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# Evaluation of Collision Probabilities for Offshore Structures

## Evaluation des probabilitiés de collision pour les constructions offshore

## Beurteilung der Wahrscheinlichkeit von Kollisionen bei Offshore-Bauten

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Michael Barratt was born in 1934, and gained M.Sc. and B.Sc. (eng.) degree from the University of Southampton. He worked for several years on the development of Hovercraft before joining the National Maritime Institute. His recent work has been concerned with marine traffic collision risks, and ship manoeuvring simulation.

**SUMMARY**
Offshore structures, such as oil production platforms, are vulnerable to collisions with a variety of vessels, but the most serious consequences are to be expected from passing ships, unconnected with the operation of the structure. This paper introduces some of the methods which have been used to estimate the risk of collisions, and considers the limitations inherent in such estimates.

**RÉSUMÉ**
Les constructions offshore, comme les plates-formes d'exploitation pétrolière, courent le risque de collision avec toutes sortes de vaisseaux mais l'on peut s'attendre à ce que ce soit les navires de passage, qui n'ont rien à voir avec l'exploitation de la construction, qui entraînent les conséquences les plus graves. L'article présente certaines méthodes adoptées pour évaluer le risque de collision et considère les limitations inhérentes à de telles estimations.

**ZUSAMMENFASSUNG**
Offshore-Bauten, wie z.B. Oelproduktionsplattformen, sind der Gefahr von Kollisionen mit den verschiedensten Schiffen ausgesetzt, wobei die schwersten Folgen durch Zusammenstöße mit vorbeifahrenden Schiffen, die mit dem Betrieb der Konstruktion nichts zu tun haben, zu erwarten sind. In diesem Referat werden einige der Methoden, die zum Zwecke einer Einschätzung des Kollisionsrisikos herangezogen worden sind, aufgeführt und die Grenzen besprochen, die einer derartigen Einschätzung naturgemäß gesetzt sind.

## 1. INTRODUCTION

Offshore structures, mainly in the form of oil and gas drilling rigs and production platforms, have become increasingly common in Northern European waters in recent years, and efforts have been made to estimate the likelihood of ships colliding with them. This paper introduces some of the methods which have been used for collision risk estimation, and assesses their value and limitations.

It is necessary to consider separate categories of collision, for vessels visiting the structures or in attendance, and the original traffic in the area, particularly passing vessels. Of these risks, the latter is potentially more important because of the larger sizes of vessel which could be involved.

It is possible to compare the risk for a proposed structure with the risks for existing structures, taking into account traffic densities and environmental factors such as visibility. However, estimates of the absolute likelihood of collision by passing vessels at present depend upon analogies with other marine collisions, and some methods which have been used are discussed.

Simulation methods are considered to be particularly applicable to specific cases involving visiting vessels, but require further information to provide more reliable probablistic inputs for general use.

The sources of data and the methods mentioned are not claimed to be exhaustive, but rather to provide an introduction to the possibilities and limitations of collision probability evaluation for offshore structures.

