Risk modeling; Definitions and methods of risk modeling in relation to shipping in Lake Mälaren

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Abstract

An increased amount of ships in the narrow water lanes results in an increased possibility for collisions. This study is illustrating the risk-modelling processes in the scenario of increasing ship activity in Lake Mälaren, central Sweden.
About 1.5 million people are daily dependent of fresh water from Lake Mälaren. Meanwhile a lot of hazardous goods and cargos are transported on the lake with all the potential risks that this can bring up. Therefore risk-analysis can be important tools in future policy buildings if it is related to environmental legislations. Cost-benefit and cost-effectiveness is also important tools in allocating procedures when different results are weighted against each other.

Introduction

Today about 90% of the export from Sweden is transported at sea. (Johnsson 2001). Shipping is considered as the best logistic transportation system regarding environmental impact divided by transported tonnage, compared with regular terrestrial transportation systems.
There are important concerns with respect to environmental and health risks as well as economically risks with the increasing amount of ship transportation. Especially in a freshwater system like Lake Mälaren in central Sweden. The harbours in Lake Mälaren, Västerås and Köping harbours are considered as net balance import harbours, which means they are receiving more cargo and bulk than they are sending. According to statistical estimations, over 1.5 million people, living and working near Mälaren are daily dependent of freshwater from the lake. (Wallin et. al. 1999).
So, therefore it is important to estimate and predict every kind of risk situation that can occure in the area. With the Just-In- Time (JIT) policy in logistic systems, the number of short sea shipping is likely to increase. Therefore the risks for congestions in the narrow water lanes will also increase which can lead to very severe consequences, not only ecologically, but also with respect to health and economy. To understand this problem with JIT in a perspective of increasing risks, there are some

mathematically illustrations presented which this study is based upon.

The study of shipping

Shipping in Lake Mälaren is very important for the future infrastructure in the central part of Sweden, and especially in the perspective of the great European transport system structures which is developing all over the European continent.
It is also well known that the environmental benefit is higher valuated in shipping then in other equivalent systems such as all the terrestrial transportation systems, when technology and policies decreases the risks. To illustrate this is one of the purposes of this study
This is especially important in an ecologically sensitive area like the present. In this study one of the major issues is to illustrate the importance of adapting the results of the study to the national environmental laws, and the EU:s environmental legislations in the process in an early stage of policy building, so therefore these are chosen to be an important part of the present model. The Swedish environmental law system (Miljöbalken) argues that principle of considerations is very important to protect the nature, culture and prevent bad public health. But before the policies can be implemented, a proper risk assessment has to be done. And this is also an important part of the major purpose of this model.

First of all, an inventory is imported to perform before going any further in the process which hopefully will result in a more safe shipping business.
Risks have to be studied from a statistical point of view. A technical and legal progress for the society in the field of water policy will then follow. It is very important to interact between different perspectives in the whole process of policy buildings.
Statistical and technological data are individual for each carrier. Scientific data is usually specified as weather parameters, water lane marks, and other environmental data specific for Lake Mälaren (water chemistry,

underwater streams etc). But other aspects are also important. Environmental ethically aspects can not be denied when the questions about environmental sustainable transport systems are preferred.
Benson argues (Benson 2000) that environmental sustainability must not prevent the development of better technological systems. He also claims that the environment does not have to coop with all different kinds of preventable risk situations. (Benson 2000)
His conclusions are that it is a matter of valuations. Do we want more cargoes on the cost of a poorer environment? (Benson 2000)

The principle of the model

The hard core of the risk analysis in the present model is divided into environmental and technological aspects. Therefore it is considered as being multi variable.
As already mentioned, it works out of two different criterions for decisions; decisions with or without reliable basis.
But there are difficulties in this process if two equally weighted decisions are standing against each other.
In the present model cost-effectiveness and cost-benefit analysis are therefore supporting tools in estimating the values of the results.
But cost-effectiveness and cost-benefit analysis can not be used in the model at a too early stage. The problem is then that the results can be misinterpreted in later aspects of the model. It can not be properly compared to the environmental legislation in a proper way, if the economical aspects in cost-benefit or cost-effectiveness are used to early in the model. Important is that the environmental legislation system is weighted higher in this model then cost-benefit or cost-effectiveness are.
But they are considered as very good supporting tools, especially in the allocation process.

