Advancement in maritime technology and its impact on safety

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ADVANCEMENT IN MARITIME TECHNOLOGY AND ITS IMPACT ON SAFETY.

BY


TANZANIA.

A paper submitted to the Faculty of the World Maritime University in partial satisfaction of the requirements for the award of a

MASTER OF SCIENCE DEGREE IN MARITIME EDUCATION AND TRAINING (NAUTICAL).

The contents of this paper reflect my own personal views and are not necessarily endorsed by the University.

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IN MEMORY OF MWALIMU LUKA MOKIWA AND BARNABA LUKA MOKIWA.
ADVANCEMENT IN MARITIME TECHNOLOGY AND ITS IMPACT ON SAFETY.

BY

GILBERT LUCA MOKIWA.

High Speed Waterborne Transportation Services Worldwide
This paper is entitled "Advancement in Maritime Technology and its impact on safety".

In 1964 Diebold stated "THE EFFECTS OF THE TECHNICAL REVOLUTION WE ARE NOW LIVING THROUGH WILL BE DEEPER THAN ANY SOCIAL CHANGE WE HAVE EXPERIENCED BEFORE".

It is twenty three years now since Diebold gave the statement and he surely could not be more right if a close look is conducted on what is happening today.

This paper is written with the aim of bringing to the people's awareness, the current level of advanced maritime technology and its impact on safety.

The methodology used has been collection of data from books, international and national organizations and firms through correspondence, proceedings from seminars, lectures given in class, individuals, colleagues, etc. This data was then processed and compiled to form the paper.

The paper starts with an overview of the different transportation modes before going into the maritime industry.

The paper covers a wide range of the maritime industry but emphasis is given to what is happening at sea especially in the nautical field where the author spent thirteen years of his working life before embarking into teaching.
Effects of advanced maritime technology towards safety are covered throughout the paper and examples have been given where more emphasis was deemed necessary.

The paper is slightly technical but very much within the scope of understanding of many people connected with the shipping industry.

The paper winds up with the following recommendations:-

1. Shipping should be given due consideration in all countries.

2. Governments should continue delegating responsibilities to non-government institutions where it is in the interest of all parties.

3. Technology based training should be used where appropriate.

4. The implications of purchasing highly sophisticated second hand vessels should be considered before doing it.

5. Technology must be allowed to advance.

6. A deep desire to prevent accidents must be cultivated to all people involved with maritime affairs.
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ACKNOWLEDGEMENTS

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CHAPTER I

TRANSPORTATION MODES

Despite the advent of aircraft and the development of the land transport (rail and road) by far the greatest part of the world's trade is still carried by the oldest of the three transportation modes which is the sea. It is also a known fact that the sea is up to this time the cheapest and the most efficient means of transport. Furthermore increased use of the sea arising from the exploitation of oil and gas in the seabed, coupled with continued needs of the fisheries, imposes ever more stringent demands upon the mariner. Not only has the mariner's job been made harder by the introduction of larger, faster and more diverse ships, but also by their increase in number, sophistication of equipment due to increased technology and by obstacles to safe passage which now include man-made structures as well as shoal waters and rocks. Also one need not forget that commercial pressures for expeditious passage making do not diminish either. Having recognised the heavy task with which the mariner is entrusted, all the help that is available must be given to him, to make his duty a successful one.

A successful duty means one that has been carried safely from all aspects of the word. That is, safe to human life and health, ship and cargo, navigation and environment, and economical to the operators. This involves a big group of different parties and undoubtedly of different goals/interests so to satisfy such a group may be close to impossible.

1
The paper takes the view that many people assume that safety is universally desired and by implication that danger is something everyone wants to avoid. This assumption is superficially true and often demonstratably false. Look at many popular sports which are not far from committing suicide (boxing, car racing, etc). Do accidents and disasters not fascinate a good number of people which a good safety record badly lacks! Isn't the appeal of hazard, danger and sudden death instinctive and part of man's historical heritage. How many people die everyday from the powers of small men! To quote Nietzsche, "A heart full of cheerfulness and courage needs a little danger from time to time or the world gets unbearable". From Prince Charles, "There is enormous satisfaction in achieving something which is potentially hazardous and which requires concentration and self discipline". One then just wonders as to what man is actually up to. This leads to the suggestion that man reveals split personalities towards questions of safety (Dr Jekyll and Mr Hyde). The paper takes the view that many of us know that while we can completely banish some accidents, disasters and injuries, there would be other dangers. To quote Jung, "In view of the rapidly increasing avalanche of world population, man has already begun to seek ways and means of keeping the rising flood at bay. But nature may anticipate all our attempts by turning man against his own creative mind. The H-Bomb for instance would put an effective stop to over population. In spite of our proud domination of nature, we are still her victims for we have not yet learned to control our own nature. Slowly but it appears inevitably we are courting disaster".
Jung could not be more right when we look at the number of people dying from self inflicted diseases like drug abuse associated diseases, or when we look at what happens frequently from man's worst invention—the gun and the sophisticated improvements done on it both in quality and in damaging capability. Man will never fail to put a clause which will allow him or give him the excuse to show his negative side of safety. An example of this is the surety that man had even when drafting the United Nations Charter, that complete peace is impossible. To quote part of a paragraph from the preamble to the charter, "To ensure, by the acceptance of principles and the institution of methods, that armed force shall not be used, SAVE in the common interests". Man had to put the clause so that when he needs it for his own good, he can justify its application and may be, defend it latter.

