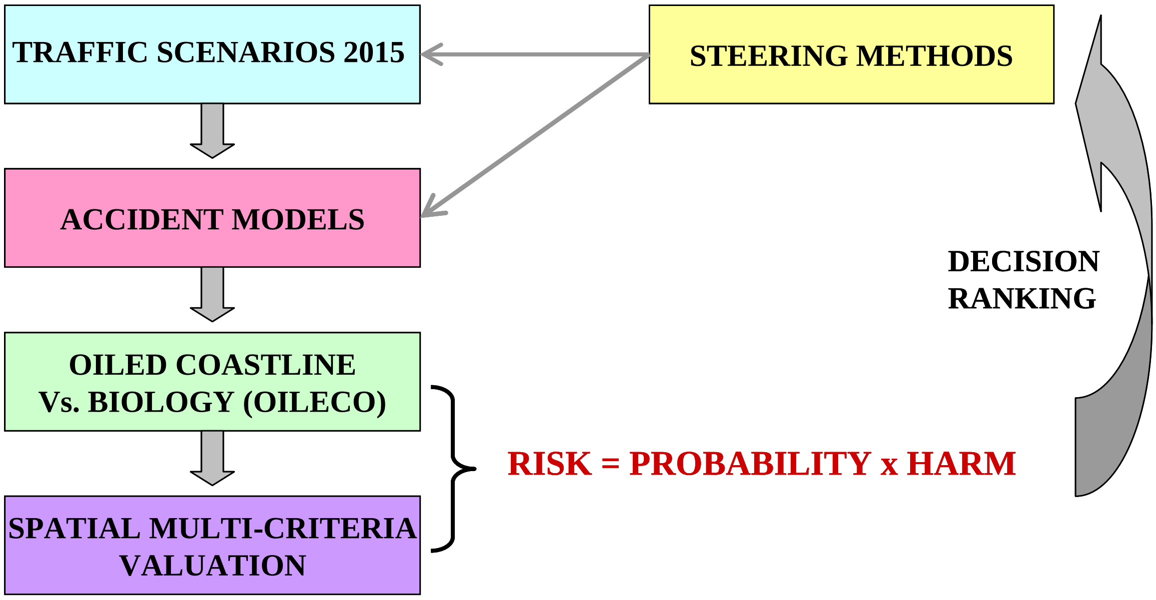

Figure 3 – Principle of the SAFGOF risk and decision analysis meta-model.

The BID structure includes decision variables defining the future maritime traffic scenario for year 2015, alternative accident probability management actions (preventative risk management) and oil recovery design solutions (secondary risk management) (Fig. 4). In addition, the user can select one of the five accident prone hot spots on the map, for which the model can be run separately. The decision variables are providing input both to traffic pattern variables and directly to the sub-models of different accident types and factors. Accident types modelled are collisions and groundings. Separate sub-models for geometric and causation (human factor) probabilities are included (Hänninen, 2008; Kujala et al., 2009; Mazaheri, 2009; Ylitalo et al., 2008).

Three probabilistic future growth scenarios for the maritime traffic in the GoF are created based on earlier forecasts, current statistics and expert interviews (Kuronen et al., 2008). The main factors behind these scenarios are economic, industrial and transportation trends in the GoF's coastal countries as well as on European Union and global level. In the current model, the probability distributions of traffic volume in different locations, ship types and sizes and the amount and type of the oil transported are conditioned scenario-specifically. These all are affecting the oil accident probabilities and consequences and providing input for the collision and grounding models (Fig. 4).

The preventive management actions are selected so that they affect different parts of the BBN: either the traffic parameters related to the geometric accident probabilities or the human factors affecting the causation probabilities given the growth scenario and location (Fig. 4). Despite the preventative actions, whenever the oil is transported, the possibility for an oil accident still exists. If a tanker collision or grounding happens, the spill occurrence and size are dependent on the variety of factors, e.g. the size and speed of the tanker as well as the magnitude of damage to the hull, arrangement of the tanks, height of the oil column in the tanks, oil type etc. (see e.g. Devanney, 2006). Leak size modeling is a field so far quite poorly studied. In the current work, probability distributions for the likely spill size are modeled basing on the approach of Maxim and Niebo (2001) given the tanker size (dwt) and type of the accident (grounding or collision) (Seppälä and Montewka, unpubl.). However, the contents and structure of BBN are easily updatable whenever more sophisticated leak models - that are under construction for the GoF - will be available.

