MARCS – A Computer System For Assessment and Management of Ship Accident Risks

The safety of ships at sea and the environmental risks of marine accidents involving hazardous cargo receive much attention in the world's press. Accidents such as *Exxon Valdez*, *Erika* and *Prestige* in particular highlight the need to evaluate and control the risks of oil pollution from the worldwide tanker industry. The costs of oil pollution incidents can run into hundreds of millions of dollars, including pollution cleanup and compensation costs, fines, asset loss and legal costs. Subsequent effects on the coastal environment, tourism and corporate image add to the impacts of major spills.

As a reaction to these incidents, new measures to reduce risk are being proposed which may themselves have significant costs. For example double-hulled tankers typically cost 15-20% more than conventional single-hulled tankers, adding more than US$10 million to the cost of a new tanker. Many other risk-reducing measures are being considered for marine transport, including the development of marine contingency plans, vessel traffic service schemes and improved ship crew standards, as required by the International Safety Management code.

Against this background it is essential for those concerned with the control of shipping traffic, protection of the marine and coastal environments, and emergency response to marine accidents, to have an objective means of assessing and controlling marine accident risks in a cost-effective manner. Equally it is important to the builders, operators and insurers of ships that these are adequately designed and operated to ensure protection against accidents while keeping capital and operating costs within acceptable limits.

This brochure describes work performed by Det Norske Veritas (DNV) which applies quantitative risk analysis techniques to marine accident risks. The result of this work has been the development of a major computer-based system for assessing the risks of shipping accidents, including oil tanker traffic and other hazardous cargo trades, which can be applied to shipping in any area of the world. The system is called MARCS and its main features are summarised in Box 1.

Box 1 - The Marine Accident Risk Calculation System (MARCS)

MARCS provides a geographical picture of the distribution of marine risks, in terms of traffic densities, accident frequencies and accident consequences (for example, the quantity of oil spilt) at each location within an area. These results may be integrated to show total risks for an area, and may be used to assess potential risk reduction measures, assist in contingency planning and to support cost-benefit calculations.

MARCS can be tailored to marine traffic and environmental conditions in any area, allowing assessment of overall risks in the area or risks associated with specific shipping trades, routes or vessels. A variety of outputs can be produced in a cost-effective manner by MARCS to assist decision-making.

Detailed analysis of the results provides an objective and transparent understanding of the main underlying causes and factors influencing marine risk levels. The most effective ways to reduce risks can be identified, and risk management decisions are, therefore, based on sound assessment.

MARCS can be used to evaluate the effectiveness of a wide range of measures to reduce overall risk, both onboard ships (e.g. hull design) and over a marine area (e.g. vessel control service); cost-benefit analysis can then be used to compare alternative proposals. Running MARCS with alternative vessel traffic data provides information to assist planning for possible future shipping traffic levels and new hazardous cargo trades.

Background

In 1993 the UK Marine Pollution Control Unit commissioned DNV to develop a computer-based risk assessment system for crude oil tanker transport in UK waters. Their objective was to support their oil spill contingency planning capabilities in response to marine accidental events. The resulting system is called MARCS. It predicts the location, frequency and size of oil spills that may be expected from crude oil tanker movements, by calculating the risk of various types of shipping accidents at each location within the study area.

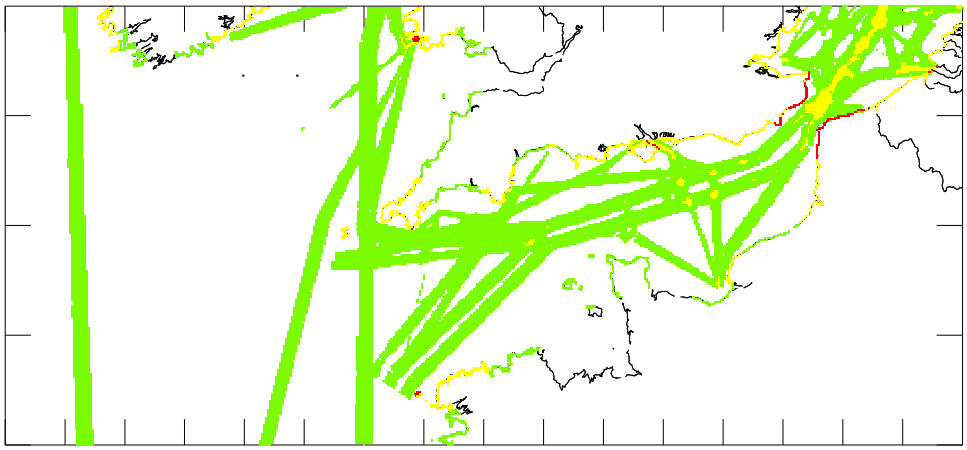
Since 1993, MARCS has been used to assess marine transport risks in major projects, such as in Prince William Sound (location of the *Exxon Valdez* accident) and the EU Safety of Shipping in Coastal Waters (SAFECO) projects, as well as in many smaller projects worldwide.

