Ship Offshore platform Collision Risk Assessment (SOCRA)

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ABSTRACT

Knowledge of maritime traffic and knowledge of the behaviour of this traffic is essential for a successful maritime risk assessment study. For many years such knowledge has been built up and improved within Dutch national projects for the Maritime Safety Agency (DGSM) and North Sea Directorate, both part of the Ministry of Transport, Public Works and Water Management, and within European projects, COST 301 and EURET, for the European Commission. Based on this knowledge the MANS-model (Management Analysis North Sea) was developed, a toolbox with models to facilitate the comparison and evaluation of policy alternatives with respect to the use, physical planning and management of the North Sea. One of these models is the Ship-Offshore platform Collision Risk Assessment (SOCRA) model. This model is described in more detail in this paper.

1. INTRODUCTION

Over the years a considerable number of ship-ship collisions have occurred, but ship-platform collisions are a rare phenomenon. Over the last decades a large number of platforms was built in the North Sea. Until now no serious ship-platform collisions have occurred. Platform collision models are developed to assess the collision risk for platforms. The SOCRA-model implemented in the MANS-model is one of them.

An essential part of such a model is the traffic database, which describes the maritime traffic in numbers, density, composition and behaviour. For many years this traffic database has been built up, extended and improved. The maritime traffic consists of the route committed and non route committed (or random) traffic. The route committed traffic consists of the merchant vessels sailing along the shortest route from one port to another. The random traffic has mainly a mission at sea, containing fishing, supply, working and recreation vessels.

The traffic database is described in the next section. Then the SOCRA-model is dealt with. Section 4 gives some results of the SOCRA-model followed with a section with conclusions.
2. TRAFFIC DATABASE

The traffic database is designed to provide information about the ship movements in the North Sea. With such a traffic database it is possible to give answers on questions like:
- pollution risk
- planning the use of the space
- adequacy of safety measures

The route structure of the traffic model is designed by determining the shortest distance between two pilot stations. Each port around the North Sea has a designated pilot station. This does not necessarily mean that a pilot-cutter is stationed at the pilot station. Many small ports have a designated location where ships, which need a pilot, can embark/disembark a pilot. However, it is not always possible to take the shortest distance between two pilot stations. Four important reasons to deviate are listed:
- When there are shallows which can not be traversed by the vessels. These deviations are draught dependent.
- When the shortest track is in the vicinity of a Traffic Separation Scheme (TSS), the TSS should be used. On the other hand if the track is crossing a TSS that vessel should cross a TSS at right angles as far as practical.
- Where the shortest track uses a part of an inshore zone, the inshore zone should be avoided.
- When, in bad weather conditions, the shortest track might be dangerous for the safety of the crew, the vessel or its cargo.

The first and last reason may be time dependent. This dependency can be of a different nature. Some ships may cross shallow waters as tide permits. Small ships have to take bad weather conditions into account. The other reasons have a permanent nature and are based on official routing measures as agreed by IMO.
The traffic database is described with the following items:

**Points:**
Each point is defined by a geographical position. Different types of points are defined:
- 79 pilot stations
- 217 waypoints
- 70 course change points
- 30 sea terminals
- 243 platforms
- 7 ferry locations
- 194 ports/regions outside the North Sea

**Links:**
A link is the straight connection between two points. More than 5000 links are defined of which more than 2000 concern the southern part of the North Sea.

**Movements**
On each link the traffic information is determined in the format of a ship type/size matrix. The assignment in one of the 36 types and 8 size classes is done by means of the ship's description given by Lloyd's. This type/size matrix is essential for carrying out additional calculations such as the **drifting speed** in case of an engine failure and the **impact energy** in case of a collision.

**Filling of the database:**
The traffic database has been filled by processing almost 700 000 voyage records obtained over the year 1987. These records contain Lloyd's number, port of departure and port of destination. The Lloyd's data file does not include the ferry voyages or the movements of random traffic. The ferry movements are obtained from ferry time tables.

**Random traffic:**
The random traffic, fishing-, supply-, work- and recreation traffic is added by means of area densities extrapolated from the observations from airplanes (VONOVI), during a great number of flights over many years. The fishing traffic is improved with the VIRUS database, maintained by the Dutch Ministry of Agriculture and Fishery. The random traffic is only available on the Dutch Continental Shelf.
Validation of the database:
The total traffic database is validated by comparing the results with the aerial observations from 1987. This validation indicated that the routing model resulted in an accurate and complete representation of the reality. A limited number of shortcomings were identified, which have been corrected in the most recent update of the traffic database within the EURET project ([2] and [3]). The UK participant has performed additional validations within the EURET project ([4]).