A man needs to be reminded that while complete safety is impossible to achieve, room for improving the current level of safety still exists and that given serious thought, consideration and positive approach towards its improvement, a safer level is within reach. It is the aim of this paper to show the accidents that happen at sea every year, their causes, and to elaborate on some of the contribution of advanced maritime technology towards safety and to give some recommendations.

1.1 SHORT HISTORY OF MARITIME TRANSPORT.
Recorded history fails to put an exact date when maritime transport started but all in all it can be said with certainty that it was very long time before Christ. The Aborigines are known to have crossed the Torres Strait from New Guinea to Australia as early as 40,000 BC. (Guinness book of Records 1986).
The following reasons must be among the many which prompted man to go to sea or over the water.

1 - Creation of Islands:
Man found himself separated from the other land which meant that he had to cross the water when he wanted to land over the other land for reasons like hunting, search for food, search for better land and also fights or wars for control of land.

2 - Something to do on the water, for example going fishing and sometimes need arose when people had to go to fight against water-borne enemies like crocodiles.

3 - Carrying heavy objects by floating them on the water.

Functions 1 and 2 played their biggest role in the earliest period but they also have their history of development. Function 1 developed into being a source for immigration, sending troops and diplomatic parties, business trips, studying abroad, carrying mail and press papers. This was the time when we had no cars, no aircraft, no public radio, no television etc. Of late function one's importance has been declining steeply. No longer do we have long distance passenger transport, nor is urgent information carried by ship any more. Function one is mostly left to Ferries and Cruise ships for holiday makers.

Function 2 is the one which has taken a very interesting turn. Man has found a lot to do on the water. Leaving aside the military use, man has developed technology which helps him in harvesting the resources that are
either on water, within the water, on the seabed and under the seabed.

Floating docks and floating ports are things which man can now talk with ease. Erection of submersibles and laying of platforms for oil drilling are more examples of what is being done at sea. Another function of function 2 is the fishing industry where mankind is heavily dependent upon fish for protein and expected to be so for a long time to come.

Lastly but not least for function 2 is the increase in number of pleasure crafts. In 1978, state registered pleasure crafts in the USA numbered twelve million with approximately 20 million gross tons. At the same period, passenger boats and ferries in the whole world totalled about nine million gross tons. This pleasure yacht hobby is spreading worldwide and sometime in the near future yatching will have some impact on the maritime affairs.

Early awareness is very important for effective future plans.

As civilization developed, trade developed and merchants had to move to distant places in search for exchanging goods and for new markets. Discoveries of new goods were then made and need for exporting and importing goods back home increased. This increased the importance of reason 3 which resulted in the beginning of commercial shipping.

1.1 COMPETITIVENESS OF MARITIME TRANSPORTATION.

It is normally the case that when a new invention is brought into a system, for it to have maximum success then
the old systems that existed before it are either scrapped or improvement to them is suppressed. To a certain extent, this was so in shipping. The inventions of land transport and air transport have had negative growth effect to shipping in an area like passenger traffic but what can positively be said is that there is still no doubt as to the importance of water transport.

Water can support heavy loads.
The same is neither true for land transport nor is it true for air transport. The ship is also the most efficient carrier when you compare the tonnage she carries per given energy, with the other modes of transport.

The table below illustrates this.

CARGO CARRYING CAPACITY OF THE VARIOUS VEHICLES.

<table>
<thead>
<tr>
<th>Type</th>
<th>DWT</th>
<th>Vkt</th>
<th>HP</th>
<th>DWT * Vkt/HP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tanker</td>
<td>20000</td>
<td>13</td>
<td>18000</td>
<td>144</td>
</tr>
<tr>
<td>Bulker</td>
<td>60000</td>
<td>14</td>
<td>12000</td>
<td>70</td>
</tr>
<tr>
<td>General Cargo</td>
<td>20000</td>
<td>16</td>
<td>11000</td>
<td>29</td>
</tr>
<tr>
<td>Cargo boat</td>
<td>20000</td>
<td>20</td>
<td>22000</td>
<td>18</td>
</tr>
<tr>
<td>Cargo Train (Rail)</td>
<td></td>
<td></td>
<td></td>
<td>5 to 10</td>
</tr>
<tr>
<td>Diesel Truck</td>
<td></td>
<td></td>
<td></td>
<td>2 to 3</td>
</tr>
<tr>
<td>Cargo Jet</td>
<td></td>
<td></td>
<td></td>
<td>0.1 to 1</td>
</tr>
</tbody>
</table>

Where, DWT represents Deadweight in tons
Vkt is speed in knots (1 knot = 0.5144 metres/sec)
HP is Propelling Horse Power (1 HP = 0.734Kw)
ie Energy consumed per time.
DWT * Vkt/HP = Ton mile/HP * Navigation hours =Ton mile/Energy consumed.
1.2 AIR TRANSPORTATION MODE

Commercial air transport started in the 1930s. As a faster means of transport than the sea transport, important services which were urgent soon turned to the air transport mode. Mail which was only carried by sea now had the option of being air lifted. The same option was open to passengers. In 1937 Atlantic flights between Europe and North America were started. While it now takes about eight hours from Frankfurt to New York, it took twenty-nine hours to perform the same operation by then.

