The final two papers discussed the use of cellular telephones for automatic vehicle tracking. I have already remarked that the availability of suitable communications links is one of the significant issues highlighted in our discussion, and cellular telephone systems may well be one answer to this problem in areas where cover is adequate. What conclusions can we draw from this conference – apart from the very real interest in AVL which has been so apparent? There are a few which seem worth mentioning.

(i) The market for AVL exists even if it has not been adequately defined. It could be both large and diverse.

(ii) The basic technology exists but a great deal of refinement may yet be necessary.

(iii) More than one solution may be appropriate depending upon whether the target is navigation or location, urban or rural and so forth.

(iv) Adequate communication links may yet, particularly in Europe perhaps, be one of the most difficult problems to resolve.

(v) Most importantly, the next decade will see widespread development and adoption of AVL systems.

'Collision Rate as a Danger Criterion for Marine Traffic'

from A. N. Cockcroft

Dr Kwik suggests (p. 203) that there are basically two ways to assess the probability of ship collision; either to estimate it directly from collision statistics or to calculate it with the aid of mathematical models of the traffic. The shortcomings of the statistical approach and the advantages of mathematical modelling are set out at length in his paper, and he concludes that the analysis of past accidents should be superseded by prospective and preventative investigation of possible accidents.

Mathematical modelling is becoming increasingly important to marine traffic safety assessment and is well established in other fields. However, it does not follow that statistical analysis is being superseded or becoming less important. Mathematical modelling must be based on the results of the relevant statistics. It would surely be preferable to consider the two approaches as complementary, rather than as distinct alternatives, one of which should be discarded.

There are also various shortcomings associated with the mathematical approach. As Dr Kwik has admitted, the human factor has always been of great importance but cannot easily be taken into account in mathematical equations. Mathematical models used to assess the probability of ship collisions are likely to be based mainly, if not entirely, on parameters which may be easily quantified including traffic density, visibility and relative velocity, as indicated in Dr Kwik's equations.

The following example, based on an analysis of sea collisions, serves to illustrate the considerable influence of human factors on the probability of ship collisions. In the Dover Strait, traffic surveys have indicated that about 300 ships pass though each day and that crossing traffic can amount to over 200 ships per day, but despite the very high frequency of broad-angle crossing encounters only two collisions between vessels crossing at a broad angle have been recorded in the last 24 years. Most of the collisions arising from broad crossing encounters have occurred in areas of low traffic density and can be attributed to poor visual and/or radar lookout. In areas of high traffic density the master is likely to be on the bridge and a higher standard of lookout is usually maintained.

As an example of the use of mathematical modelling Dr Kwik has calculated the collision rate for ships sailing south-west in the English Channel, between the traffic separation schemes at Casquets and Ushant, before and after the changes to the schemes made, in January 1979, after the stranding of the *Amoco Cadiz*. His conclusions are that the collision rate has increased considerably due to crossing encounters and that the changes have reduced the danger of stranding at the expense of a greater danger of collision.

The *Amoco Cadiz* was proceeding towards Lyme Bay, on the south coast of England, when she passed through the inner traffic lane of the Ushant TSS before stranding off the Brittany coast. There is little doubt that some masters were under the impression that they were expected to use the traffic separation schemes at the western entrance to the Channel, although there was no requirement for them to do so. The original TSS off Ushant was almost certainly reducing the danger of collision at the expense of a greater danger of stranding.

In view of the catastrophic effects of the accident the Maritime Safety Committee of IMO responded to a request by the French Government to take urgent action to prevent a recurrence. It was not possible to move the TSS further offshore because of the requirement that ships should be able to fix their position anywhere within the limits of a scheme. A decision was therefore taken to prohibit use of the inner lane by laden tankers and other vessels carrying hazardous cargoes. A third lane was established in the outer part of the scheme for use by north-eastbound ships fitted with an electronic position-fixing appliance appropriate to the area, intended mainly for use by vessels excluded from the inner lane.

The arrangements made at the time were not considered by the Maritime Safety Committee to be entirely satisfactory but to be the best interim solution. The Governments of the United Kingdom and France undertook the task of producing a comprehensive routing scheme for the entire Channel. The revised arrangements have since been approved by IMO, but changes to the Ushant TSS will not be implemented until a major navigational aid has been installed in the south-western approaches to the island.