To date MARCS has been mainly used to calculate the risks of oil spills from crude oil tankers and bunker spills from all ship types. However the system has also been applied to the transport of other hazardous cargoes, and could be used to assess other types of risk such as human fatality risk. MARCS has recently been applied to assess risks due to interactions between shipping and offshore wind turbine arrays.

Results

The primary results of MARCS are charts showing the expected frequency of accidents; an example taken from the English Channel is shown in Figure 1.

Figure 1: Distribution of Calculated Accident Frequencies in the English Channel
(Green, Yellow and Red for Low, Medium and High Risk respectively)

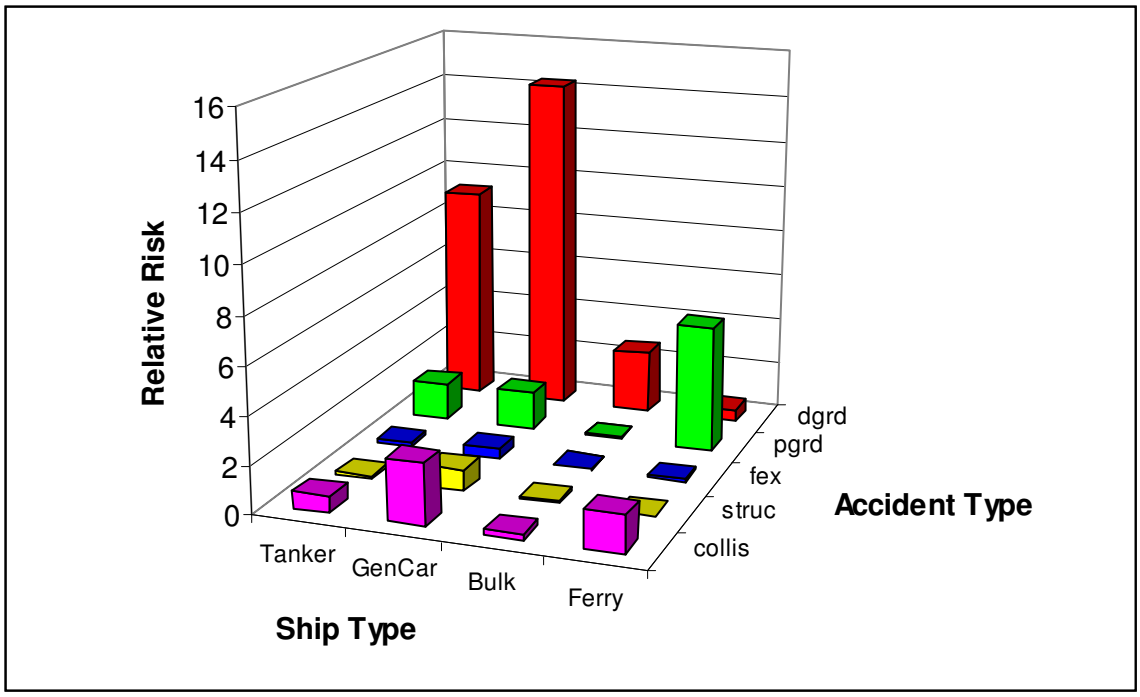


Many alternative charts may be generated to show the risk results, for example for:

- Specified accident types (such as collision accidents or structural failures);
- Specified vessel types (such as oil tankers or ferries);
- For defined consequence ranges (such as oil spills greater than 10,000 tonnes);

The results can also be integrated to produce histograms showing how, for example, the risk varies with accident and vessel type within the study area. An example is shown in Figure 2.

Figure 2: Predicted Relative Accident Risk as a function of Accident Type and Ship Type



Applications of MARCS

The results obtained from MARCS provide a prediction of overall risk levels and their geographical distribution for the study area. The proximity of high risk areas to sensitive environments can be determined and the need to implement risk reduction measures judged. The system models the major factors determining risk levels (e.g. traffic levels, locations of shipping lanes, accident causes, etc.); therefore, examination of the breakdown of risks by these factors gives considerable insight into the major causes of risk levels in a given area.

MARCS may be used to assist in the optimisation of emergency response strategies for shipping accidents, for example by indicating suitable types, amounts and locations of emergency response equipment and resources (e.g. oil dispersant and containment systems).

The effectiveness of a wide range of preventative and mitigating measures can be modelled, such as vessel traffic service schemes, exclusion zones, recovery tugs and ship design features (e.g. hull design, advanced collision avoidance systems, etc.). Detailed "what if" calculations may be performed to show the level of risk which may be expected for alternative risk management scenarios. The costs and benefits of these alternatives may be evaluated in order to optimise expenditure on risk control measures.

Finally, the predictive capability of MARCS enables future possible scenarios and their associated risk levels to be evaluated, to inform and assist the process of future policy development. Future ship traffic levels, or new types of ships and trades, may be modelled using the system, and their potential impacts on current risk management strategies assessed. Results focusing on key risk areas can be used to develop detailed risk control strategies for the future.