As already indicated, improvements in the air transport have been rather fast when compared to the maritime transport. In 1947 the International Civil Aviation Organization (ICAO) was formed. This is a UN specialized agency and its main objective is to make it safer and easier to fly from one country to another. This is done by updating and setting up of new safety measures to be applied by operators of airlines of its member states, setting up uniform regulations for the operation of air services and simpler customs, immigration and public health procedures at international airports.

1.3 LAND TRANSPORT

Land transportation is done by road transport vehicles and trains. It started by the turn of the 19th century. It complements the sea transport on land. With improvements on highway construction and railway construction, more cargo is lifted between inland points easier than it was done before. Railways and roads have penetrated the work areas and factory premises. It is the second cheap mode of transport after maritime transport. Its regul-
lations are mostly national to regional but not as international as the other two modes. The only transportation mode without an UN embracing body. Technological improvements in this field are soon going to enable us to travel in trains running at 400km/hour. These three transportation modes all offer services. After services have reached the customers, the next questions of interest to the customers are quality of the service, efficiency of the service, reliability, safety of the service etc.

The three transportation modes have all got their records of accidents which need improving by man through regulations, public awareness, training, enforcement of law and through improvement of existing standards and technology. The paper would like to give an indication of the fatal accident rates of some activities again for public awareness.

The fatal accident rate for the merchant navy is about $3.5 \times 10^{-15}$ per person/hour.

The fatal accident rate for flying is $6 \times 10^{-9}$ per person/hour or per person/600 miles. Taking 600 miles per hour as the average speed of the aeroplane.

The fatal accident rate of car driving is $1.2 \times 10^{-9}$ per person/hour which is approximately $12 \times 10^{-9}$ per 600 miles.

The fatal accident rate in the chemical industry is about $5.8 \times 10^{-16}$ per person/hour, the main reason for this seemingly low rate being the preventive measures that are taken in this industry.

8
This should improve when all the chemical plants are protected by hoods so that leakages will be confined to small areas.

The motorcycle fatal rate is about $30 \times 10^{-9}$ per person /hour. Motorcycling is the worst activity of the ones that have been considered but the trend for all the fatal accident rates over the years has shown a big improvement.

The fatal accidents rates above indicate the supremacy in safety level of the merchant shipping transport when compared to the other transportation modes.
CHAPTER II

TECHNOLOGICAL ADVANCES WITHIN SHIPPING.

2.1 SHIP TECHNOLOGY.

Improvements in the Structural Safety.

Structural safety depends upon the integrity of design principles, the validity of the calculations, the quality of the materials and the standard of their fabrication within the design concept and also on the degree of maintenance applied throughout the life of the structure.

2.1.1 SPECIFICATIONS AND DESIGNING.

A person wanting to build a new ship, will first have an outline of his specifications for the new ship. The fundamental requirements being: Type of ship, whether it is a bulk cargo, dry cargo, tanker, etc. Deadweight required, service speed, whether it will carry passengers or not. If it will carry passengers then the total number of passengers per class and accommodation requirement for crew and passengers will also have to be considered.

In addition to the above basic requirements the following specifications are also provided in most cases.

- Intended route and type of trade

- Limitations on ship dimensions; for example Length, Breadth, Depth and/or Draft.

- Ships class which enables the builder to know the
Classification society regulations to be followed

- The flag State applicable rules and regulations. (These would normally be in addition to the existing international requirements and the Classification Society's.)

- The kind of cargo that is going to be carried.

- Number of holds or tanks and capacities of each.

- Type of cargo handling gear if any.

- Special equipment/s for example the heavy lift gear

- Other requirements which have not been mentioned above.

From the above requirements, the design work commences, using the design principles. The designer, having obtained the preliminary dimensions of the ship, will now try to accurately estimate the amount of steel and outfit masses that will make up the lightmass of the ship. He will do his design optimisation which is intended to come out with the best ship which is within the requirements and also economical to run. He does this by varying the features of design such as length, breadth, draft, speed etc. The calculations involved in varying these features for optimal design are dimensionless and during the old time this was rarely done because they did not have the help of the computers to do these tedious lengthy calculations. Therefore the level of accuracy, thus safety was not as good as it is today.
Having come to what is considered as the designed ship, a scaled mathematical model of the ship is built. The ship model is then taken to the towing tank for tests. Experiments on static and dynamic behaviour of the prospective ship are carried out and the results recorded. Positive and negative responses will be indicated by the experiments, and the behaviour of the ship will also be known.

