THE IMPORTANCE OF A RISK BASED INDEX FOR VESSELS TO ENHANCE MARITIME SAFETY

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Abstract: At the last French/Spanish top meeting in Malaga after the Prestige accident (November 2002), these two countries have decided to exclude « suspicious » vessels from their 200 miles Exclusive Economic Zone. « Suspicion » about a vessel must not only be attached on the basis of static parameters such as her age, flag, class, number of crew, state of the hull, nature of cargo, etc., but also on time dependent elements like weather and traffic conditions which exist in the area of navigation of this ship. It is thought that such a dynamic ship’s risk index may be built to assist in real time the VTM (Vessel Traffic Management) actors in the monitoring process of vessels sailing in their area of responsibility, using the concepts designed for Risk Assessment Models developed in the framework of FSA. This paper recalls first the objectives and the principles of such risk models. It will propose in a second part some developments made in the framework of the European project EMBARC about an analytical formulation of a dynamic risk index to be attached to certain type of ships and the methods to define its value.

Keywords: marine, risk, models, assessment, dynamic risk index

1. INTRODUCTION

Recent or very recent disasters in European waters (Erika, December 1999), Ievoli Sun (October 2000), Prestige (November 2002) and Tricolor (December 2002) led the European Commission and countries of European Union to implement a framework of safety measures and actions. In this framework, the Erika I and II packages have been adopted by the European Parliament. At the last French/Spanish top meeting in Malaga after the Prestige accident, these two countries have decided to exclude « suspicious » vessels from their 200 miles Exclusive Economic Zone.

The idea is currently taking shape of using the concepts that underlie Risk Assessment Models developed for many years by some countries in order to assign a specific dynamic casualty risk index to a vessel. This index would depend not only on static parameters such as the vessel’s age, cargo, flag etc. but also dynamic parameters such as the visibility and traffic conditions it is likely to encounter while navigating. It would help the representatives of coastal states who monitor and track shipping off their coasts to detect in real time any vessel which presents a pollution threat in order to take appropriate steps.

This paper describes first the general objectives and principles of risk assessment models. It will propose in a second part some developments made in the framework of the European project EMBARC about an analytical formulation of a dynamic risk index to be attached to certain type of ships and the methods to define its value.

2. RISK ASSESSMENT MODELS: OBJECTIVES AND PRINCIPLES

2.1. General

Traditionally, maritime safety has depended on preventive measures which are specified by analyzing maritime transport malfunctions in the form of incidents or accidents. This approach has frequently been criticized on the grounds that as it is only reactive it is always outdated, and recent years have seen the development of methods based on risk assessment techniques which aim to be more anticipatory and more proactive. Thus, in the Netherlands, for example, the SAMSON model was
designed in around 1975 and constantly improved since and a similar approach has also been adopted in Canada.

The primary aim of maritime risk assessment models is to evaluate the level of safety in a certain maritime zone using a systematic approach which is both methodological and quantitative and which, in particular, takes account of the vessel traffic management measures which exist in the zone. The models can then be used to conduct a cost-benefit analysis of the safety impact of any new management measure — for example new navigational aids, a traffic separation scheme, areas to be avoided by shipping, an obligation to employ a pilot, a certain level of Vessel Traffic Services (VTS), etc. After such recent maritime disasters such as the Erika (December 1999), the Ievoli Sun (October 2000) and the Prestige (November 2002), these models can also be used to evaluate the impact of some of the measures contained in the Erika I and II packages adopted by the European Parliament.

These models are subject to the recent Formal Safety Assessment (FSA) guidelines issued by the United Nations body in charge of maritime questions, namely the International Maritime Organisation (IMO). In 1993, at the instigation of the United Kingdom, the IMO recognised for the first time the importance of these assessment techniques in the appraisal of new vessel traffic management schemes. In 1997, interim FSA guidelines were drawn up by the IMO and applied on a trial basis. The FSA guidelines were given final approval in 2001.

2.2. Casualty risk

The first task is to identify the commonest types of accident. For this, we can produce a classification based on that drawn up by Lloyd’s Maritime Information Services i.e collisions, groundings, contacts, foundering, machinery and hull failures, explosions and fires.

A specific type of casualty risk exists for each vessel navigating in the zone in question. Classically, casualty risk is defined as the product of the probability of the type of accident in question occurring (or its frequency) and the consequences of the accident in question.

Casualty risk can be expressed in monetary units (Euros or Dollars, for example) or in terms of the number of human lives lost, the scale of pollution, physical damage to vessels, etc.; as a consequence of the way risk is defined, two types of model are required in order to assess it:
– Models that estimate the number of different types of accident,
– Models that estimate their consequences.