There has been much criticism of the changes made by the Maritime Safety Committee to the TSS in the western Channel, particularly because of the resulting increase in crossing encounters. Such criticism does not usually take full account of the type and frequency of collisions in the area and of all the alterations made. A survey of collisions in the area between Casquets and Ushant revealed that, even after the establishment of the TSS in 1968, almost all collisions between the TSS involved vessels proceeding in opposite directions, and the incidence of broad crossing collisions was negligible. Changes were therefore made in order to reduce the frequency of meeting collisions.

A recommended direction of traffic flow was established, extending in a direction 051° true from the outer lane of the Ushant TSS, to discourage vessels using that lane from attempting to cross the south-westbound traffic stream at a fine angle. This is a recommended direction of flow, not an obligatory track. It was not intended that there should be a specific crossing point, but that masters should use radar to watch for a clear gap in the traffic bound for the Ushant TSS before crossing at a broad angle to join the traffic stream heading towards the Casquets TSS.

In order to reduce the frequency of meeting encounters in the approaches to the TSS the width of the separation zones and the lane widths were increased for each scheme. Off Ushant the width of the separation zone was increased from 2 miles to 8 miles and

https://doi.org/10.1017/S0373463300000187 Published online by Cambridge University Press

the total width between the outer edges of the two inner lanes was increased from 10 miles to 24 miles. Off Casquets the total width between the outer edges of the traffic lanes was increased from 8 miles to 15 miles.

The changes made in January 1979 have almost certainly caused an increase in the frequency of broad crossing encounters, but are likely to have reduced the frequency of the much more dangerous meeting and fine crossing encounters in the area between the two separation schemes. A clear indication of the effect of the changes may be obtained from the collisions recorded in *Lloyd's Weekly Casualty Reports*. As Dr Kwik has pointed out, collisions involving only minor damage may not be reported, but collisions between vessels over 100 tons proceeding on passage in the open sea are unlikely to involve negligible damage, so reliable statistics can be obtained for areas such as the English Channel.

The TSS off Ushant and Casquets were established in 1968. In the 11-year period 1968–1978 fourteen collisions were reported between vessels proceeding in opposite directions, and one between vessels going in the same direction in the area between the TSS. No collisions were reported between vessels likely to have been crossing at a broad angle.

During the 6-year period 1979–1984 only five collisions between vessels of over 100 tons proceeding on passage were reported in the same area. Three of these were between vessels proceeding in opposite directions and two were between vessels going in the same direction. So far there has apparently been no report of a collision involving a tanker proceeding from the outer lane of the Ushant TSS towards Casquets and a vessel proceeding from the Casquets TSS towards Ushant.

It is not claimed that the above results provide conclusive proof that there has been a reduction of the danger of collision in the sea area west of Casquets, but the measures to reduce the incidence of meeting or fine crossing collisions appear to be proving effective, and the consequences of increasing the number of crossing encounters have not been as disastrous as sometimes predicted.

Dr Kwik replies

The paper deals with the prediction of rare events. Because ship collisions are relatively rare events, collision statistics (perhaps I should say historical collision data) are less suited as a basis for the calculations. Instead, the use of mathematical simulation derived from the principles of systems engineering has been appealed to.

In fact, there is no advantage in the historical data method over simulation for our purpose. The knowledge that a number of collisions, say 14, has occurred within a given period, say 20 years, is of little value. Those 14 collisions could in fact have been bunched together within a few years only, whilst a sequence of years failed to yield a single casualty. It is also very unlikely that we would include 7 collisions within an arbitrary 10-year period. In other words, the mean value depends not only on the chosen duration of the time interval, but also on its position on the time axis. This is a serious difficulty known to statisticians when dealing with rare events.

Let us assume casualty records show that there have been 9 collisions in the 10-year period beginning 20 years ago and 5 collisions in the following 10-year period. We would not be in a position to specify why this is so because the change might be attributable to many reasons in the course of time; nor would we be able to say what the collision