Corrective measures will be done to the spotted weak points until the vessel is structurally fit to perform the duties of her intended adventures.

The experimental findings are safely kept for future reference and consultancy. These records are not only of good use to the shipowner but also to the shipbuilder in future, in enabling him to produce a design at a competitive price.

An area which is still not satisfactorily explored is the structural optimization. The problem being to find a given strength of structure for the least mass or weight of material or for least cost. Substantial savings in the material and cost will result if a breakthrough will emerge from this research.

Advances in this section have moved us from older types of stems and sterns which were both unattractive and unscientific, to the modern ones we have today. The old knuckled counter stern saw itself changing to cruiser spoon, to cruiser spoon 2 and to full cruiser. The modern sterns are beautifully and gracefully rounded.

Yesterdays bow- the plumb bow- was straight, undistintive and unscientific. With its massive vertical bar, the result from collision was a long deep slash above and below the waterline of the unfortunate ship.
This plumb bow had another unscientific characteristic in that its entrance was not fine thus increasing water resistance and pitching tendencies.

The newer bows - the raked or raking bow, the spoon bow, and the Meier form type, are not only beautiful, but have also increased economy and safety to their functions. The stem bar has been replaced by a fabricated or plate bow which crumbles well above the waterline of the unfortunate struck vessel, thus giving the struck vessel the possibility or probability of not flooding. These designs have improved the sea keeping behaviour of the vessels. Reduced water resistance from finer forms together with better hull designs have resulted in the increase of the average speed of merchant cargo vessels from 10 to 16 knots.

The bulbous bow which is the latest bow design decreases water resistance at certain speeds. It is more effective for speeds between 16 or 17 knots and 22 or 23 knots. (John H. La Page : Modern ships Elements of their design, construction and operation, Page 10).

Building of the vessel commences after satisfactory results have been obtained from the experiments. Manufacturing of steel plates has been greatly improved and measurements of precise strength of steel plates is done to a very good standard. Protective measures to plates just after manufacture, during transportation from manufacturing plant to place of use, during storage period before use, during use and after leaving the shipyards are to an astonishingly high level which now does not call for high frequent maintenance attention as was done decades ago.
Riveted ships which dominated the initial history of steel ships have been replaced by welded ships. The manual cutting of steel plates, manual welding and time-consuming tedious proficiency check has been replaced by machine.

Thanks to modern technology, computer programmes do exist which command the machine to not only cut the plates to required shapes and sizes, but also cut them under water if required, weld the pieces and simultaneously test the quality of the weld. Standard has been reached whereby deformation of weld joint from poor workmanship is becoming forgotten.

The shipping industry may soon enter an era in which one may not be able to recognise a welded plate. How safe that is going to be is beyond the scope of this paper. Prefabrication of parts of ship and then joining the parts is the order of the day now. Yesterday's problems of joining plates of different materials eg steel and aluminium are now under control and it is not unusual to find a ship with more than four different materials in her. Improvements in this section have seen the disappearance of right angled corners at the hatch coamings, other openings and sheer strakes in preference to rounded up corners. Combinations of longitudinal and transverse framing, specially designed and built panting arrangements forward are all improvements under this section.

Specially built vessels for special cargoes and trades has been made possible due to the technological advances done in this area. We now talk of gas tankers, SWASH, SWATH, RORO, WOWO etc.
Reduction in scantlings due to near perfection of strength of steel measurement has left the shipowner with the same size of ship but with more carrying capacity. Some of these vessels leave a lot to be admired but the technology to make them is there.

Completion of shipbuilding is done after the ship has been launched. It is the last significant high risk operation in ship construction therefore we can regard it as the climax of shipbuilding. With the increase in sizes of ships, variations in shapes and design, launching is no longer solely left to the shipbuilder.

2.1.2 GOVERNMENTAL AUTHORITIES AND CLASSIFICATION SOCIETIES

The role played by Governmental Authorities in the level of maritime safety in a country is very big.

The maritime policy of a country clearly indicates the extent at which that particular country wants to involve itself with its maritime affairs. In a country where maritime affairs have priority, a well defined maritime policy will be available. All maritime activities that need to be attended to will be outlined, plus the accepted methods of attending to these activities.

From this policy, all parties interested in conducting maritime activities with that country or in that country will be able to roughly estimate their expected level of participation.

It is from this point that the paper would like to give all the credibility to the governmental authorities with regards to the remaining topics in this chapter.
Without the blessing of the governments, establishment of Classification Societies, proper set up of education and training colleges, improvements on equipments, etc would hardly be possible. The paper takes the view that in dealing with different topics in this chapter, the government is in one way or another, directly or indirectly involved.

Ship safety can be divided into two main categories.

1. Structural safety
2. Operational safety

Classification Societies mainly deal with structural safety. Classification societies came into existence in the 18th and 19th centuries when a need arose from all business interests connected with ship operations. These included owners, underwriters, shippers, consignees, bankers etc who accepted risks in varying degrees.