## 2. TYPES OF INSTALLATION

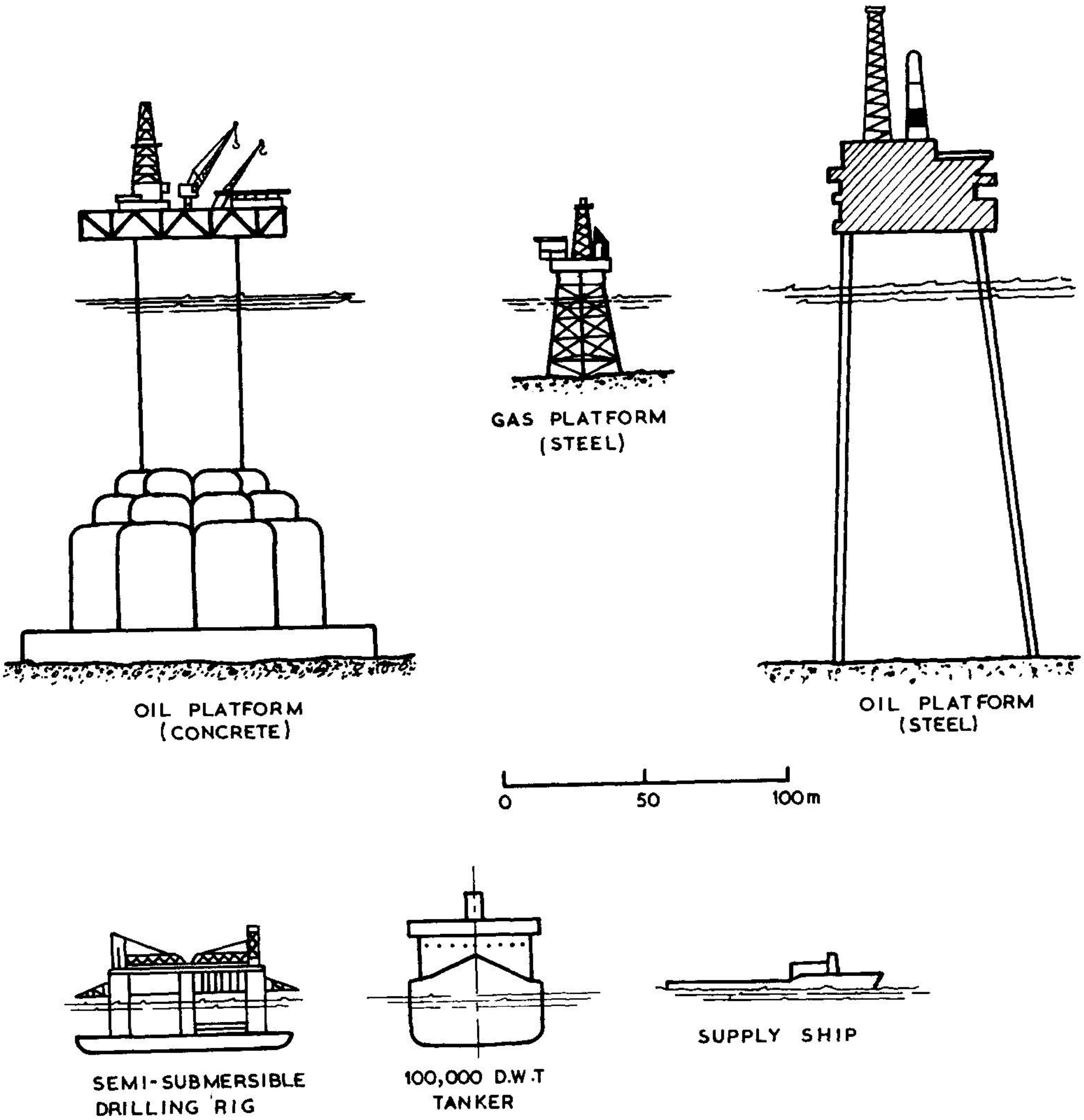
The commonest type of offshore structure for which risk estimates are required is the oil or gas rig or production platform. These can cover a wide range of types and sizes. Rigs for performing exploratory drilling are moveable from place to place, and in sufficiently shallow waters take the form of jack-up structures, supported by legs on the sea bed. In deeper waters semi-submersibles are used, moored to the sea-bed. In the deepest waters drill ships are used, with dynamic positioning devices to maintain station above the drill.

Fixed production platforms may well remain in position for many years and therefore become permanent features posing a possible collision risk over an extended period of time. They consist of two types, steel structures attached to the sea-bed by means of piles, and reinforced concrete structures which remain in place because of their weight.

A range of types of offshore structures and attendant vessels is shown in fig.1.

## 3. VESSELS INVOLVED IN COLLISIONS

Different types of shipping can be involved in collisions with offshore structures, and a basic breakdown of these is shown in the table of collision risk categories. A fundamental distinction must be drawn between collisions involving the original traffic present in the area and that associated with the structure. This division is not




TYPICAL STRUCTURES AND ATTENDANT VESSELS

FIG. 1

straightforward to make, as will shortly be shown, but is necessary because of the different importance attached to risks external and internal to the operation.

This paper will deal mainly with collisions with the original passing traffic, as estimates of this risk are needed when considering operations in a particular area. The other categories are likely to depend strongly on operational procedures.