In the case of a realized oil accident, effective oil combating plays a major role in minimizing the negative impact of oil on the vulnerable ecosystem of the GoF. Current oil combating is mainly based on mechanical recovery as recommended by Helsinki Commission (HELCOM, 2001). In this study, different oil recovery design and capacity alternatives are tested and the mechanical open sea recovery efficiency given the accident location modeled. This BBN model will be linked to the main BID as a sub-model as well (Fig. 4).

The final product of the leak size and recovery efficiency sub-models (given the accident scenario) is variable (final amount of) “Oil in water” producing the probability distribution for the amount of oil that will be washed ashore (Fig. 4). For simplification, the offshore oil combating is not included into this study so far. The oil drifting model SpillMod (Ovsienko, 2002) is used for producing scenario-specific probability maps to evaluate the magnitude and spatial distribution of the Finnish coastal areas that are in the greatest risk to be oiled. It calculates the trajectory and fate of oil in different hydro-meteorological conditions sampled from historical weather statistics.

The concept of risk contains both the probability of a certain event and the magnitude of harm caused if it becomes true. The magnitude of harm or utility is always somewhat a subjective question, thus being problematic to be defined unambiguously (Burgman, 2005). The current approach SAFGOF is not designed to reflect the views and values of its creators, but to produce risk assessments that are commonly acceptable and follow the current concerns and decisions of the society. Protection of the biodiversity and threatened species is an international objective regulated and supported by several laws, acts and conventions (e.g. Council directive 92/43/EEC; Council directive 79/409/EEC; Rassi et al., 2001). Evaluation of the harm caused by a random oil accident in the GoF is thus based on these commonly accepted rules and values also in the SAFGOF risk model.

Kokkonen et al. (2010) have developed decision support software OILECO for the prioritization of coastal oil combating in the GoF. It is based on the mapped knowledge of spatial distribution of the detected threatened species occurrences on the Finnish coastline. For each occurrence, indexes of conservation value and recovery potential (resulting from several sub-factors, such as exposure and mortality indexes), ranging between 0 -1, are defined. In the SAFGOF model, the “harm-value” of each SpillMod -map cell is determined by summing up the product of these two indexes to each of the occurrences included in that area. The higher the value in a cell, the greater the harm caused in the case that this particular cell would be contaminated by oil.

Finally, when both the integrative BBN model - including the traffic scenarios, accident and leakage models - and the SpillMod maps have been produced, they are integrated with a GIS-software to run as one risk model (Fig. 4).

