Evaluating ship collision risks

Silveira, P., Teixeira, A.P, & Guedes Soares, C.

IRIS – Project risk management: Improving risk matrices using multiple criteria decision analysis
Evaluating ship collision risks

**Objective**

To develop a multicriteria ship collision risk index combining the contributions of different types of impacts of ship collisions.

The ultimate objective is to have an integrated crisis management and rescue operations system.
Maritime Safety

Traditional approach to safety

Marine accidents:
- loss of life
- environmental damages

Safety concerns have been reflected in the attention given to:
- design and building activities
- operation of the ships
- education and training of the ship operators

Improvement of rules and regulations
A pro-active (risk) approach to safety

Decision support tools for maritime regulators, based on risk and cost-benefit assessments.

It will act pro-actively by means of:

- Deciding upon a target for risk level
- Analysing risks using a systematic approach
- Identifying measures to achieve the target risk level
- Monitoring performance

Formal Safety Assessment

Risk-based approach to Maritime Safety
Accident Statistics

- Provide an overall quantification of the risks levels existing in maritime transportation
- Allow the identification of the time evolution of the levels of safety,
- Allow the identification of the main modes of failure

Based on maritime accident statistics, groundings and collisions are the dominant accident types
Collision risk assessment

Collision risk assessment at sea is an important issue for maritime traffic management, crisis management and planning rescue resources and operations.

Collision risk

Product of the probability of an event (P), and the consequence (C) associated with the realization of the event.

\[ R = P \times C \]

P – Collision probability

C – Consequences of collision:

The consequences of the ship collisions can be represented in different categories, classified as follows:

- safety impacts (loss of life, limb and health);
- damages to ship structure, equipment and cargo (including total loss), loss of reputation;
- damages to the marine environment (Oil spills)
Collision probability

Collision probability is most commonly assessed based an approach suggested by Fujii MacDuff.

The probability of a collision is defined as

\[ P = N_A \, P_C \]

where

- \( N_A \) is the number of collision candidates, i.e. ships that are in a collision course
- \( P_C \) is the causation probability, i.e. the probability of failing to avoid a collision when ships are on a collision course.
Causation probability (Pc)

\( P = N_A P_C \)

The causation probability is the probability of failing to avoid a collision when ships are on a collision course due to human errors, equipment failures or external environmental factors.

The causation probability can be estimated in two ways, by a:

Scenario approach

Based on available accident statistics

Comparing the estimated number of collision candidates with the actual number of collisions that have occurred.

Synthesis approach

Based on a Bayesian network that models the influence of human errors, equipment failures or external environmental factors on the ship collision
Causation probability (Pc)
Estimation of collision candidates based on AIS data

The number of collision candidates varies both with geographic location and with time, reflecting the intensity of maritime traffic during different periods.

**Automatic Identification System (AIS) data**

The Automatic Identification System (AIS) is an automatic tracking system used on ships and by vessel traffic services (VTS) for identifying and locating vessels in real time.

AIS messages are transmitted using VHF radio waves and include:

- speed; position (latitude; longitude); course; heading; ship type; ship main dimensions; etc.

AIS data has become an important source of information for studying maritime traffic and associated risks.
Automatic Identification System (AIS) data

Computer programs have been developed for decoding and visualization of AIS data.

The resulting image allows an analysis of the traffic, identifying the main routes and areas where the traffic is more or less intensive.

Intensive traffic flow at the traffic lanes of the traffic separation schemes and on the main routes connecting the main ports to the traffic lanes.

(one month AIS data)
Estimation of collision candidates based on AIS data

The collision candidates have been calculated directly from decoded AIS data, using two methods:

- Method based on the Closest Point of Approach (CPA) and the collision diameter defined by Pedersen (1995).