COLLISION RISK CATEGORIES

| ORIGINAL TRAFFIC | | ASSOCIATED VESSELS | |
|---|---|---|---|
| ON PASSAGE | FISHING etc | VISITING | STANDING OFF |

## 3.1 Original Traffic

The original traffic in the area is the shipping measured or to be expected in the absence of the structure. It consists of vessels undertaking voyages between ports, generally on pre-determined routes, and others such as fishing vessels, whose pattern of movement will depend upon day-to-day considerations. Military and pleasure vessels may also be included in this category.

### 3.1.1 On Passage

The vessels on routes between ports are of major importance because they are likely to be the larger vessels in the original traffic, and therefore could inflict the greatest damage on any structure with which they collided. Fortunately, their routes follow regular patterns, and the traffic density due to this source can be estimated.

### 3.1.2 Fishing etc

A large proportion of the vessels approaching within the safety zones of production platforms consists of trawlers and other fishing vessels, and these are therefore a potential source of accidents , although they are comparatively small in size. There are two difficulties in analysing this class of traffic, firstly that the original pattern can often not be described in statistical terms, and secondly that the pattern may be greatly modified by the presence of the structures.

The numbers and distribution of fish in many areas vary not only in a cyclical way from season to season, but also in ways that are largely unpredictable from year to year. Also there is reason to believe that fish are attracted to structures, thus making the adjacent sea a potentially profitable fishing ground.

The activities of military and pleasure craft are also essentially unpredictable.

## 3.2 Associated Vessels

The vessels associated with the structures can conveniently be divided into those which need to approach close to the structure, for supply or other purposes, and those which will normally stand off, e.g. in the role of safety vessel or a tanker loading oil from a buoy at a distance from a production platform. With the exception of the tanker, such vessels are comparatively small and unlikely to cause disastrous damage.

#### 3.2.1 Visiting

Supply vessels are required to unload a wide variety of stores and equipment, sometimes in severe weather conditions. It is occasionally necessary to lift large loads by crane from a vessel experiencing considerable motions. Minor collisions are an inevitable hazard.

#### 3.2.2 Standing off

These include the safety vessel which will normally be in attendance to an oil production platform, and in some cases tankers loading oil from a buoy or other mooring. In this case we have to consider the possibility of mechanical failure, followed by the vessel drifting on to the platform. The consequences of such a collision by a tanker could be severe, but the attendant safety vessel would be available to give towing aid.

## 4. DATA SOURCES

Before considering methods of risk estimation in detail, the sources of data which are available or could be obtained need to be known. It must be emphasised that certain types of information involving human behaviour are either unreliable or simply not available.

As a general point, all the data sources are necessarily historical in nature, and predictions of future risks must take this into account.

### 4.1 Collisions

Apart from collisions with fixed structures, data on other collisions can be valuable in supporting risk estimates on the basis of analogies between the different types of collision.

#### 4.1.1 Fixed Installations

Data on collisions are collected by oil companies and by national governmental departments. Clearly information on actual occurrences is of vital importance, but it is limited in extent (ref.1). In particular, collisions by passing vessels in the North Sea are sufficiently rare to prevent any sort of statistical analysis. However, information on incidents involving support vessels does provide valuable operational guidance for operators.

#### 4.1.2 Light Vessels

Because of the shortage of data from structures, collisions with fixed light vessels have been considered as a possible guide. Although the number of collisions of this type is still not large, information supplied by Trinity House and other authorities gives useful guidance on collision rates with fixed vessels.

#### 4.1.3 Other Vessels

As a final source, collisions between moving vessels have been used, although this may be straining the analogy rather far. Nevertheless, such information is available in sufficiently large quantities for a correlation to be possible between the traffic density and the number of collisions (ref.2)

### 4.2 Infringements

Production platforms are surrounded by a designated safety zone of 500m. radius, which is out of bounds for vessels not having business there. Details of contraventions of these zones go to national authorities, and such information is a guide to possible 'near misses' (ref.1). However, over a period of 5 years in the British sector of the North Sea, three quarters of these contraventions have been by fishing vessels, presumably drawn by concentrations of fish, rather than by ships simply passing through the area.