This paper will consider only the first of these.

2.3. Models that estimate the frequency of accidents

In general terms, the (mean) number \( N_{acc} \) of accidents of type \( acc \) in a given period of time and a given zone is estimated using the following model (equation (1)):

\[
N_{acc} = (\text{nb. of exposures})(\text{accident prob.}|\text{exposure})
\]

The first term in this equation — the number of exposures to risk — is the number of potentially dangerous situations that occur during the selected period of time in the zone in question. The second term involves the concept of conditional probability (the probability of an accident occurring once a potentially dangerous situation has arisen). It defines and describes the casualty rate for the type of accident in question and the number of exposures to the danger in question. This rate can be estimated using a variety of methods, as we shall see below. In order to compute expression (1), the following are therefore required, for each type of accident:
– A risk exposure model, which defines the nature of the exposure in question in mathematical terms and computes the number of exposures that occur during the selected period of time (for example one year);
– An accident probability model, which defines the casualty rate for the type of accident.

Risk exposure models: In most of the existing models that estimate the number of accidents, the nature of risk exposure depends on the type of accident that is considered. Thus, for example in the case of a collision, risk exposure will consist of a potential encounter and for fire or explosions it will consist of the number of vessel miles, and so on.

When the type of risk exposure has been selected and formulated mathematically, the model computes the number of exposures that take place during the selected time period and in the selected zone. This depends on many items of data, such as the geographical characteristics of the zone (coasts, deep waters, number of platforms, traffic separation schemes, etc.), the characteristics of the traffic in the zone (types and sizes of vessels, flows, speeds, spatial distributions of routes within navigation corridors) as well as environmental conditions such as visibility, wind, and currents, etc.

Accident probability models: For each type of accident and each type of risk exposure that is considered the following will be specified in the models that compute casualty rates: the probability of a transition from the dangerous situation to a real accident, and an estimate of the value of this probability.

For example, a probabilistic model of this type for collisions could take the following form (equation (2)):

\[
(\text{clear} \cdot \text{col,clear} + \text{badvis} \cdot \text{col,badvis})
\]

where \( \text{clear} \) and \( \text{badvis} \) are the respective probabilities of good and poor visibility in the zone in
question and \( P_{\text{col,clear}} \) and \( P_{\text{col,badvis}} \) are the probabilities of a collision occurring when there is a potential encounter with another vessel in good and poor visibility respectively. The values of \( P_{\text{clear}} \) and \( P_{\text{badvis}} \) are determined from statistics about the zone in question. The values of \( P_{\text{col,clear}} \) and \( P_{\text{col,badvis}} \) could be derived either by purely probabilistic methods, from analyses of deficiencies using casualty databases or by applying statistical methods founded on these databases.

2.4. Example of a specific model: the Samson’s accident number estimation model

Since 1975, the SAMSON model (Safety Assessment Models for Shipping and Offshore in the North Sea)\(^1\) has received continuous funding from the Dutch Ministry for Maritime Affairs, which wishes to use it to support its views on maritime safety. The model SAMSON used to estimate the number of accidents has the general form of a combination of equations (1) and (2). This model uses equation (3) below to estimate the average casualty rates, i.e. the estimated average number of accidents per unit of risk exposure, with reference to the environmental conditions in the zone in question and the level of vessel traffic management that is applied.

\[
\text{CASRAT}_{\text{acc,area}} = \left( P_{\text{storm}} F_{\text{storm}} + P_{\text{badvis}} F_{\text{badvis}} + P_{\text{rem}} \right) F_{\text{manag}} \text{CASRAT}_0
\]

\( \text{CASRAT}_{\text{acc,area}} \) denotes the casualty rate for the type of accident (acc) and the zone (area) in question. \( \text{CASRAT}_0 \) denotes the basic casualty rate for the type of accident acc, computed under good visibility and calm weather, in a given reference zone (for example the entire North Sea). The period of time and the reference zone used to calculate \( \text{CASRAT}_0 \) are selected to provide a statistically significant number of accidents of each type in the zone during the period.

\( P_{\text{storm}}, P_{\text{badvis}}, P_{\text{rem}} \) denote respectively the probabilities of a storm, poor visibility conditions and conditions other than these in the zone in question. \( F_{\text{storm}}, F_{\text{badvis}} \) are factors aggravating the collision rate in the event of a storm or poor visibility in comparison with calm weather and good visibility; these are strictly positive real numbers.