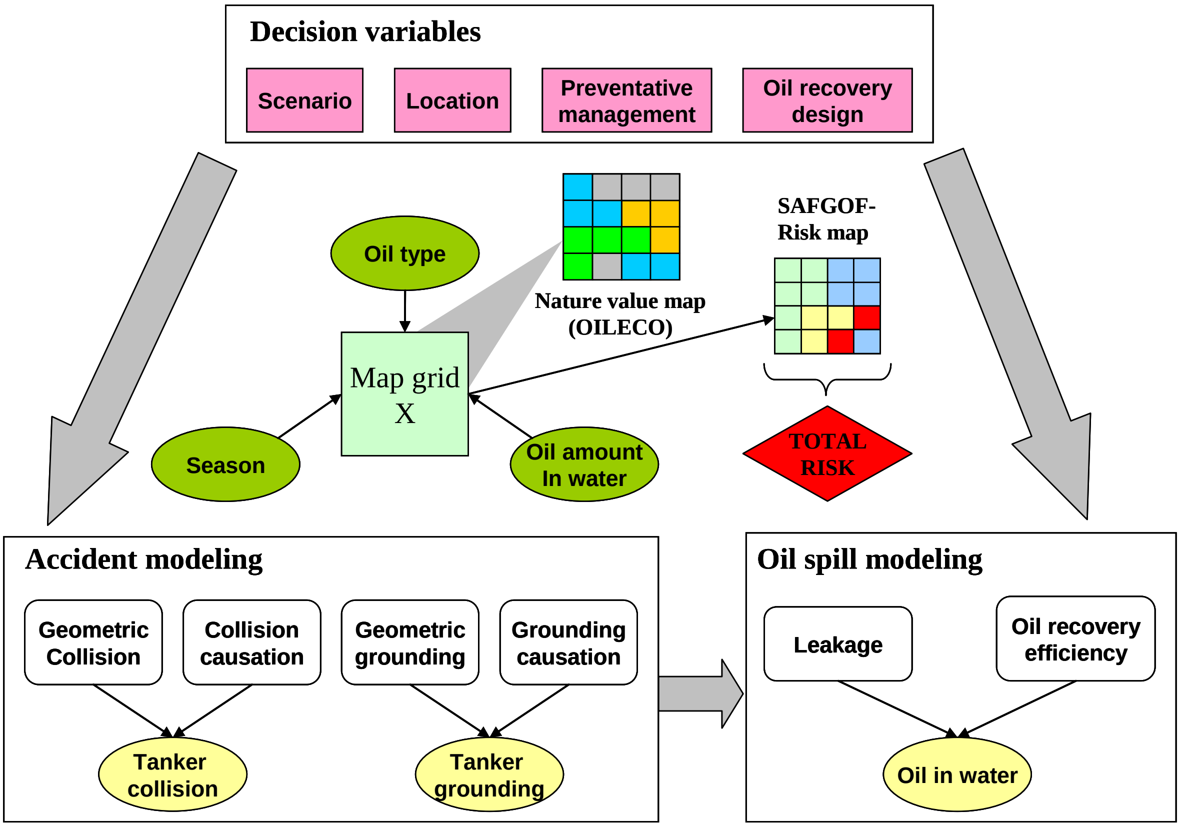

Figure 4 – Simplified model structure of SAFGOF risk assessment and decision support model. Pink squares illustrate decision variables, round-cornered boxes are sub-models and green round nodes input information transformed from BBN to GIS.

SAFGOF meta-model and effectiveness of management actions

The assessment of total risk-value produced by the meta-model enables summarizing probabilistic information from multiple models and spatial distribution of both oil contamination probability and harm into one value. As such this value does not tell us much, but it is rather meant to be compared with the end results of the other scenarios. By comparing the total risks of alternative scenarios, it is possible to evaluate the effectiveness of different preventative management actions and oil recovery design solutions against each other. This can be done e.g. by choosing a certain future growth scenario and / or accident location as starting points for the analysis or in the light of overall uncertainty concerning the future development and place where the accident happens. This also provides for assessing robustness of the ranking order of management actions when uncertainty in certain part of the model is manipulated – something which can also be utilized for directing the further research work most cost-effectively.

Remarkable uncertainties are related to each of the model components: the future development of maritime transportations, the effect of management actions, the severity of a possible accident and the biological consequences as well as the ecosystem response. A probabilistic approach enables providing a realistic picture of the accuracy of current knowledge. In addition, with BBNs it is possible to integrate the best available knowledge of different forms. Both the model structure and results can be presented in a graphic form that is relatively easy to understand. This provides an excellent base for planning of future actions although careful orientation to underlying ideology and discussion on the acceptable risk levels is first demanded to avoid gratuitous misconceptions.

Combining the criteria for effective policy instruments and the SAFGOF meta-model in the evaluation of a management action: an example on ENSI navigation aid system

In this chapter, we give an example on how the affectivity of one individual management action, which is going to be included in the prototype, can be evaluated with the SAFGOF risk a decision analysis tool. Operation in question is a new proactive control system in vessel traffic, called ENSI (Enhanced Navigation Support Information), which is being developed in co-operation with John Nurminen Foundation and Finnish Maritime Administration, Finnish oil shipping company Neste Shipping Ltd., Furuno Finland Ltd. (the distributor of FURUNO maritime products e.g. for navigation) and Navielektro (privately owned company specialized in the development and maintenance of maritime surveillance and communication systems). John Nurminen Foundation has two key areas of operation: cultural activities focusing on maritime history and the environmental work in its Clean Baltic Sea Projects. (John Nurminen Foundation 2010)