The purpose of this is to develop a more effective logistic system for cargos and bulk from supplier to customers. This model will illustrate that JIT principle is therefore increasing the risk in this transportation system. More ships in the water lane transporting hazardous goods along with the increased risk for the environment and public health is therefore becoming a major problem.
If this trend will develop to faster transport methods, more ships, smaller cargos, it will contribute to a more difficult traffic situation on the Lake Mälaren, with higher risk of congestions and collisions in the narrow water lanes.

Nilsson and Winnes (Nilsson, I. & Winnes, H. 2003) argue that "An increased use of short sea shipping can balance the European transport system and contribute to a better environmental situation. The competitiveness of short sea shipping is dependent upon improved logistic efficiency including high environmental performance"

The part of the present model, called risk management, where all the facts and all the results are very well investigated, can be prepared to become vital parts in the policy building process. The out coming policy is supposed to be well worked through and will become the result of the model, to project the legal parts on. The legalisation in the model is considered as the normative to the policy and has to be reflected to the policy building process. Here tools like cost-benefit and cost-effectiveness will be useful.
The relations between the different facts and the policy building procedure are shown in figure 1.

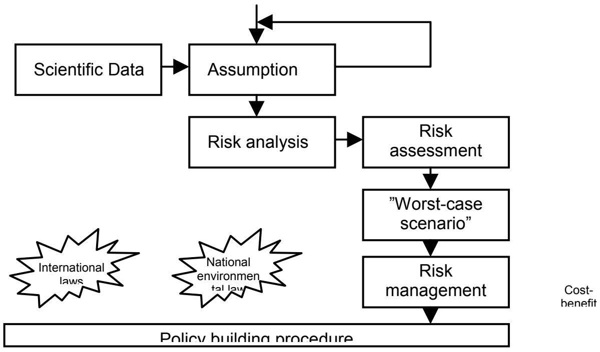

Figure 1.
Statistical facts of ship accidents

The total amount of shipping distresses in Sweden or in Swedish coast water is presented in a diagram below (see figure 2). During the period from the year 1992 to the year 2000 grounding is considered as the most frequently accident, followed by collisions with other ships. This study is focusing on just collisions with other ships, and it is according to the water lane conditions and other physical structures of Lake Mälaren.

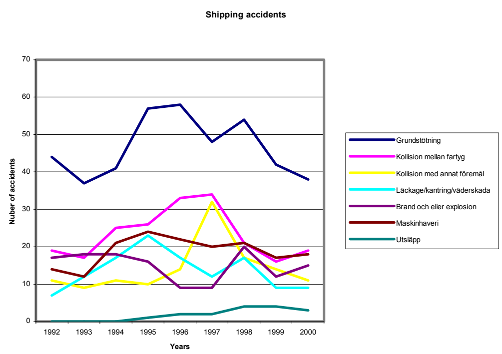

Figure 2.
(Diagram extracted from statistical results of SCB)
Shipping accidents in Sweden between 1992 and 2000.

The diagram shows seven modes of accidents. They can as a first approximation is considered as fully independent modes. Thus it can formally assign the following probability notations; P_{gr} denotes the grounding probability, P_{coll} the collision with ships probability, P_{obj} the collision with other objects probability, $P_{weather}$ the leakage/capsize/weather damages probability, P_{fire} the fire and explosion probability, P_{eng} the engine trouble probability, and P_{disc} harbour discharges probability. Furthermore, formally, the accident situation probability can be written:

$$P_{AS} = P_{gr} + P_{coll} + P_{weather} + P_{fire} + P_{eng} + P_{disc} \quad (1)$$

As they are independent of each other, they are added and not multiplied by each other.