Lateral distributions:
For each link the lateral distribution of the ships using that link is determined. The analysis of the VONOVI observations provided information for improving the assumed lateral distributions on the links. The new distribution functions correspond with the reality.

3. PREDICTION OF PLATFORM COLLISIONS

3.1 Introduction

Two separate models are developed for the determination of the collision risk. These models describe collisions with different causes. The two models are:
- a ship is on a collision course with a platform and a navigational error occurs. This error is undetected until the point of no return and the ship collides with the platform. The collision may be at high or low speed depending on the time lapse between the point of no return and the implementation of a corrective action after the detection of the error. This mode will be called the 'navigational error mode' and the collision type a 'ramming' collision.
- a ship in the vicinity of a platform experiences a failure in the propulsion engine or in the steering equipment. Since the ship slowly becomes uncontrollable as it loses speed, the combined effect of wind, waves and current may carry it towards the platform. If dropping an anchor does not help or is not practical and the repair time exceeds the available time, the ship may collide against the platform. This generally happens at a low speed. This mode will be called the 'engine failure mode' and the collision type a 'drifting' collision.

Collisions involving ships alongside a platform such as supply vessels and anchor-handling tugs are not considered here. In practise such a collision can cause extensive local damage to both the vessel and the platform. However, the impact will rarely impair the structural integrity of the platform.

The following remarks elucidate aspects of the ramming and drifting model:
- In the navigational error mode, the navigator might have left the bridge and upon his
return he notices that the vessel is on a collision course with a platform. He will do whatever he deems necessary to avoid the platform by initiating an emergency turn or by giving "Full Astern". Since navigators are rarely absent for long periods he might be back before impact. In cases where the navigator returns to the bridge and realizes what is happening, he can implement a certain escape manoeuvre which can reduce the impact speed.

- Heart attack, drunkenness and sleep deprivation are contributory factors to the navigational error mode. Other infrequent factors are: criminal negligence of duty and suicidal behaviour.

- Some measures might avert a collision in the engine failure mode. It might be possible to drop an anchor during the drifting process. If one takes the design conditions of an anchor and the anchor chain into consideration the speed of the vessel in relation to the ground should not exceed a certain threshold speed. A higher speed will invariably mean that the anchor cable breaks. Another possible method is to pump out the anchor and use it as some sort of drag. A number of other methods like ballasting, use of rudder and bow thruster can be used to obtain a small change in the direction in which the ship is drifting. In some cases tugs or supply vessels in the vicinity can be used to assist the ship avoiding a collision with the platform.

### 3.2 Ramming model

The probability of a platform ramming in the North Sea depends on the following factors:

- position and dimensions of the platform.
- maritime traffic.
- some of the physical characteristics of the vessels.
- navigational error rate.

The maritime traffic is described by the link structure. The intensities and composition of the vessels using these links is known. Fig 2 shows the situation for two traffic links and the platform. For known lateral distributions of the vessels using the links, the number of vessels potentially ramming the platform can be estimated. A great disadvantage of this method of ignoring the platforms is that the result is very sensitive to the centre lines and the lateral distributions of the traffic links. This information is also inaccurate in regions outside the vessel traffic separation schemes,
where vessels are free of choice where to sail.

For this reason a new approach is followed which is less sensitive to the above characteristics. In this approach not only the passings over the platform contribute to the ramming risk but also the passings near the platform itself. All passings are weighted with a factor depending on the passing distance.

The model for the weighting of the passage is:

$$ WP_{iklm} = (B_i + B_{km}) e^{-\alpha d_{km}} $$

Herein is:
- $WP_{iklm}$ weighted passing for ship i on lane l of link k and platform m
- $B_i$ breadth of ship i
- $B_{km}$ the exposure breadth of platform m in direction of link
- $d_{klm}$ distance between lane l of link k to platform m
- $\alpha, \beta$ parameters describing the weighting

Each link k is divided in a number of lanes l containing ships following the lateral distribution of that link. It is clear that the probability of ramming depends linearly on the exposed breadth to the platform. This is the reason for the summation of platform dimension and breadth of ship in the above equation.

The ramming model assumes a linear relationship between the real number of rammings and the number of weighted passings. The multiplier is a kind of navigational error NER and the number of rammings for platform m is modelled by:

$$ \text{Ramming}_m = NER \sum_k \sum_l \sum_i N_{ik} WP_{iklm} $$

Herein $N_{ik}$ is the number of passings for ships i over link k.