The aim of ENSI is to prevent an oil catastrophe by easing the way of actions and transmission methods in navigation. The first aim of the project is to implement a pilot system, where tankers can a route plan to a VTS centre when they arrive at the GoF. In the next phase, tankers are reciprocally going to get navigation related information, such as traffic image and weather or port information, in such a form that it is easy to utilize on the bridge. The system will technically be based on the Internet and on the other navigation systems that are already in use onboard. (John Nurminen Foundation 2009)

Nowadays IMO recommends ships to make route plans but they are not obliged to send it to the authorities. The aim of the ENSI is that VTS centres get route plans from ships, which helps them to foresee traffic situations, and if a route plan is not the safe one, they can advice a ship to take another route. Ships get advantage from sending route plans by getting easy to use information, which helps them in safe navigation. If the experiences on ENSI in the pilot phase are going to be positive, the aim is to expand the system to other ships as well, either as a commercial application or/and with regulatory means. (John Nurminen Foundation 2009)

In the SAFGOF project, ENSI system will first be evaluated against the criteria of effective policy instruments, which were presented previously. Table 4 contains this evaluation.

Table 4 – The evaluation of the ENSI system according to the criteria of effective policy instruments

Criterion	*Evaluation*
Effectiveness and appropriateness	The purpose of the ENSI system is to provide a system that supplies authorities with the route plans of ships, and ships with information that helps them in safe navigation. Usefulness of route plans is dependent on the activities and technical possibilities of authorities – are they able to utilize route plan information in traffic control activities? Problems may arise in the authority questions of VTS centres. VTS centres cannot either inspect every route plan – they must for example have a system that recognises risky route plans. Ships must have an incentive to send a route plan to VTS centres – in this case it is easy-to-use information about various factors that affect navigation. The incentive has to be strong enough – the ENSI should clearly be a better system than the current way of receiving that information.
Acceptability	Stakeholder's acceptance of the ENSI system is related to previous points – ships must benefit from the new system - otherwise sending the route plans to VTS centres is just another bureaucratic burden on them. In the case of ENSI, it is good that the system is tested first with small target group, rather than putting it into force in the large scale. This way lessons can be learnt and the system can be developed further or even abandoned.
Economic efficiency	The good aspect of the ENSI system is that it doesn't require investments in technology because it uses devices that are already in use. The extra costs it causes are in the workforce to make and send a route plan to VTS centre. If information that ships receive reciprocally from VTS centres manages to help the current burden on the bridge, the system brings savings.
Enforcement	In the first phase, the ENSI system is developed on the voluntary basis. If the system will be successful, shipping companies have an incentive to adopt the system voluntarily. Another route is to develop the system with regulatory means, which is usually, in the case of maritime industry, a long route in IMO. There should not be financial or technical barriers to the ENSI system, but there are legal and cultural factors that can become barriers, e.g. authority problems of VTS centres and shipping companies may see the sending of a route plan to authorities as just another bureaucratic burden. In the maritime industry sovereignty of a ship master in navigation is still strong, both at legal and at cultural level.

This qualitative evaluation shows that the ENSI system has some advantages and some barriers to its implementation. Advantages are that the system doesn't need great investments and it gives something also for the ships (navigation related information in easy-to-use format). The problems may arise in that the sending of route plans to authorities is seen as a bureaucratic burden and VTS centres don't have enough authority to affect the route choices of ships.

Here the qualitative evaluation of the ENSI system was a preliminary analysis, but it could be also done based, for example, on statistics, cost analysis, expert interviews or on other relevant sources.

In the SAFGOF meta-model the ENSI system will be tested from the different point of view, focusing on the effectiveness and appropriateness criterion. Testing will be done by using different traffic scenarios. Before that can be done, we have to describe the effect of ENSI on the relevant variables of accident probability models, which are sub-models in the meta-model. In practice this will happen by first identifying the sub-models and specific variables within them to which the system would probably have an effect. The strengths and directions of these effects, as well as the variance and uncertainties related to them, are defined by interviewing the personnel of the VTS-centre and tankers contributing to the testing phase of the system. Some assessments on the likely extent and rate of the implementation will also be done as the effectiveness of this system is clearly proportional to the amount and share of the vessels using it.