\( F_{\text{manag}} \) is a positive factor, that may be greater or less than 1, depending on whether vessel traffic management in the zone in question is deemed to be inferior or superior to that in the reference zone.

The values of \( P_{\text{storm}}, P_{\text{badvis}}, P_{\text{rem}} \) are easily obtained from statistical observations in the zone in question. In the North Sea, for example, \( P_{\text{badvis}} = 2.7\% \) of the time in the case of visibility of less than one thousand five hundred metres, and \( P_{\text{storm}} = 2.5\% \) for winds force 8 on the Beaufort scale or stronger.

The values of \( F_{\text{storm}}, F_{\text{badvis}} \) and \( F_{\text{manag}} \) are more difficult to define. They depend on the type of accident and are usually determined by analyzing casualty databases. The orders of magnitude for \( F_{\text{storm}} \) and \( F_{\text{badvis}} \) are between, for example, 2 and 17 for a collision and between 20 and 1 for a stranding due to engine failure, etc.

The value of \( F_{\text{manag}} \) is also difficult to establish. On the basis of expert opinion, it is accepted, for example, that a VTS reduces the average collision rate by 20%.

Finally, in the SAMSON model, the basic casualty rate \( \text{CASRAT}_0 \) is used to redistribute the casualty data collected in the reference zone within a certain zone, as a function of the number of exposures to risk calculated for the zone and the local conditions (as regards weather and traffic management) on the basis of the probabilities \( p \) and the factors \( F \).

3. THE DYNAMIC RISK INDEX ASSOCIATED WITH A VESSEL

3.1 Introduction

The risk equation may also have applications, such as:

- Determination of required nautical support of vessels arriving in a port, number of pilots, remote pilotage or certificate of exception for a ferry captain
- Determination of the necessity to monitor a vessel when such a vessel transits the littoral sea

The first issue can only be discussed when the interaction between the vessel and the port’s infrastructure can be sufficiently accurately described. This requires an in-depth analysis of the movement of a vessel in a port and the human reactions on the response of the vessel.

The second issue is important when the AIS networks along the European coastlines are established. They will enable the competent authorities to monitor high risk vessels plying along their coasts. There is however no need to monitor all vessels when it is possible to pinpoint highly risky vessels. The risk index may include information that is required by the monitoring authorities.

Each vessel produces risk, since there is always the probability of an accident even when this probability is very small.

Accident frequencies are dependent on a variety factors, such as:

- Ship type,
- Ship size,
- Flag,
- Age,
- Class,

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\(^1\) This model was developed by MSCN/MARIN still under the name of the MANS model.
• Weather conditions,
• Visibility conditions.

Casualty rates are dependent on ship type and ship size. Smaller and large vessels show higher casualty rates. Smaller vessels are often involved in groundings and foundering due to the low manning rates and their small relative sizes. Large vessels are often involved in groundings due to large drafts and collisions due to large manoeuvring time constants. Bulk vessels and General Dry Cargo vessels are more vulnerable than gas carriers and chemical carriers. The first two classes of vessels are often substandard, whilst the second group are often operated by high standard owners. An analysis showed that flag might not be the best way to describe risky vessels.

3.2 What is the effect of age on casualty rates?

When a maritime catastrophe occurs, especially with old single hull tankers, the opinion is that these tankers should be banned. These tankers are often used for the transport of very heavy fuel. Some of these tankers are older than 20 to 25 years. Are these tankers more accident prone?

Answers to this question are not difficult to obtain. The Lloyds’ casualty database is used. The number of accidents is counted for vessels that have the same age when the accident occurred. The magnification factor is normalised with the age of 10 years. The results are that the average frequency of accidents of vessels that are 25 years old is 3 times as much since the time the vessel was commissioned.

3.3 Dependency between casualty frequency and classification society

The relation between the accident rate and the vessels classified at a classification society has been analysed by using again the Lloyd's casualty database. The results of the analysis indicate a ratio which is the contribution of the vessels classified by the classification society to all accidents and the contribution of these vessels in the world fleet. The accidents used are serious accidents on a global scale for 12 years. Only these accidents are considered since evidence exists that the coverage of these vessels is about 100%. The fleet composition has been taken of the year 2000. The assumption is that the relations between classification societies was constant during the preceding decade. This is not true, but the assumption is not very bad either and serves as a first approximation.

The results are not in line with what most experts expected. They believe that the well-known West European Classification societies do have a high level and consequently that the vessels they register are good. The results show a different pattern. Since nearly a decade discussions are pursuing on the contributions to safety through the acceptance and inspection policies implemented by these societies. The results show that the Authorities are right when they state that Classification Societies should be audited.