- Method based on the projection of rectangles with the same dimensions as the ships’.

\[ D = f (\text{length, breadth, crossing angle and relative velocity of the ships}) \]
Estimation of collision candidates based on AIS data

Geographical distribution of collision candidates

- A total of 1766 collision candidates were identified in the area monitored by the Portuguese coastal VTS (traffic control centre), using data recorded during one month.
- This corresponds to an average number of 55 collision candidates per day.
Ship collision consequences

Consequences of ship collisions may be classified as:

- Loss of life / injuries
- Damage to property
- Environmental impacts

Consequences depend on:

- Ship striking or being struck
- Angle of encounter, relative speed
- Type of ship, cargo, age of ship, loading condition
- Extent of damage: breach of hull, loss of watertight integrity (LOW)
- Location of incident (in port, coastal waters, open sea, near environmentally sensitive areas,…)
- Availability and distance to means of rescue
- Weather conditions
Loss of life / injuries

Cost of loss of life may be estimated using a common index used to express the cost effectiveness of risk control measures, the NCAF (Net Cost of Averting a Fatality).

NCAF depends on the life expectancy at birth (e), on the gross domestic product (g) and on the proportion of life spent in economic activity (w=1/8 in developed countries):

\[
NCAF = \frac{ge}{4} \left( \frac{1 - w}{w} \right)
\]

For health effects and injuries the DALY/QALY criterion (that can be derived from the NCAF criterion) may be used:

\[
DALY = \frac{NCAF}{2e}
\]
Environmental impacts

Cost of environmental impacts may be estimated using IMO (International Maritime Organization) formulae:

<table>
<thead>
<tr>
<th>Dataset</th>
<th>C=f(V)=Total Spill Cost (TSC) [in 2009 US dollars]</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>All spills</td>
<td>67,275 V^{0.5893}</td>
<td>MEPC 62/INF.24</td>
</tr>
<tr>
<td>V &gt; 0.1 tonnes</td>
<td>42,301 V^{0.7283}</td>
<td>MEPC 62/18</td>
</tr>
</tbody>
</table>

Functions of spill costs had been proposed by Japan, Greece and Norway:
Using AIS to define collision scenarios

- Information from AIS is not only useful to estimate the number of collision candidates, it can also be used to define the collision scenarios.

- Ship type and ship size can be used to estimate number of persons on board (loss of life / injuries).

- Ship type, ship size, draught, dangerous cargo and relative speed can be used to estimate quantity of fuel or cargo spilled in case of a collision (environmental impacts) and the property losses (ship and cargo).
Using AIS to define collision scenarios

- Scenarios defined using AIS information:

  - **Head on**
    - L1, L2
    - B1, B2
    - D1, D2
    - V1, V2

  - **Crossing**
    - L1, L2
    - B1, B2
    - D1, D2
    - V1, V2

  - **Overtaking**
    - L1, L2
    - B1, B2
    - D1, D2
    - V1, V2
Improved risk matrices

• Improved risk matrices can be used to quantify risks associated with different types of consequences: human, property, environmental.

• \( R_{col} = P_{col} \times [(N_{crew} \times NCAF \times %HL_{lost}) \times (CB_{oil} \times TSC \times %Oil\,spilled) \times (Val_{Ship,Cargo} \times %Ship_{lost})] \)

• For each scenario, probabilities for different %HL lost, %Oil spilled and %Ship lost may be elicited from experts.

• Based on that information, the risk related to each type of consequence for each scenario can be calculated.

• Real situations being monitored may be compared with existing scenarios to estimate a risk level.
Evaluating ship collision risks

Work Performed

A method has been developed to calculate the probability of occurrence of a ship collision using AIS data,

This provides information on the likelihood and the geographical locations of the collision events

Future work

A multicriteria ship collision risk index will be developed combining the contributions of different types of impacts of ship collisions (human, material, environmental, etc).

AIS data also provide information on the ship type, main dimensions and loading condition of the ship that can be used the quantify, in a qualitative way, the possible impacts of a collision event

The ultimate objective is to have an integrated crisis management and rescue operations system