**Weighting parameters:**

A large problem of a model describing the number of rammings is lack of validation data. So far only two rammings have occurred. For this reason the model itself has to inspire confidence. Describing the weighting with two parameters $\alpha$ and $\beta$ seems contrary to this statement. Fig 3 shows a number of different weightings as a function of the passing distance. Only the shape of the curve is important, because the level is assessed through the *Navigational Error Rate*. In fact each plausible weighting can be chosen if consequently used. For the present calculations the weighting $e^{-2d^{1.5}}$ is used, which looks like the curves...
given in [5], showing the frequency against distance between lane and platform.

Assessment of the Navigational Error Rate

The casualty database of Lloyd's with casualties occurred on the whole North Sea from 1978-1991 is used to assess the number of times a platform is struck by a vessel. The cases included in this database are:

- struck satellite platform. (ramming)
- struck self-elevating drilling platform. (ramming a MDU)
- struck drill platform after having dragged anchor in heavy water. Vessel had anchored due to developing main engine trouble. (drifting)

The database contains also 8 cases with non route committed vessels, 4 standby safety vessels and 4 tug/supply vessels. According to the specifications of the Lloyd's casualty database not all cases with non route committed vessels have to be included so in reality more cases could have occurred.

It can be concluded that one ramming occurred by a route committed vessel to a fixed platform and one ramming by a route committed vessel to a Mobile Drilling Unit.
(MDU). The collision risk for a MDU will be higher because not all navigators are known with the temporary platforms.

All links with a centre line at a distance of 20 nm or less are included. The contributions of links with larger distance are negligible by the weighting. The calculation under the above mentioned assumptions resulted in 193150 weighted passings and 4680 platform years until mid 1994. Based on one realisation (ramming) with a fixed platform the Navigational Error Rate for fixed platforms can be estimated to \(1/193150 = .518 \times 10^{-5}\) weighted passings. With this rate the collision frequency for each individual platform can be assessed.

All assessments of the rammings are 50/50 estimates, based on only one realisation, thus with a large 95% confidence interval.

### 3.3 Drifting model

The determination of the number of drifting collisions is based on the concept of a danger mile which is the part of a link starting from which a drifting vessel of a given length will strike the platform, given a certain speed and wind direction (see Fig 4). The distance travelled downwind is the drifting speed that will be generated by the wind force multiplied by the duration of the engine failure (MTTR = Mean Time To Repair). If the platform is beyond this distance no collision will occur and consequently no danger miles are produced. The danger miles should be multiplied with the failure rate for different MTTR's.

![Fig 4 Drifting vessel threatening a platform](image)
The number of danger miles is given by:

\[
DM_{ij} = \sum_{b} \sum_{\phi} \sum_{n} \sum_{k} \sum_{l} p_{b\phi} p_{n} p_{kl} N_{ik} \left( x_{2bijklm} - x_{1bijklm} \right)
\]

Where:

- \(DM_{ijkm}\) the danger miles for ship \(i\), failure \(j\) on link \(k\) to platform \(m\)
- \(p_{kl}\) the fraction of the traffic of link \(k\) in lane \(l\)
- \(N_{ik}\) the yearly ship movements over link \(k\)
- \(p_{b\phi}\) the probability for wind force Beaufort class \(b\) in direction \(\phi\)
- \(p_{ln}\) the probability for loading condition \(n\) for ship \(i\)
- \(B_{m\phi}\) the exposure breadth of the platform for drifting direction \(\phi\)
- \(L_{i}\) length of ship \(i\)
- \(x_{1bijklm}\) start of danger interval
- \(x_{2bijklm}\) end of danger interval

Only that part of the interval \((x_{1bijklm}, x_{2bijklm})\) of the above relation is counted for which the drifting time is given by \(MTTR_{j}\) is long enough for reaching the platform, thus for

\[
\frac{d_{km}}{v_{dib}} \sin \phi > MTTR_{j}
\]

Herein is \(v_{dib}\) the drifting velocity that follows from:

\[
v_{dib} = \sqrt{\frac{\rho_{air} A_{L i} c_{dwind}}{\rho_{w} L_{i} T_{in} c_{d}}} v_{p} + \frac{\xi^{2}_{b} g}{T_{in} c_{d}}
\]

Where:

- \(v_{dib}\) drifting velocity of ship \(i\) in loading condition \(n\) by wind and waves belonging to Beaufort class \(b\)
- \(v_{p}\) wind velocity for Beaufort class \(b\)
- \(\rho_{air}\) density of air
- \(\rho_{w}\) density of water
A_{L_{in}} the lateral wind surface of ship i
L_{i} the length of ship i
T_{i_{n}} the draught of ship i in loading condition n
\dot{\zeta}_b the significant wave amplitude assumed to be generated for Beaufort class b
C_{d_{wind}} the lateral wind resistance coefficient of the ship
C_d the lateral resistance coefficient of the underwater body of the ship
C_{wave} the wave drift coefficient

By tide current the real drifting velocity differs from the value calculated here. During some tides the velocity will be larger and during other tides smaller. It is assumed that the average contribution of tide to the drifting probability can be neglected.