The just-in-time system (JIT)
Today JIT is very common in businesses. Just in time or JIT is in many businesses an effort to minimize or eliminate the whole warehouse systems. The JIT-system is a business philosophy showing that the order itself is initiating the manufacturing. When the customer is placing their order the manufacturing is getting started. The philosophy of the JIT-system is to decrease the stock of materials. All materials are "on the move" from manufacturers to customers at every levels. (Greve 1996)
In the present model JIT is the most central issue. JIT means, in the perspective of shipping that the amount of ships will increase. But it doesn't have to result in smaller ships. It is quite possible that it can initiate larger ships as well in the transportation line, but most important is the risk with the increasing amount of traffic. In this simple model we consider the impact on accident situation probability when the total amount of cargo L_{total} is transported using n ships. Thus:

$$L_{ship} = \frac{k_{coll}}{n} \quad (2)$$

Denotes the cargo per ship (or shipping). If we consider the case where we increase the number of ship in order to obtain a smooth supply only using minimal storage at the customer's location then we have the following general relations between number of ships and the different accident mode probabilities.

$$P_{coll} = k_{coll} \cdot n\,(\text{n-1}) \quad (3)$$

Where n ships are passing in the water lanes. As the numbers of ships is increasing, the probability for collisions also increase.

For grounding holds:

$$P_{gr} = k_{gr} \cdot n \quad (4)$$

Furthermore relation (4) can be applied on the other accident modes just changing the constants ki.
In principle the constants k can be estimated from statistical data or application of models discussed later in this paper.

The potential environmental impact $E_{accimpi}$ of a specific type of accident (i) can be written as;

$$E_{(accimp)}I = f_{(health,animals,economics,...)i}$$

And the probable environmental impact for a certain scenario $E_{scenario}$ with respect to traffic, risk prevention etc, can be written as:

$$E_{scenario} = \sum_{i=1}^{N} P_i \bullet E_{accimpact_i} = \sum_{i=1}^{N} P_i f_{(healtn,animal,economi)i} \quad (5)$$

Assuming as a first approximation the linear independence in (1) we obtain the potential environmental impact as a sum of functions $\sum f_i(P_i)$.
In the simplest case the environmental impact of an accident is potential to L_{ship}, thus using (2) in (5) it is found that all terms except the collision term will be only dependent of the total cargo to be delivered, but the collision term will scale as;

$$E_{scenario} \alpha \bullet L_{total} + constant \quad (6)$$

Thus if JIT needs more ships the basic hypothesis will be that the accident environmental risks increases.

Definitions of risks
In the present model, the risk assessments in shipping begin with the assumption of different risk scenarios.
It is a common knowledge that every kind of risks is in the extension decisions made by humans. The human factor is, as shown later, very important in the basic risk assumption. According to this basic assumption, first of all it is important to put in risk assessment related to scientific data in the model. This is done by indata structures. In all kind of risk models the first inventory of assumptions are the most important ones.
Those assumptions are the first step in getting adequate results in the model.

The indata to the model will be divided in two different categories, certain and uncertain assumptions.
The certain assumptions will directly be connected with the incoming scientific data, while the uncertain data will be tested again with more incoming facts iteratively until we find it more certain and reliable, with more feedback data the accuracy of the model will be improved.

Assumptions
The assumption in this present study is shipping at only Lake Mälaren, but it can easily be adapted to short sea costal shipping. Worth to recognize is the principle of just-in-time (JIT) and how this principle is becoming the major driving force in the model.
To reach the best prerequisite as possible it is important to define ingoing facts to the model.
Keeny (Keeny. At al. 1993) argue therefore about two kinds of important consequences to observe:
those that are based upon a reliable basis or those that are based on an unreliable basis.

As mentioned earlier, observed consequences which are built up by unreliable information have to be worked through up to a higher reliability level before it can be used in the model.
This is a hard, costly and time-consuming process to perform.
Preliminary an elimination of the subject's limit must be done. Therefore the model will not grow too big and cumbersome. The question is what kind of expected result the model will create and what kind of results we want.