The collected information will be entered to the SAFGOF tool, after which both the changes in accident probabilities and the overall effects on ecosystem risk can be easily evaluated and the results transparently presented and discussed. In the end, we have analyzed the ENSI system from varied angles and we should be able to give our evaluation of ENSI: does it fulfil the criteria for effective policy instrument and is it likely to have an effect on accident probabilities in the Gulf of Finland and to what degree of certainty this will happen? This kind of information helps not only decision makers, but in this case also the developers of the ENSI system – it gives them accurate information about the strengths and weaknesses of the ENSI system and helps them in their work. So the SAFGOF meta-model is not meant only to test existing management actions, but also management actions that are under development. In the future, our goal is to analyze different kinds of management actions and to compare their effectiveness with each other in order to provide comprehensive information about different policy instruments and management actions.

CONCLUSIONS

The maritime traffic in the Gulf of Finland (GoF) is expected to greatly increase in the future. At the same time, the indirect environmental effects of the traffic will increase. Cost-effective decisions should be made to manage the risks of maritime accidents. We provided a review on the current situation of maritime safety policy in the GoF and presented the criteria for effective policy instruments and a new integrative meta-model for the evaluation of effectiveness of management actions in prevention of an oil accident and its biological consequences in the GoF. We suggest that this kind of cross-disciplinary, probabilistic decision aid tools should be developed and used as a part of the decision-making and investment optimization processes as they can help in creating more realistic and holistic view of the complicated process and the related risks.

We showed that the effectiveness of certain policy instrument or management action can be evaluated from several different perspectives according to multiple criteria. At this stage – the assessment tool described is developed mainly for the evaluation of effectiveness and appropriateness -criterion. In the future we aim for adding the other aspects of assessment as well. Commitment of stakeholders, cost-efficiency and implementation uncertainty are components that should be included in future to enable true multi-criteria evaluation and ranking of the alternative actions.

Efficient risk management actions are – in the first place – typically dependent on the political will prevailing in the society. By compiling the existing multi-disciplinary knowledge and clearly and realistically showing the risks and our potential influence over them as well as the possible consequences of passivism, we can not only help the decision-makers in their demanding work, but also raise public awareness and discussion on the situation. The magnitude of increasing knowledge and more holistic understanding about the system should not be undervalued either.

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SOURCES

Borsuk, M.E., A.S. Craig and K.H. Reckhow (2004). A Bayesian network of eutrophication models for synthesis, prediction and uncertainty analysis. Ecological Modeling, 173, 219-239.

Bromley, J., N.A. Jackson, O.J. Clymer, A.M. Giacomello and F.V. Jensen (2005). The use of Hugin® to develop Bayesian networks as an aid to integrated water resource planning. Environmental Modeling and Software, 20, 231-242.

Burgman, M.A. (2005). Risks and decisions for conservation and environmental management - Ecology, biodiversity and conservation. Cambridge University Press, Cambridge.

Clemen, R.T. (1996). Making hard decisions: an introduction to decision analysis. 2nd edition, Duxbury Press, Belmont, CA.

Commission of the European Communities (2009). Commission staff working document – Accompanying the Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions concerning the European Union Strategy for the Baltic Sea Region – action plan. SEC(2009) 712. Available online at: http://ec.europa.eu/regional_policy/cooperation/baltic/pdf/communication/action2009.pdf.

Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora.

Council Directive 79/409/EEC of 2 April 1979 on the conservation of wild birds.

Devanney, J. (2006). The tankship tromedy: the impending disasters in tankers. The CTX Press, Tavernier, Fla.

Finland's Environmental Administration (2008). Öljykuljetustietoja (Oil transport information). Excel-file by e-mail from Meri Hietala, Finland's environmental administration, to Jenni Kuronen, Centre for Maritime Studies, 2.10.2008.

Finnish Maritime Administration (2009). Maritime safety measures in key position in preventing accidents at sea – actions taken to prevent major maritime accident looming in the future. Available online at: http://portal.fma.fi/portal/page/portal/fma_fi_en/Mediatiedote%203%204%20_E.pdf

Gilks, W.R., A. Thomas and D.J. Spiegelhalter (1994). A language and program for complex Bayesian modeling. The Statistician, 43, 169-177.

Greiner, R., M.D. Young, A.D. Macdonald and M. Brooks (2000). Incentive instruments for the sustainable use of marine resources. Ocean & Coastal Management, 43, 29-50.