### 4.3 Traffic

The traffic density and pattern in the areas under investigation is a major factor influencing the collision risk. Depending upon the area, information may be available or obtainable by a variety of methods which will now be considered.

#### 4.3.1 Surveys

In a few cases, particularly for busy traffic regions, marine traffic surveys have been performed, using extensive resources and including individual identification of vessels, (eg ref.3). For most areas of interest however, such information will not be available, nor would the cost be easy to justify. Existing surveys have been valuable in checking and calibrating the alternative, less comprehensive methods of obtaining traffic data (ref.2).

#### 4.3.2 Aerial Observations

Aerial surveys are a quick way of obtaining the shipping distribution over a large region, (ref.3), although many flights are needed to establish the shipping density distribution accurately. Further information may be necessary to obtain speeds and courses, and the sizes and types of vessels.

#### 4.3.3 Voyage Details

Details of vessels entering and leaving ports are obtainable from Lloyd's List and harbour authorities. Provided that the vessels can be assumed to take a direct course between ports, and all possible combinations of ports have been considered, this is an economical way of building up the regular traffic pattern. Further assumptions are, however, needed on such details as the spreading of courses within a particular route.

#### 4.3.4 Voluntary Observer Ships

Some 10% of the world's merchant ships send back weather observations to meteorological organisations. The geographical distribution of such reports is thus a guide to the general distribution of ships. Subject to an under representation of small vessels, these ships appear to be a reasonably representative sample of the world fleet, but caution is needed, as reports are not necessarily sent back at uniform intervals. However, traffic distributions can be obtained over wide areas, and with suitable calibration form a valuable alternative source of data (ref.2).

#### 4.3.5 Fishing Vessels

As was mentioned earlier, fishing vessel distributions in many areas are unpredictable from year to year, and appear to be influenced by the presence of fixed structures. However, national authorities do record activity within different regions, and a qualitative impression may be gained of the regions which have had most fishing vessels in recent years.

### 4.4 Environment

The importance of the different environmental factors depends upon the type of collision which is being considered. For collisions involving passing vessels, failure to sight or identify a structure sufficiently early could be a contributory factor, and therefore the visibility is of major importance. For visiting vessels close in attendance to a structure, the sea state will be the main consideration. Strong tides could affect the time available after mechanical failure, or possibly lead to misjudgement of closest points of approach.

#### 4.4.1 Visibility

The variation of visibility has been shown to be important in collisions between ships (ref.4), and the same may be inferred to be true for ships and fixed structures. Observations of visibility are widely available through meteorological organisations, and the distribution of reduced visibility may be found over extended areas.

#### 4.4.2 Sea State

Sea state observations at sea have been published, eg (ref.5), for large parts of the earth's surface. Larger numbers of observations are of course available for the regions with most traffic, where collisions would be the greatest hazard. Tidal streams are available on charts for navigational purposes.

### 4.5 Failure Rates

Estimation of failure rates of various types is implicit in risk estimates based on analysing the possible causes of collisions. It is in this area that the available data is weakest.

#### 4.5.1 Mechanical

Information on mechanical breakdowns is available for instance from Lloyd's intelligence, and will give considerable statistical help. However, close examination shows that most such breakdowns occur at convenient anchorages, indicating the ability to continue far enough to reach relative safety, or avoid a fixed structure.

#### 4.5.2 Human

The frequency of human errors is the most difficult of all to estimate. Not only will such errors be complex functions of many variables, but reliable information on them is extremely hard to obtain.

Examination of individual ship collisions has shown that it is often possible to determine the situation preceding the collision (ref.6), but admissions of errors are unlikely to be available.

## 5. RISK ESTIMATION

From the general consideration of types of collision, it will be seen that collisions involving passing traffic merit the greatest attention, both because of the greater damage to be expected, and because they are accidents involving vessels unconnected with the business of the structure. However,it will also have been noted that not many data are available on such collisions because of their infrequency, and that contributary failure rates are difficult to estimate reliably.

In considering possible methods we shall therefore pass from the comparatively crude but reasonably reliable, to methods seeking more detailed answers but requiring more assumptions about the causes of collisions.