The total number of driftings can be determined by summing the drifting collisions over all ships and distinct failure. This is given by:

\[ Drifting_{m} = \sum_{i} \sum_{j} FR_{ij} DM_{ij} \]

Where:
FR_{ij} de engine failure rate for ship i with MTTR_{ij}

The wind distribution of Lightvessel Texel is used for all platforms in the North Sea. However, the wind compass can be defined for each platform individually.

**Temporary change of traffic links on interaction with platforms:**
During the development of the route structure the platforms are ignored. This means that some of the traffic links will pass platforms too closely. During the drifting calculations the centre line of the traffic links are moved to a distance of at least 1 nm from the platform centre. By the lateral distribution ships can pass closer to the platform. However, always a minimum passing distance of .5 nm is assumed.

4. RESULTS OF MODEL CALCULATIONS

4.1 New platform

The risk assessment model can be applied to assess the platform collision risk for a new platform. In Fig 5 the traffic density around such new location is presented. It gives an overview and shows in which direction the platform has to be moved to reduce the collision risk. The drifting and ramming risk can be assessed with the SOCRA-model. One can use
the absolute value of the risk or one can use the result by comparing it with the average level. Each collision frequency is given in the form of a complete matrix, with ship types and sizes. This is essential for additional calculations. For example: the design requirements can be assessed that are necessary to bring the collision risk at a required level. The effect of risk reducing measures can also be better determined by the knowledge of the type and size of the vessels that are involved.

4.2 Ramming and drifting frequencies for the four sectors

The yearly risk within the four main sectors of the North Sea are calculated and presented in this section. The drifting calculations are carried out for three cases. The mean time to repair (MTTR) between 0-2 hours, 2-6 hours and >6 hours are considered. 1, 4 and 6 hours drifting are coupled to these cases respectively.

The ramming and drifting collisions have been determined for the four sectors. The calculations have been done for the platform file of 1989 that was available. The summary of the results is presented in Table 1 and in Fig 6. The detailed output shows that the dedicated traffic also contributes to the ramming frequency. Especially in the Norwegian sector, the fraction of the total rammings by supply vessels and shuttle tankers is relatively high. Fig 7 gives the cumulative distribution for increasing ship sizes in each sector.

<table>
<thead>
<tr>
<th>Sector</th>
<th>ramming</th>
<th>1 hour drifting</th>
<th>4 hours drifting</th>
<th>6 hours drifting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Denmark</td>
<td>.0019</td>
<td>.0033</td>
<td>.0009</td>
<td>.0020</td>
</tr>
<tr>
<td>Norwegian</td>
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<td>.0163</td>
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<tr>
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<td>.0313</td>
<td>.0335</td>
<td>.0167</td>
<td>.0101</td>
</tr>
</tbody>
</table>

*Table 1* Survey of ramming and drifting collisions per year
Fig 6 Ramming and drifting collision per year

Fig 7 Cumulative distribution of ship sizes
5. CONCLUSIONS

The SOCRA-model can be very usefully applied for Safety Case Studies. Only for the Dutch sector the collision risk can be assessed for fishing vessels and other non route committed vessels, for reason that this type traffic is only available (validated) for the Dutch Continental Shelf.

The effect of risk reducing measures can be implemented in the SOCRA model. In most cases this can simple be done by multiplying the collision frequency with a factor corresponding with the effect of the risk reducing measures. This factor may vary over the ship types and sizes. The SOCRA-model can be used to determine the optimal set of risk reducing measures for a specific platform.

The traffic database of the MANS-model is also applied for the assessment of the pipeline damage risk by sinking ships, containers, dropping and dragging anchors.

Applications outside the offshore scope

The MANS-model contains also models of other type of casualties e.g. ship-ship collisions, foundering, strandings, contacts and fire explosions. The frequency and the consequence in terms of spills can be assessed for each area. This kind of output is required for contingency planning aspects.

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