HELCOM (2001). HELCOM Recommendation 22/2. Restricted use of chemical agents and other non-mechanical means in oil combating operations in the Baltic Sea.

HELCOM (2007). Baltic Sea Action Plan. Available online at: http://www.helcom.fi/stc/files/BSAP/BSAP_Final.pdf

HELCOM (2010). HELCOM web pages at: http://www.helcom.fi/.

Huppes, G. and U.E. Simonis (2009). Environmental policy instruments. In: Principles of environmental sciences (J.J. Boersema and L. Reijinders, eds.). Springer Science + Business Media B. V., Aldershot.

Hänninen, M. (2008). Analysis of human and organizational factors in marine risk modelling – Literature review. Faculty of Engineering and Architecture, Department of Applied Mechanics, TKK-AM-4. Available online at:
http://www.merikotka.fi/safgof/Hanninen_2008_Analysis.pdf

International Maritime Organization (2006). Resolution A.982(24) – Revised guidelines for the identification and designation of particularly sensitive sea areas. Available online at: http://www.imo.org/includes/blastDataOnly.asp/data_id%3D14373/982.pdf

Jensen, F.V. (2001). Bayesian networks and decision graphs. Springer-Verlag, NY.

John Nurminen Foundation (2009). Tanker safety project. Presentation material. (In Finnish).

John Nurminen Foundation (2010). John Nurminen Foundation web pages at: http://www.johnnurmisensaatio.fi/

Kjærulff, U.B. and A.L. Madsen (2005). Probabilistic Networks - An Introduction to Bayesian Networks and Influence Diagrams. Unpublished. Available online at: http://www.cs.aau.dk/~uk/papers/pgm-book-I-05.pdf

Klemmensen, B., S. Pedersen, K. Dirkinck-Holmfeld, A. Marklund and L. Rydén (2007). Environmental policy – Legal and economic instruments. The Baltic University Press, Uppsala.

Klemola, E., J. Kuronen, J. Kalli, T. Arola, M. Hänninen, A. Lehikoinen, S. Kuikka, P. Kujala and U. Tapaninen (2009). A cross-disciplinary approach to minimizing risks of maritime transport in the Gulf of Finland. World Review of Intermodal Transportation Research, 2(4), 343-363.

Kokkonen, T., T. Ihaksi, A. Jolma and S. Kuikka (2010). Dynamic mapping of nature values to support prioritization of coastal oil combating. Environmental Modelling & Software, 25, 248-257.

Kuikka, S. and O. Varis (1997). Uncertainties of climatic change impacts in Finnish watersheds: a Bayesian network analysis of expert knowledge. Boreal Environmental Research, 2, 109-128.

Kujala, P., M. Hänninen, T. Arola and J. Ylitalo (2009). Analysis of the marine traffic safety in the Gulf of Finland. Reliability Engineering and System Safety, 94(8), 1349-1357.

Kuronen, J., R. Helminen, A. Lehikoinen and U. Tapaninen (2008). Maritime transportation in the Gulf of Finland in 2007 and in 2015. Publications from the Centre for Maritime Studies, University of Turku A45. Available online at: http://www.merikotka.fi/julkaisut/Kuronen_Maritime_transportation_2008_v2.pdf

Kuronen, J. and U. Tapaninen (2010). Evaluation of Maritime Safety Policy Instruments. WMU Journal of Maritime Affairs, Vol. 9, No 1, 45-61.

Madsen, A. L., F. Jensen, U. B. Kjærulff and M. Lang (2005). The Hugin tool for probabilistic graphical models. International Journal on Artificial Intelligence Tools, 14, 507-543.

Marcot, B.G., R.S, Holthausen, M.G. Raphael, M.M. Rowland and M.J. Wisdom (2001). Using Bayesian belief networks to evaluate fish and wildlife population viability under land management alternatives from an environmental impact statement. Forest Ecology and Management, 153, 29-42.

Maxim, L. and R. Niebo (2001). Oil spill analysis for North Slope oil production and transportation operations. In: Environmental Report for Trans Alaska Pipeline System Right-of-Way Renewal, Appendix B (Trans Alaska Pipeline System Owners).