There is a risk of jeopardizing the focus on a predicted result and therefore fabricating the prerequisites in an early stadium in purpose to get a wanted result in advance. To prevent this one has to be very careful about what kind of information to use in the model.

The relations are seen in figure 3 below.

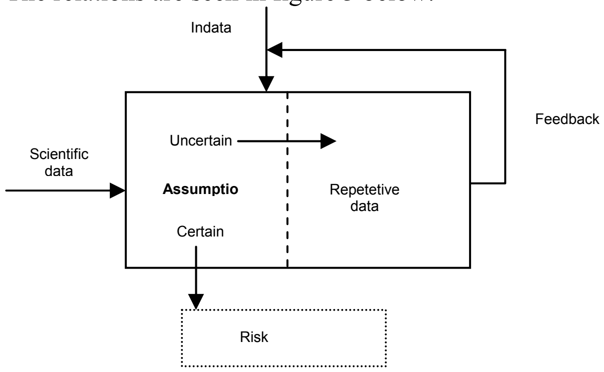

Figure 3. Uncertain and certain information as input to the model.

Scientific data
The scientific data is the out-coming result of technical data, physic data, economical data and engineering data that we can use to build up a risk analysis.
From here, the basic facts come out to make the basic risk analysis. The scientific data will be investigated scientifically and can hopefully help answering three questions we have, before it can be connected to the rest of the model. (See figure 4.)

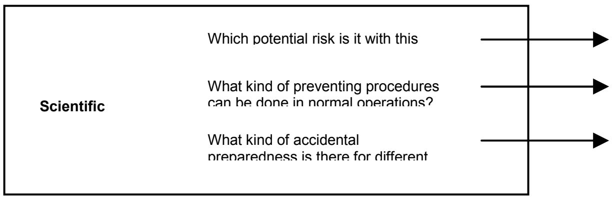

Figure 4. About the process in with scientific data

It is very important to have the scientific data in order with a good reliability as well as validity before we can use it as a part of the process in answering the three questions. This can not be emphasized enough.
In general, every ship trafficking Lake Mälaren is constructed individually.
"Ships are built individually for different transporting purposes where cargo and route is concluded factors" (Pålsson et. al. 2000)
But in the present model we are using a kind of standard ship.

Risk analysis
Now the process has reached the most vital part of the model. The risk analysis. According to all previous data and results a screening method is most valuable to be done here. Its purpose is to give us an overview of the whole procedure of the analysis. It is common that the risk analysis is divided into a qualitative or a quantitative part. We use the same structure in this present model. Here, some important questions have to be answered. As shown here the model is considered to create the base of a "worst-case scenario".
It is now time to line up all possible kinds of potential risks that can occur.

In Sweden, National Maritime Administration (Sjöfartsverket) has got the main responsibility for shipping policies along our coast and in major lakes, such as Lake Mälaren. Sweden National Maritime Administrations subsection Maritime inspection (Sjöfartsinspektionen) is the authority, working with just risk assessments and such questions. In the year 2000 an important report was published on this subject. It is called "Security valuations" (Säkerhetsvärdering) This report contains information and policy questions in the risk area.

Ecological data
To understand the environmental impact and how to involve this into the present model Håkansson (Håkansson 1998) has developed a method comparing environmental dangers. This is done in the PER method. The PER (Potential Environmental Risk) method is constructed as a method to illustrate criteria to rank, model and remediate chemical threats to aquatic ecosystems. (Håkansson 1998)
Håkanssons models are very well compatible to the model of this study. Ecological data is involved to the risk analysis. This is shown in figure 5

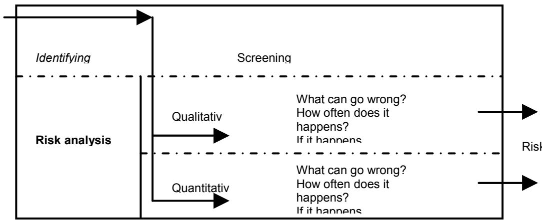

Figure 5. Risk analysis. The screening method which results in qualitative and quantitative questions.

