programme is under way to throw more light on contentious issues. IMO has no funding for research directly, but it encourages member states to carry it out.

The Attained Subdivision Index, *A*

There are many factors that will affect the final consequences of hull damage to a ship, including the actions of the crew. These factors are random and their influence differs from ship to ship. The mass and velocity of the ramming ship is such a random variable. Other factors include:

- which particular space or group of adjacent spaces is flooded;
- the draught, trim and intact stability at the time;
- the permeability of flooded spaces which may vary during a voyage;
- the sea state at the time and for a time after the accident;
- possible heeling moments acting;
- the effect of hull strength on penetration in the case of ramming or grounding, and the consequent damage to that structure.

Although damage is random, the probability of flooding a given space can be determined if the probability of occurrence of certain damages is known from experience, i.e. damage statistics. Such statistics are not as extensive as desirable to give good probabilities of some factors and those available must be analysed to reflect ship type and size. Older statistics would not be relevant to modern ships because of design changes over the years.

The probability of flooding a space is given by the probability of occurrence of all damages which open that particular space to the sea. Because of the mathematical complexity and insufficiency of data, it is not practicable to make an exact or direct assessment of their effect on the probability that a particular ship will survive a random damage if it occurs. However, with some qualitative judgements, a logical treatment may be achieved using the probability approach as the basis for a comparative method for the assessment of ship safety. Using probability theory the probability of ship survival can be calculated as the sum of probabilities of its survival after flooding each single compartment, each group of two, three or more, adjacent compartments multiplied, respectively, by the probabilities of occurrence of such damages. This leads to an attained subdivision index, A, as a measure for the ship's ability to sustain collision damage.

The probability that a ship will remain afloat without sinking or capsizing as a result of an arbitrary collision in a given longitudinal position breaks down to the probability that:

- the longitudinal centre of damage occurs in just the region of the ship under consideration;
- this damage has a longitudinal extent that only includes spaces between the transverse watertight bulkheads found in this region;

- the damage has a vertical extent that will flood only the spaces below a given horizontal boundary, such as a watertight deck;
- the damage has a transverse penetration not greater than the distance to a given longitudinal boundary;
- the watertight integrity and the stability throughout the flooding sequence is sufficient to avoid capsizing or sinking.

By grouping these probabilities, calculations of the probability of survival, or attained index A, have been formulated to include the following probabilities:

- of flooding each single compartment and each possible group of two or more adjacent compartments;
- that the stability after flooding will be sufficient to prevent capsizing or dangerous heeling due to loss of stability or to heeling moments in the intermediate or final stages of flooding.

Producing the index requires the calculation of various damage scenarios defined by the extent of damage and the initial loading conditions of the ship before damage.

Three loading conditions are specified, with different draughts and trim. To produce the overall index the results for these three conditions are weighted as follows:

$A = 0.4A_s + 0.4A_p + 0.2A_l$, where subscripts s, p and l denote the three loading conditions, and:

A_s = the attained index at deep subdivision draught
A_p = the attained index at partial subdivision draught
A_l = the attained index at light service draught.

The index A for each loading condition is expressed by

$$A = \sum p_i[v_i s_i]$$

where

- p_i is the probability of a compartment, or group of compartments (forming zone 'i') being flooded, disregarding any horizontal subdivision, but taking transverse subdivision into account. p depends only on the geometry of the ship and its subdivision;
- s_i is the probability of survival after flooding zone 'i';
- v_i depends on the geometry of the horizontal watertight arrangement (decks) of the ship and the draught in the initial loading condition. It represents the probability that the spaces above the horizontal subdivision will not be flooded;
- the summation for A is carried out over the subdivision length of the ship – basically this is the length embracing the buoyant hull and the reserve of buoyancy.