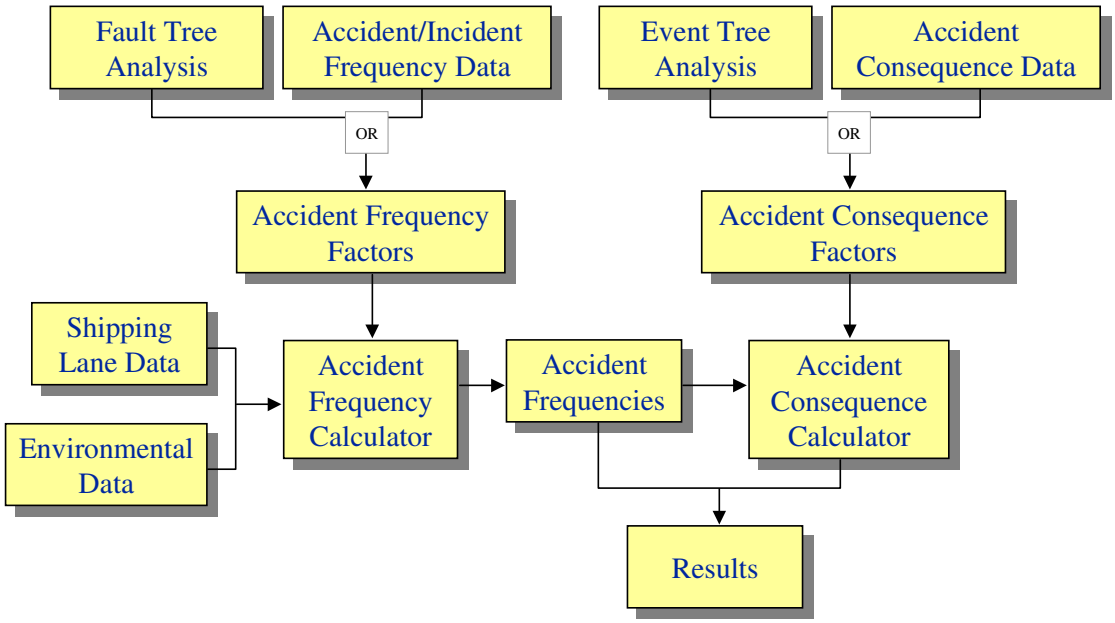
These applications provide a transparent justification for contingency plans and risk management decisions. This can assist in reaching agreement between authorities and the shipping industry over risk reduction measures, and ensures that the most cost-effective measures are selected. Such information is of value to a range of potential users including:

- Regulatory authorities, such as coastguards and emergency response units;
- Shipping industry associations responsible for policy development;
- Ship owners and chartering companies;
- Insurance companies.

Modelling Methodology

The modelling methodology is summarised in the model block diagram shown in Figure 3. MARCS models a number of different types of marine accident, see Box 2. Fault and event tree models, and/ or historical accident statistics, are used to deduce accident frequency and accident consequence parameters for each accident type. These are combined with data on shipping lanes and environmental data (e.g. wind, sea state, coastal location and visibility) to produce geographical distributions of accident and spill risks. The frequency and consequence of all accidents is determined for each calculation location within a study area. The size and resolution of the study area may be varied to look at a large area, or to "zoom" in on a small area for detailed analysis.

Figure 3: Block Diagram to Illustrate the MARCS Model



Marine traffic data is typically stored in 4 to 8 (or more) separate databases for different types of ships in the study area (e.g. oil tankers versus ferries). The movement of ships is modelled assuming a Gaussian distribution of ships across lanes, and a speed distribution along lanes based on observed speeds of different vessel types. These distributions may be changed to suit the needs of a specific study as required.

Box 2 - Accidental Events Modelled

Examination of world wide historical data on shipping accidents identified the following accidents as the major causes of oil spills from tankers:

- *Inter-ship collisions;*
- *Ship grounding, whilst under power or whilst drifting;*
- *Collisions between ships and offshore platforms or offshore wind turbines, whilst under power or drifting;*
- *Fire and/or explosions whilst under way;*
- *Structural failure and/or foundering;*
- *Cargo transfer operations in open water.*

All of these accident types are included within MARCS.

An inherent advantage of the MARCS modelling approach is that data elements are reduced to two basic types: data characteristic of shipping lanes and data characteristic of geographical locations. Shipping lane data for each lane currently includes:

- Location of lanes, lane widths and lateral distribution functions;
- Annual traffic frequency;
- Design factors, such as percentage of tankers with double hulls;
- Size distribution of vessels.

Location specific data included in MARCS are:

- Physical features such as coastlines and oil platforms;
- Meteorological data such as sea state, visibility and wind roses;
- Operational data such as locations of vessel traffic control zones;
- Information on tug availability and performance (bollard pull, speed, response and connection time).

Whilst the current version of MARCS models all the above factors, it has the potential to incorporate other data elements, such as type of cargo carried, ocean current data or any other factors considered to be significant to a particular application.

Company Information

Det Norske Veritas is one of the world's leading ship classification societies. DNV is also a leading provider of engineering, safety, reliability and environmental services to the shipping, offshore and onshore industries. DNV has worked for many government and industry organisations on marine and environmental risk studies around the world, including the UK, USA, Southeast Asia, Norway and The Netherlands.

Further information on the application of MARCS to specific areas, or on other marine risk issues, can be provided by contacting:
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