The main aim was to have independent technical opinion on the fitness of the ship to trade, which meant thorough inspection of the ship and indicating weak areas which needed attention. By properly attending to these areas, the level of risks was reduced. One of the duties of a classification society is to attend to a ship during its whole life cycle. This means among other things, participation of the classification society during structural design, construction and during ship operations by enforcement of class rules and regulations so as to maintain the class of the ship.

The vast knowledge, skill and experience that they have accumulated during their time of existence make them number one in the influence of design, construction and safety of ships.
The governmental authorities do not only deal with operational safety but are also very much concerned with structural safety. Since unnecessary duplication of responsibilities is a waste of resources and benefits nobody, and that the work of the Classification Societies and governmental authorities overlap to a certain extent, governments often delegate authority to Classification Societies. A good example of this is the government authority’s acceptance of the strength of a ship as being adequate if it was built to the rules of such a Society. A lot of research in different disciplines in the field is carried out for better performances of the future ship.

2.2 TRAINING TECHNOLOGY

The time for walking, talking and chalking is becoming history in many big institutions. Technological advances in the training systems involves inter alia, expenditure. In a system in which cost involvement exists, cost/benefit analysis plays a major role in the negotiations.

In training, cost/benefit analysis plays three major roles: planning, selection and justification. As regards this paper, planning would mean estimating the anticipated costs of different training programs in traditional classroom lecture approach programs and modern technology based programs. For selection it means evaluating one training approach relative to another in terms of costs and outcome. In this paper outcome is to be construed among other things, as doubtless compliance with relevant international rules and regulations, relevant national rules and regulations and requirements from the industry.
When used for justification, cost/benefit analysis should mean the ability to measure the effects of a particular training program, especially in terms of improved job performance.

When a training centre is established, at one time or another, evaluation of the three major roles played by cost/benefit analysis will be carried out and comparison of two or more approaches to the same training need will likely be necessary.

Different cost/benefit models have been developed to meet these different purposes. They are normally general in nature and apply to almost all training approaches or applications, however their accuracy and validity depends on the accuracy of input of assumptions made and the variables that are included in the particular training technology involved. For example, when computer based instruction is costed, it is of paramount importance to ensure that the model covers all the necessary components (Hardware, Software, Courseware, Humanware etc) and that assumptions are made about degree of usage and life span of equipment/human match.

The cost/benefit of using technology in training exhibit some major differences when compared to traditional classroom lecture approach.

As indicated in the figure below, technology based training program approach has higher start up costs but lower ongoing cost while the opposite is true for traditional classroom lecture program approach.
To strike a better deal in choosing training program, one needs to consider the duration of the course and the anticipated life span of the demand for that course or the equipments. National and/or non-national academies are established to last for life if possible and nautical education has never stopped since being established and probability for failure (ie probability that nautical education will be discontinued) does not exist at moment.

If we all agree to this, then the motto should be to fully support technology based instruction programs.

Cumulative Training Costs

![Graph showing the relationship between instructor and technology based training costs](https://via.placeholder.com/150)

Course relationship between instructor and Technology based Training.

Source: Training Technology Page 153
SELECTION OF TRAINEES.

Having decided on the training program model the establishment is going to follow, including the objectives of the particular course, the next important thing is getting the appropriate candidates for the course. Since modern training is technologically orientated, the prospective candidates must be technologically sound to their required entrance level. The paper suggests students who have done the last examination before joining the University as the appropriate ones. They must have taken science subjects. Physics, Chemistry and Mathematics should be in their scope of knowledge. Such candidates are expected to be able to manage the workload of the course. These people must be physically fit and mentally sound.

Old selection was based on defined standards on academic/professional knowledge and skills, health and body fitness. To be able to cope with the anticipated ship of the future these requirements must be completed by an examination of the psychical structure.

Knowledge on psychological selection can be acquired from other transport systems where this selection is obligatory (Aviation).

We now talk of deck-engine bivalence, ship-shore bivalence, future ship, reduced manning to an officer/ratings ratio of below one and where total complement may not exceed 10 (ten) people. These factors plus the trails that go with them must be known to the candidates and the interviewers must also make sure that they choose candidates whom they positively think, at least at that time,
that they will perform what is expected of them. It should be remembered that proper selection can help the candidates to avoid a wrong decision and in consequence to evade an unhappy, unsuccessful life at sea and it would in principle, support the efforts to reduce accidents and improve safety at sea.

2:2:2 SYLLABI AND FLEXIBILITY OF COURSES OFFERED TO MATCH DEMAND AND MEET OBJECTIVES.

Syllabi development is a difficult task. It needs a lot of input from different sources. Important points to be remembered when developing one, in a time experiencing rapid changes, are:

- to make it as broad as possible so that it can accommodate changes without itself being changed,
- it should be designed to suit its objectives.

A syllabus developed for watchkeeping certificate shall be so designed such that a graduate can confidently keep a safe watch. The aim of the training is to make the training/job gap as small as possible.