Accident situations

Accident situations (AS) are identified by a systematic survey of the operational and technological possibilities to loose control over the ship and its cargo. (Pålsson, Svensson, Hammar 2000)
Accidents situations are evolved when the crew is loosing control of the situation due to insufficient or incorrect awareness such as, information failure, management failure, the whole activity or a part of it will collapse. (Pålsson, Svensson, Hammar 2000)
Accidents have always occurred, but today the trend is decreasing though the accidents have become more serious. The purpose with risk analysis is to identify and value unwanted situations which can harm people and the environment.

The next step in the process is the Riskassesment. Here, the scientific data will be the base of the assessment procedure. To make this easy a binary tree is helping out illustrating complex circumstances. (see fig 6.) For example, if a red lamp is lightened then we got a machinery problem etc. Important is that we here have a possibility for feedback information again, to the first step of the model, if it is found necessary. Within the technological judgement it is very important to begin with the ship's security valuation, if there is any.

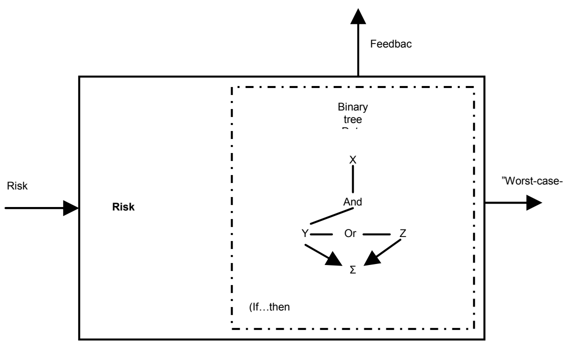

Figure 6. Riskassesment including the binary tree.

It is the International Maritime Organisation (IMO) which has the international comprehensive responsibility for formal safety assessments worldwide, for the IMO's rulemaking process. (Pålsson, Svensson, Hammar 2000)
According to this formal safety assessment on ship is here divided of three major parts:

1. Risk; Unwanted happenings which can lead to damages if it can not be managed properly
2. Operation; failure and deviation from normal operation which can lead to accidental situations.
3. Distress; preparedness for distress at sea.
(Pålsson, Svensson, Hammar 2000)

In normal operational procedures a lot can happen which can result in an accident situation where the crew has lost control over the situation and ordinary operation procedures have lead to distress at sea. Pålsson, Svensson, Hammar, argue that there are three important questions to be answered in this case, and these questions are so vital so they are given special thoughts in the present model;

1. Which potential risk is it with this transportation?
2. Which kind of preventing procedures can be done in normal operations?
3. What kind of accidental preparedness is there for different kind of distresses?

The concept of risk is defined as the probability of an undesired consequence which can lead to injuries of humans, the environment or other ships and objects. The situation of accident (SA) is defined as situations were the crew has lost ordinary control over the ship, and the situation is turning over to a distress. Accident prevention measures are both operative and technical. Furthermore the surrounding environment and other traffic and navigation circumstances can be very important, especially in a holistic perspective.

All kind of risk assessment is created from more or less subjective judgements, and from this foundation we can continue the analyses. From this point of view, it is very important to understand how to continue the modelling. To solve the problem with unreliable in coming data, it is very important to estimate the whole problem scenario and to improve the in coming facts iteratively again, just to develop concrete quantitative technological data, which already is gathered in the "scientific data" square.

Worst-case-scenario

The most interesting part in all kind of risk analysis is when the results ca be placed in different kind of "worst-case-scenarios". (See fig. 7) A "worst-case-scenario" is a very important parts of the process of defragmentating the main problems.
When a "worst-case-scenario" is accomplished, it gives a base of important knowledge to continuing the rest of the process, for example to exploit resources in rescue efforts.