### 5.1 Relative Risks

Probably the most reliable estimate possible at present is the overall comparative risk of collision for positioning a structure at alternative locations. This can be based on the traffic density and the visibility at the positions compared.

The basic assumption is that the overall collision rate is proportional to the flow density - the number of vessels passing within unit distance in unit time. This is linked with the concept of encounter radius originally developed for air traffic control theory (ref.7) and now used in ship-ship collisions, where the number of collisions is assumed proportional to the number of 'encounters'. In the absence of avoidance action, the assumption may be considered self-evident, and for practical purposes it should only break down when the density of shipping is such that one vessel might impede another.

The influence of visibility can be based on analysis of the variation of collision rates with visibility for collisions between ships. (ref.8) A 'fog collision risk index' (FCRI) has been proposed which links the collision rate to the amounts of the thickest fog. Some caution should be exercised in applying it outside the Northern European Waters for which it was derived, and also in using it for fixed structures rather than ship-ship collisions.

We then have

Collision rate = k x traffic flow rate x FCRI

and a direct comparison may be made with some chosen location.

### 5.2 Analogies

The use of the above method to obtain estimates of the collision frequency in absolute terms is hampered by lack of information capable of giving the size of the constant k in the above equation. As mentioned earlier, collisions by passing ships with fixed structures are too rare to allow a reasonable estimate, and so more or less distant analogies have been used.

5.2 1 Light Vessel Analogy

The light vessels stationed around the coasts of Britain and in some other European waters have suffered enough recorded collisions to allow estimates of collision rates. Also, they are situated in regions where the traffic flow can readily be estimated. In many cases they also act as weather reporting stations, and so allowances can easily be made for the visibility. Against these advantages must be set their dissimilarity in size with at least the larger fixed structures.

The effect of size is not clear when considering such analogies. On the one hand, the larger targets can be detected at a greater distance; on the other, larger course deviations are necessary to avoid them. Some idea of the balance of these effects as size becomes smaller is given by the fact that large 'high focal plane' bouys suffer much larger numbers of collisions than would be expected on the basis of the nearby traffic. It is probable that all large fixed objects attract some traffic for navigational purposes, whether that is one of their purposes or not.

Bearing in mind all such limitations, the light-vessel analogy has allowed estimates of collision risk which have the major virtue of requiring comparatively few basic assumptions.

5.2.2 Ship-ship collisions

Ship-ship collisions are, of course, unlike collisions with fixed structures in that some at least must be ascribed to misunderstanding each others' intentions. However, it is interesting to compare the results of this analogy with the previous one. Taking the effect of a fixed structure as equivalent to an extra vessel within an area, we can calculate the incremental effect of this extra 'vessel' on the number of collisions.

It is generally assumed that the number of collisions between vessels is proportional to the number of encounters between vessels, that is the number of times the vessels approach within some arbitrary distance of one another. But the number of encounters is proportional to the square of the shipping density (eg ref.7).

Hence the collision rate

$c = k'n^2$ where n = number of vessels in given area
and $dc/dn = 2k'n = 2c/n$

That is, the number of collisions per extra vessel or structure is twice the mean number of collisions per vessel.

Given the traffic density in the area, and the collision rate for that traffic density, the expected collision rate for the extra obstruction can then be calculated. It is interesting to find (ref.2) that the result of this calculation can compare closely with that of the light vessel analogy.

5.2.3 Safety zone infringements

Although outright collisions with structures are very rare, there are more frequent infringements of the 500m. radius safety zones which surround oil production platforms. The assumption can reasonably be made that these events for passing traffic correspond to gross failures of navigation, and hence position within safety zones approaches a random distribution. Therefore, collisions = infringements x(structure+ship) size / safety zone size

Since most infringements are by fishing vessels which are presumably within the zone deliberately, it is not surprising that this method has initially led to considerably higher estimates of collision frequency than those previously mentioned. However, if allowance is made for the proportion of infringements which are not fishing vessels, the agreement is remarkably close.