This is not easy because it involves many inputs eg college staff, equipments plus system of training, administrations system of education, developments in the industry, location of institute with regards to location of industry, availability of experts at and/or near location of institute etc.
SELECTION OF TRAINING EQUIPMENT

Depending on where the college or institute is located, and the customers of the college, and also the availability of funds for the purchase of equipments, a college should have the latest equipments available in the market, supported by the old equipments which may still be featuring in the industry. These are in addition to the recommended equipments for the given courses as stipulated in the STCW 1978 convention of IMO.

Example.
Dar es salaam Maritime Training Unit (DMTU) in Tanzania is the only well established maritime training centre in East, Central and Southern Africa which offers courses leading to all certificates of competence except Class 2 and Class 1. If DMTU stocks itself with equipments including many which only feature in class 2 and class 1 courses then that would not be a perfectly planned expenditure because the cost/benefit analysis on justification can not be satisfactorily explained. But if the industry uses these equipments effectively and that funds are available, then no sound reason exists for them not being purchased.

Colleges can be very influential to the industry with regards to standard of equipments, especially in less developed regions. While the paper admires shoulder by shoulder progress between colleges and the industry, it also understands the problems involved in achieving this and thus continuity of the training /job gap. In developed regions it is normally the industry which is way ahead of the colleges but in the less developed regions you would find that the colleges are ahead of the
industry especially if the colleges are foreign supported. In such a situation, it would pay a lot if the college and the industry work out means of reducing this gap.

(Development with respect to regions as referred above is only in the context of maritime education and training.)

It is the paper's assumption that all readers understand the problem of training with highly sophisticated equipments which are also more convenient to use and being taken to work with equipments of much less quality and performance standard.

The paper suggests the equipments selected to have inter alia the following as part of their characteristics:
Realiability, high availability, high accuracy and nobility should be just right.

Nothing frustrates both lecturer and students like the breakdown of equipment in the middle of an exercise, having an equipment which works only twice a week and these two times are not known, and carrying out research on an equipment whose accuracy is doubtful.
Literature on human study has indicated that out of the 100% that is taught to a person, only one third remains in the memory clearly while the rest is blurred. With routine work, if this work involves greater than the one third then you are a lucky man but majority of routine workers do not use all of this one third therefore to them part of this one third easily joins the blurred part. To keep this 67% in focus for quick retrieval, one needs to read professional journals frequently, to keep contact with books and keep himself well on his toes not to be left far behind by the fast changing technology.

Many of the International and National institutions have recognised this and effectively acted on it. IMO recommendations on this are contained in the STCW 1978 Convention, but colleges do also conduct independent refresher courses which mostly assist in bridging the gap between past knowledge and experience, and current developments in the education and industry.

It can be done by short courses but these courses are very demanding and costly because for them to be effective experts are needed and often this calibre of people is from the industry.

The paper suggests close links between college and industry and to start such demanding courses from that point of understanding.

Upgrading is comforting, selfsatisfying, increases confidence, efficiency and eventually increases safety.
2.3 SHIPBOARD TECHNOLOGY

The most attractive place on board the ship is the bridge. Whether it gains this popularity from the fact that it is the commanding post of the ship's business or from its strategic positioning / location or from the items that are installed in it is left for individual opinion.

The bridge, its contents and its wings have gone through many design changes all intended at making it more convenient for the seafarer to perform his duties and consequently increase the safety level.

2.3.1 NAVIGATIONAL EQUIPMENTS AND INSTRUMENTS

The traditional navigational equipments have been the compasses (magnetic compass and the gyro), the sextant, which went through Backstaff, Quadrant and Octant stages before reaching the present level, the chronometer which is also giving way to modern Quartz chronograph clocks, echo sounder being technological advancement of the sounding rod and the lead line, Directional finder, radar, steering wheel etc.

Vessels using the above systems still exist but a lot of improvements have been introduced to increase the accuracy of navigation with the aim of making available precise decision making data for the navigator and minimise accidents.

The position fixing has been highly improved by the availability of electronic aids to navigation which mainly include Sonar navigation, speed measurement, Decca navigator, Loran C, Omega, Navigation by
Satellite, Integrated navigation systems, the ship's compass, Automatic steering, Direction finder and Radar.

We can divide these navigational aids into three main groups:

1. Short range navigational aids which use ground wave as their mode of message transportation. A very accurate position fixing system when weather conditions are ambient. Suitable for coastal navigation and in estuaries, where precise positions are a necessity. Decca, Loran A and Loran C are among them.

2. Long range navigational aids which use skywave transmission. Omega is one of these. The accuracy of this system is not comparable to Decca and Loran C, but for its area of coverage, the accuracy it offers may be considered good enough.

3. The latest development in position fixing is Satellite navigation. With precision in time keeping, accuracy of this system is very high. Proper understanding of the system is very important because the accuracy of the position depends on the input that is fed to the computer or equipment. Wrong inputs in DR position, GMT time, Antenna heights etc will aid in giving the user a wrong position.