Mazaheri, A. (2009). Probabilistic modelling of ship grounding – a review of the literature. Faculty of Engineering and Architecture, Department of Applied Mechanics, TKK-AM-10. Available online at: http://www.merikotka.fi/safgof/ProbabilisticModelingofShipGrounding.pdf

Ministry of Transport and Communications Finland (2009). Ohjelma Itämeren meriturvallisuuden parantamiseksi: Työryhmän taustaraportti (Baltic Sea Maritime Safety Programme). Publications of the Ministry of Transport and Communications 13/2009. Available online at (in Finnish): http://www.lvm.fi/c/document_library/get_file?folderId=339549&name=DLFE-7220.pdf&title=Julkaisuja%2013-2009

Mäntyniemi, S. (2006). Bayesian fisheries stock assessment: integrating and updating knowledge. Academic dissertation, Rolf Nevanlinna Institute, Department of mathematics and statistics, University of Helsinki.

Nikula, P. and V-P. Tynkkynen (2007). Risks in oil transportation in the Gulf of Finland: “Not a question of if – but when”. In: Towards a Baltic Sea Region – Strategy in critical infrastructure protection (C. Pursiainen, ed.), Nordregio report 2007:5. Available online at: http://www.nordregio.se/Files/r0705.pdf

O’Hagan, A., C.E. Buck, A. Daneshkhah, J.R. Eiser, P.H.Garthwaite, D.J. Jenkinson, J.E. Oakley and T. Rakow (2006). Uncertain judgements: eliciting experts’ probabilities. Wiley, Chichester.

Ovsienko, S. (2002). An updated assessment of the risk for oil spills in the Baltic Sea area. Available online at: http://www.helcom.fi/stc/files/shipping/RiskforOilSpillsReport2002.pdf

Pearl, J. (1986). Fusion, propagation, and structuring in belief networks. Artificial Intelligence, 29, 241-288.

Power, M. and L.S. McCarty (2000). Risk-cost trade-offs in environmental risk management decision-making. Environ Sci Policy, 3,.31-38.

Power, M. and L.S. McCarty (2006). Environmental risk management decision-making in a societal context. Hum Ecol Risk Assessm, 12, 18-27.

Rassi, P., A. Alanen, T. Kanerva and I. Mannerkoski (2001). The Red List of Finnish Species. Ministry of the Environment & Finnish Environment Institute, Helsinki. (In Finnish, summary in English).

Reckhow, K.H. (1999). Water quality prediction and probability network models. Canadian Journal of Fisheries and Aquatic Sciences, 56, 1150-1158.

Roberts, J. (2007). Marine environment protection and biodiversity conservation: The application and future development of the IMO's particularly sensitive sea area concept. Springer, Berlin.

Roe, M. S. (2008). Safety, security, the environment and shipping: The problem of making effective policies. WMU Journal of Maritime Affairs, 7, 1, 263-279.

Steiner, R. (2004). Gulf of Finland Oil Transport / Spill Issues: Summary and Recommendations from May 2004 visit. Available online at: http://www.ccb.se/newsletters/2004/summer/gulf_of_finland_oil_transport.pdf

Särkijärvi, J., J. Stenberg, H. Tuomarmäki and A. Saurama (2009). Baltic Port List 2008 – Annual cargo statistics of ports in the Baltic Sea Region. University of Turku, Turku.

Uusitalo, L., S. Kuikka and A. Romakkaniemi (2005). Estimation of Atlantic salmon smolt carrying capacity of rivers using expert knowledge. ICES Journal of Marine Science, 62, 708-722.

Varis, O., J. Kettunen and H. Sirviö (1990). Bayesian influence diagram approach to complex environmental management including observational design. Computational Statistics and Data Analysis 9, 77-91.

Vieira, J., F. Moura and J. M. Viegas (2007). Transport policy and environmental impacts: The importance of multi-instrumentality in policy integration. Transport Policy, 14, 421-432.

Ylitalo, J., M. Hänninen and P. Kujala (2008). Accident probabilities in selected areas of the Gulf of Finland. Faculty of Engineering and Architecture, Department of Applied Mechanics, TKK-AM-6. Available online at: http://www.merikotka.fi/safgof/Ylitalo_2008_Accident.pdf