## 5.3 Simulation

Simulation techniques can provide estimates of the frequency of collision, but at the moment this is not their greatest strength because of the lack of suitable probabilistic data, particularly on the actions taken by mariners. At present they may be more valuable in giving insights into the nature of particular types of incident. It may also be possible to devise and practice procedures for use in the event of mechanical breakdowns.

Three stages of simulations appropriate in the collision context may be identified - first the determination of a traffic pattern or route structure, then the allocation of probabilities of actions or failures, and finally the calculation of the outcomes of each event.

### 5.3.1 Traffic Pattern

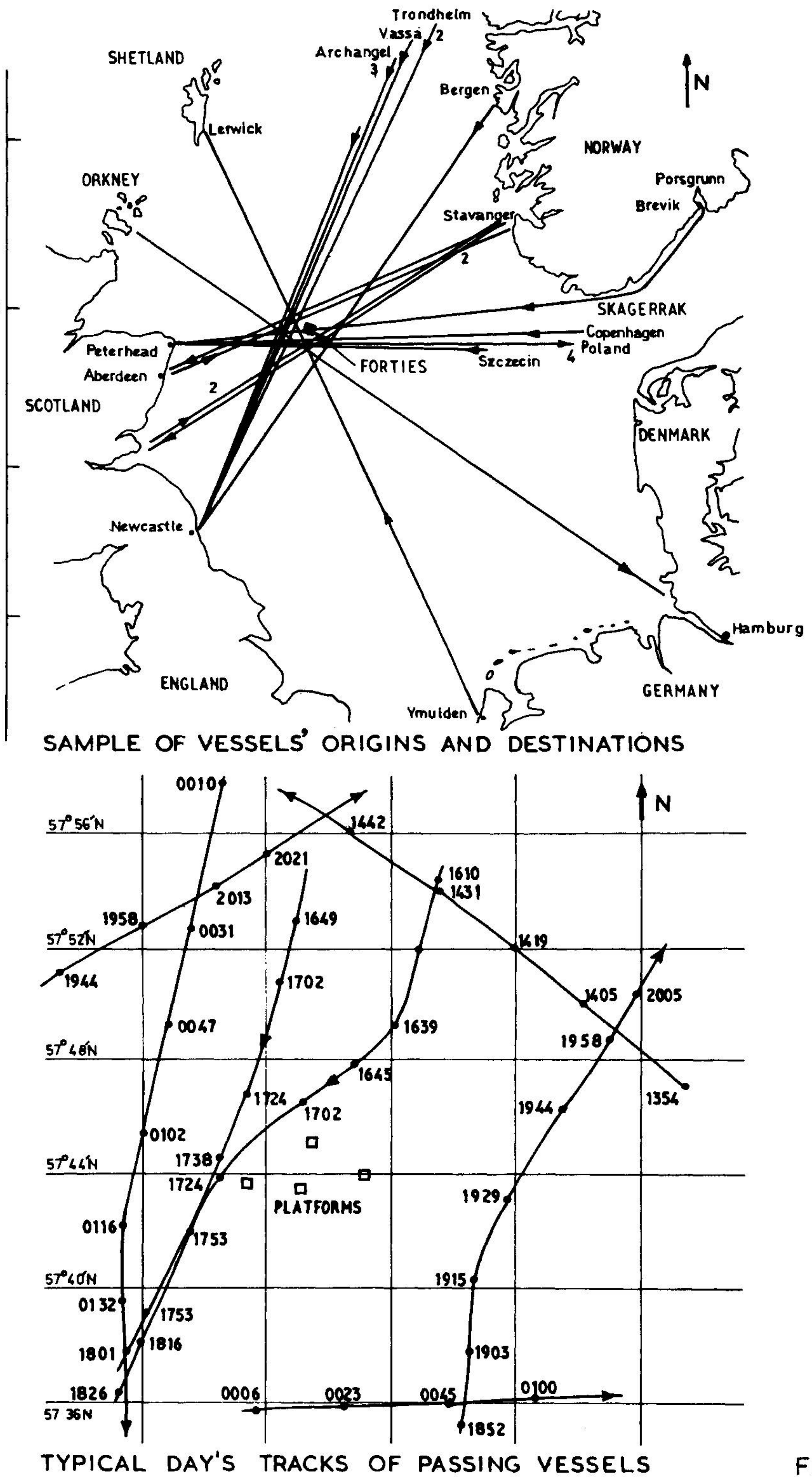
The traffic pattern can be built up in a number of ways, but it must be capable of generating sample ships' tracks. This is normally done on the basis of entry and exit points to the region under investigation, together with a spread of tracks about each route.