![Fig.1- Results of the magnification factor in accident frequency sensitivity for age of a vessel](image)

3.4 Autonomous number of serious accidents as function of time

An often heard remark is, that despite the developments in the area of maritime safety the safety level has not improved. Such an opinion can be easily assessed. The Lloyds accident database has been again taken for serious accidents to vessels. By grouping the number of accidents for each year figure 2 could be obtained.

The results are being normalised with the average over the period and the average is called 1.

The figure above indicates the relations for various ship types. The excessive “noise” may be caused by a small number of accidents for some ship types. In the line “total” the ship types “passenger”, “miscellaneous”, “tugs” and “fishing” are not included. The reason is that coverage of these accidents might not be sufficiently reliable. The line “total” has been approximated by two regression lines: a parabola and an exponential line. The exponent of the exponential line is -0.044. The annual reduction of the accidents is 4.3%

<table>
<thead>
<tr>
<th>Classification bureau</th>
<th>ratio</th>
<th>% of traffic</th>
<th>% of accidents</th>
</tr>
</thead>
<tbody>
<tr>
<td>RS Register of Shipping Russian</td>
<td>0.31</td>
<td>7.1%</td>
<td>2.2%</td>
</tr>
<tr>
<td>NK Nippon Kaiji Koyosai</td>
<td>0.45</td>
<td>18.5%</td>
<td>8.3%</td>
</tr>
<tr>
<td>KR Korean Register of Shipping</td>
<td>0.46</td>
<td>3.5%</td>
<td>1.6%</td>
</tr>
<tr>
<td>RI Registro Italiano Navale</td>
<td>0.64</td>
<td>2.9%</td>
<td>1.9%</td>
</tr>
<tr>
<td>AB American Bureau of Shipping</td>
<td>0.89</td>
<td>9.5%</td>
<td>8.5%</td>
</tr>
<tr>
<td>NV Norsk Veritas</td>
<td>1.23</td>
<td>8.7%</td>
<td>10.8%</td>
</tr>
<tr>
<td>LR Lloyd's Register of Shipping</td>
<td>1.49</td>
<td>14.6%</td>
<td>21.9%</td>
</tr>
<tr>
<td>HR Hellenic Register of Shipping</td>
<td>1.79</td>
<td>1.5%</td>
<td>2.7%</td>
</tr>
<tr>
<td>GL Germanische Lloyd</td>
<td>1.81</td>
<td>10.4%</td>
<td>18.8%</td>
</tr>
<tr>
<td>BV Bureau Veritas</td>
<td>1.92</td>
<td>9.6%</td>
<td>18.5%</td>
</tr>
</tbody>
</table>

Table 1: Ratio between percentage of accidents and percentage of exposure in ship-years for vessels classified by a given classification society
stopped. The parabola as extrapolated from the results predicts some small increase in accidents for 2002.

In fact the fleet statistics should also be used for these years. The number of vessels is increasing during this period. This leads to the conclusion that the casualty rates based on ship-years has even a higher reduction ratio than 4.3%. It is difficult to provide a convincing reason for the behaviour of the accidents ratios. One reason is the introduction of a more strict safety regime by IMO. The recent safety offensive of the Commission is of course not taken into account in the present figure, since the measures are still not effective. Another conclusion is that, although public opinion and the opinion of the policymakers are shocked by the continuous number of tanker accidents with associated pollution, the reality might be that the total number of accidents is reducing.

\[ y = 10^{38}e^{-0.044x} \]
\[ R^2 = 0.7376 \]
\[ y = 0.007x^2 - 28.087x + 28079 \]
\[ R^2 = 0.8829 \]

![Graph showing reduction factor in accident frequency sensitivity during the last decade](image)

4. CONCLUSIONS

The use of risk indices is a new technique made possible by systematic casualty and fleet statistics and voyage records, the latter in combination with a route model that is able to determine the exposures. The risk index can assist in reducing the surveillance effort of the monitoring authorities. Monitoring of maritime traffic is carried out in France where CROSS Corsen has an AIS base station in operation that surveils the Traffic Separation Scheme. Interventions of CROSS Corsen occur regularly when vessels are confused by the introduction of the new TSS at May 1st, 2003. In a later stage the risk index can be introduced and ships can be tagged so that the monitoring operator knows on which vessel to concentrate.

The concept of risk indices will intensively discussed in European platforms and might be used when the different AIS networks along the European Coasts are established.

5. REFERENCES


IMO, 1997. Interim Guidelines for the application of FSA to the IMO rule-making process. IMO resolution MSC/cir. 829.