This is in addition to Satellite errors which include disobedience to follow the precomputed path.

One of the main problems in this sector is that satellites have a life period, like human beings. But the big difference comes in the fact that the effects of
their destruction after their useful time is yet not clear.

Accuracies of the Gyro compass and the Automatic steering are some of the features which help in keeping a convenient watch as machines can be more relied upon than man. Failure alarms must be incorporated for early detection of unfavourable developments.

Speed measuring logs have been accurate enough when considering their principle of operation but the transverse motion measuring logs are definitely below the accuracy indicated in the catalogues. The beauty with this system is that it is not employed to considerable use by the merchant vessels.

Echo sounders have been of great assistance especially in shallow waters. However the positioning of the transducers could be moved more towards the bow where the ships smell the ground earlier than any other part of the ship.

Anticipated development to soon come to the bridges of merchant vessels are the electronic charts. These will do away with the paper charts and all the publications that go with them. Discs will be available which will carry all navigation information and correction of the data carried in these electronic charts will be able to be done by satellites. This system is used by some war ships. The only obstacle which the author found when visiting one firm making these electronic charts is the fact that the charts are done by digitising the current charts. The problem is the carrying forward of errors contained in that chart. The screen was also too coloured for eye comfort.
More information shown on the screen causes clutter which blunts its effectiveness.

Since computers can not yet handle large amounts of data fast, reduction of data is important to increase ease of processing and retrieval of data on display.

Some problems can be anticipated from this early stage and one of these problems is the seafarer having much less information displayed on the screen against lots of information seen outside especially on coastal waters. It still is a great step towards modern electronic navigation and once enforced improvements should move it to safer and safer levels.

Radar is the navigator’s extended eye.

The Raster scan radar screen provides the clearest echo that a radar can give. Screens are also offered in different colours for different objectives giving more choice to the users.

This has been made possible because the screen is divided into small pixels. Each pixel has an X / Y co-ordinate and can be addressed. Discrimination depends on number of pixels and area filling like colouring an area can be done since the possibility of addressing each pixel exists.

The following are some of the advantages of the Raster scan radar.

- Bright display
- Suppression of disturbances
- High resolution flicker free; high contrast picture
- Superimpose additional synthetic radar information eg ARPA, Target trails, etc

- Can display on same screen - status of radar - own ship data

- Performance / Safety - TV tube more reliable than conventional tube - Self tests by computer

- Possibility of colour radar

- Adaptive radar controlled auto pilot ( ARCAP )

- Will eventually be cheaper

All these developments are intended to help the seafarer to execute his job with highest accuracy possible and with minimum stress. The seamen should be helped more though, by being given more information with regards to the probability of failure of these equipments. Apart from Anschütz and a very few others, most manufacturing companies of electronic navigational aids do not indicate the mean time between failure of their components. The danger brought by this is making the poor seamen sail with equipments which they have no idea at all of their probability of failure.

2:3:2 CARGO EQUIPMENTS

The sole reason for operating a merchant vessel is to carry cargo from one place to another profitably, and without misfortunes in between. This means being able to load the vessel safely and to safely transport the cargo to its port of destination, and finally to discharge the cargo safely.
General cargo vessels have been the only unfortunate ones to still have equipments which are for general purposes but specialised vessels have specialised cargo equipments for their types of trade. Specialised cargo equipments are easy to deal with due to the fact that the area they cover is very limited while general equipments have the disadvantage of trying to cope up with many types of cargoes. Improvements in this area include the capability to work more cargo within a given time and the capability to cope up with varying conditions and standards of different ports. Lessons learned from accidents involving the securing of heavy lift derricks and cargo securing have resulted in recommendations on cargo securing from IMO.

Specialisation of ships and cargo has made it easier to locate sources of accidents and this may explain the reasons why general cargo ships are having the highest accident rate compared to the other ships.

2:3:3 COMMUNICATION EQUIPMENTS

Advancement in modern technology in this area is finally taking out of business the man who at one time was as important as the Master on board the ship. The traditional radio officer is leaving the ship with his make and break system of communication. The availability of communication equipments as indicated in annex 1 renders the traditional radio officer redundant in modern ships.
Successful execution of the voyage is completed when the vessel discharges her cargo safely. Ocean navigation has to be complemented by coastal navigation to complete the voyage. It is here where shorebased technology plays its major role.

The shorebased radio navigational aids can be considered fully covered in 2:3:1 above. The other main contributors to position fixing are the light buoys, light houses, light vessels with racon, ra mark and radar reflector characteristics. Refusal of a light to be seen beyond five miles while its range of visibility is thirty miles is not uncommon at sea depending on the existing weather condition. The situation can be worsened if the reliability of the light is reduced by one reason or another.

The introduction of the possibility of having six bulbs fitted to a system such that if the working bulb goes faulty, the system automatically changes to another bulb thus increasing the availability of the service and also reducing risks to safety due to fact that replacements of bulbs can be planned to be done during a calm sea period.

Below example should help to indicate the importance of this point.