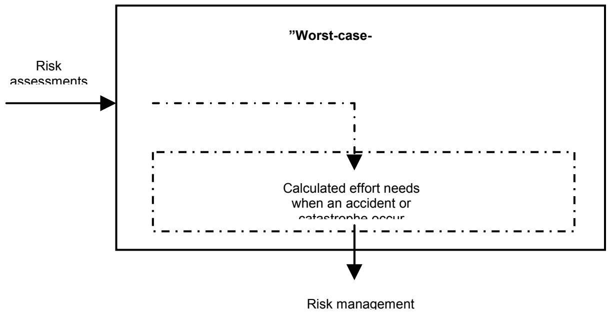

Fig. 7 “Worst-case-scenario” can be very useful when calculating effort needs when an accident or a catastrophe occurs.

Empirics from other catastrophe

There have been a lot of studies published about great catastrophes like the chemistry disaster in Bhopal, the shipping catastrophe of Zeebrügge, M/S Balins at Kvicksunds bridge between Västerås and Köping 1994 etc.

Another well known disaster is the nuclear accident at Chernobyl. In all those disasters the AcciMapp-method has been used to investigate how the disaster could happen and why.

The AcciMap-method is a very good tool for investigations after an accident situation. But results from AcciMaps can be very useful in prevention work like risk analysis. An AcciMap is a chronological map about the time just before the accident occurred.

The conclusions from these studies are that the accidents did not occure as random coincidents.

The cause is mostly failure in human procedures. An accident is a result of frequently changing behaviours which results, when it comes close to the system limits, in an accident or catastrophe. (Svedung & Rasmussen, 1997). (Mattsson 2000)

All these knowledge from other disasters are important to implement in risk analysis.

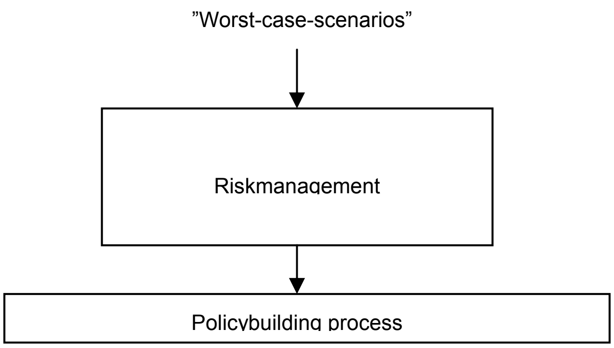

Fig. 8 Risk management is the final step in this present model and it is the base from which policy building can be developed.

Conclusions

We are all surrounded by risks in our daily life. The modern society has built up a very complex infrastructure system in order to provide our needs of transportation. But we have to reconsider this structure. If it is possible to decrease risk situations at sea and especially in freshwater, shipping is a good alternative to terrestrial transportation. The present model will illustrate that we can decrease risk situations if we recognize the structures of risks. We have to use risk analysis in plan works for expansion of shipping business in Lake Mälaren.

JIT-systems increase the total amount of ships and therefore the possibilities of collisions. To estimate these possibilities we have to recognize statistical results to be able to estimate all kinds of potential risks in the area.

Future study

A lot of studies have been done recently in risk analysis. Some of them are involving shipping. This present study shall not be considered complete yet. It is just the first step to a scientifically process of understanding the complexity in shipping accidents freshwater such as Lake Mälaren.

Much more research has to be done, especially in the valuations of incoming data in the assumption step, but also in the process of policy building. The comparing part of the results to the environmental legalisation is also of great interest. To be able to statistically identify the value of the constants in the equations is perhaps the most valuable development of the model in the nearest future. But the result so far is that JIT system does not always coop with risk potentials. This study has shown that it doesn’t matter if it is a big ship or a small ship with hazardous goods, trafficking the water lane. The issue is how many ships there are and how big the probability of collisions or grounding is.

The JIT-system will therefore be an incitement of increasing future risk situations. To predict the risk situation we have to clarify the value of the constants in the equations to the model. This can be done in a statistical calculation. The statistic data on the risk for different type of accidents are gathered from other parts of the world as well. The environmental impact is also acquired from accidents outside Lake Mälaren as well as information on what precautions had been made before the accidents. To limit uncertainties we also investigate methods to determine emissions of e.g. oil, and to limit the risk of illegal dumping methods for linkage to the source is under development.

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