Thus fig.2 from ref.9 shows routes across the North Sea which pass near the Forties field, and a sample of actual tracks near the field. A more complex representation was made in ref.10 for the English Channel, taking into account the observed spreading of ships' tracks and the constraints of existing and postulated routeing schemes. Alternatively, when considering vessels with business in the region of a structure, a point on the track may be well defined, as for instance a tanker approaching a buoy.

### 5.3.2 Actions and Failures

At some stage during the simulation, it will be necessary to generate events such as a mechanical failure which could lead to collision risk, and/or some human error or omission which could affect the outcome. For instance, for tracks passing near a structure, a mechanical failure could leave a ship out of control and liable to drift on to the structure. The probability of mechanical failure can be estimated, but it must be born in mind that recorded mechanical failures do not appear to occur as random events, as mentioned earlier. However, in the main, we are dealing with quantifiable probabilities, and sensitivity analysis is available to check the importance of the assumptions.

The probability of various types of human error is much more difficult to estimate. We have to consider the chances of mariners taking actions such as approaching a structure for navigational purposes, taking avoidance action at various stages, and making random errors in their judgements. More fundamentally difficult is to estimate the likelihood of the inexplicable events, when a vessel fails to take any avoidance action at all, apparently having failed to detect a large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FORTIES
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4
2
SCOTLAND
DENMARK
56° N
Newcastle
54° N
Hamburg
ENGLAND
GERMANY
Ymuiden
SAMPLE OF VESSELS' ORIGINS AND DESTINATIONS
57° 56'N
57° 52'N
57° 48'N
57° 44'N
57° 40'N
57 36N
PLATFORMS
TYPICAL DAY'S TRACKS OF PASSING VESSELS

FIG. 2

structure. Since the events whose probability we are trying to evaluate are in any case rare, it is possible that an appreciable proportion of them defy close analysis.

5.3.3 Outcomes

The outcomes will normally be found by a Monte-Carlo approach, with the algorithm guiding each vessel through a set of decision points, subject to random responses. The model may include the dynamic response of the vessel to its controls, or to the action of wind and waves (ref.11). At the end of a large number of runs, a proportion of vessels will have experienced collisions, or a range of miss distances will have been generated. The most reliable results are likely to be obtained for closely defined situations, such as vessels approaching a loading buoy (ref.12).

5.4 Damage

The calculation of structural damage is beyond the scope of this paper, but some pertinent facts do emerge from consideration of the available data and the possible categories of collisions.

Vessel sizes and types are likely to be known fairly accurately through port arrivals and departures and such publications as Lloyd's register.

Impact velocities will fall into two categories; ships on passage which are likely to be travelling at approximately their service speed, and drifting vessels which will have attained the velocity dictated by the wind and waves.

Therefore, the severity of typical collisions should be largely determinate, as far as the larger vessels are concerned. Lesser impacts by supply vessels are of course a different question.

## 6. DISCUSSION

A number of ways of calculating collision probabilities for offshore structures have been considered. They have largely concentrated on passing vessels, because of the more serious consequences of this type of collision.

The relative risks of different geographical locations can be estimated with reasonable confidence. Methods based on analogies with other types of incident have been described, which give remarkably consistent values for overall collision rates. However, the absolute values obtained from them should still be treated with caution.

Simulation methods, based on the analysis of possible types of event leading to collision risks, are probably not at their best for collisions by passing vessels because the events which lead to these collisions are not well understood. Their best applications may well be to particular operational risks in the region of structures.

In general, approximate estimates of collision risks can be made which allow the evaluation of new geographical locations for offshore operations. More refined methods will allow the examination of operational and emergency procedures. This introduction to some of the possible approaches is intended to stimulate discussion and the exposition of improved methods.

7.ACKNOWLEDGEMENTS

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