If a lighthouse has bulbs with the mean time between failure being two months for each bulb, then the probability of failure = $P\ (\text{fail}) = (1 - e^{-t/2})^a$ where $t =$ time in question. Power of a outside the bracket indicates the number of bulbs.
Example: Let $a = 1$

To find the probability of success of a bulb after one month, 2 months, 3 months, 4 months.

$P(\text{fail}) = (1 - e^{-t/2})^a$ since $a = 1$, when $t = 1$

$$P(f) = (1 - e^{-1/2}) = 0.39$$

Since $P(s) = 1 - P(f)$ then $P(s) = 0.61$

When $t = 2$ $P(s) = 1 - 0.63 = 0.37$

When $t = 3$ $P(s) = 1 - 0.78 = 0.22$

When $t = 4$ $P(s) = 1 - 0.86 = 0.14$

With six bulbs, the probability of failure $P(f) = (1 - e^{-t/2})^6$

When $t = 1$ month $P(f) = 0.004$ $P(s) = 0.996$

When $t = 2$ months $P(f) = 0.064$ $P(s) = 0.936$

When $t = 3$ months $P(f) = 0.22$ $P(s) = 0.78$

When $t = 4$ months $P(f) = 0.42$ $P(s) = 0.58$

The above example clearly indicates the contribution of modern technology in increasing the availability of a navigational aid, increase in number of position fixing possibilities, increase in efficiency and confidence and decreasing the risks of navigation which means inter alia, increase in safety.
2.4.2 VESSEL TRAFFIC MANAGEMENT SYSTEMS.

The main aim of vessel traffic management systems is to improve safety and efficiency. A system which is fully exploited in air transportation. At sea this is done in two ways. There are internationally recognised vessel traffic management systems and national systems. While we have both horizontal and vertical separation in air, at sea there is only horizontal separation of vessels. As such, up to this moment vessel traffic management system is mainly involved with traffic lanes, separation zones etc. Vessels navigating in international traffic schemes are bound by international law or agreement to follow the requirements of the particular scheme.

Monitoring, supervision and surveillance of area to ensure that regulations are not contravened is done by the coastal states adjacent to those waters. The setting up of these traffic separation schemes has reduced traffic density resulting in marked decline in risk of danger. This has been made possible by the fact that while it was usual for ships to converge towards one point in search of getting a proper fix (e.g. Ushant light house) and continuing with the voyage. The authorities took the seafarers requirements into consideration and came up with a solution that fulfilled his requirement and made it safer for him by reducing congestion and setting proper routes of approach / progress.

The diagram at the appendix from Seaways March 1987 Page 15 enlightens the point.

Other requirements of VTMS are constant lookout and radio listening watch, and reporting of incidences. It is the best system for easy location of vessels and thus easy reach to them during ordinary time and emergencies.
Like all systems, its problems include non-compliance from those who are ignorant of them and from some who for one reason or another have to break them.

Strict enforcement of the rules has to be complied with which requires among other things, clear recognition of the benefits in obeying the rules, from all the relevant decision makers.

For VTMS to be fully appreciated like in aviation, the legal problems concerning responsibilities of the ship when under VTMS must be solved. At moment VTMS is done by the use of traffic separation schemes, exchange of information to coastal stations in some areas, picking up of pilot/master for safety navigation during thick fog in places like Rotterdam.

The following are some of the problems which administrations intending to install the system should carefully observe. (These are personal.)

- Two targets can be merged into one on a screen
- One target can be split into two or more.
  The above are due to the size of the mathematical model used in the targets.
- Obscuring of targets
- False echoes - mainly due to reflectors -
  The solution here is having more than one radar because these echoes can not be seen in both radars at the same time. But then the possibility of ignoring a real target exists which may not be given enough weight until it is too late.
- Sea clutter is common in radars. By the scan to scan correlation technique the sea clutter can be rejected. It will be necessary to store the whole radar picture for this function to be carried out.

VTMS has three main modes:-
- It can be used for passing information only
- It can be used for giving advise - especially if a pilot is behind the screen of the shore-based VTMS centre.
- It can also be used for giving orders - if the VTMS centre assumes full responsibility of the vessel.

The preventing of a near imminent aeroplane accident whereby the pilot had for some reason not released the undercarriage in mid July 1987 at Heathrow airport deserves full credibility to the Air traffic controllers. Had not the control tower station warned the pilot in ample time (less than four minutes before landing), it would have been a different story altogether.

**2:4:3 GLOBAL MARITIME DISTRESS AND SAFETY SYSTEM.**

The concept of this system is to rapidly alert shorebased search and rescue authorities, as well as shipping in the immediate vicinity of the ship in distress, to the distress place so that they assist in a co-ordinated search and rescue operation with the minimum delay.

This will be done by establishing a global plan for maritime search and rescue (SAR) on a framework of
multilateral or bilateral agreements between neighbouring states on the provision of SAR services in coastal and adjacent ocean waters to achieve cooperation and mutual support in responding to distress incidents.

The system will also provide for urgency and safety communications and the dissemination of marine safety information, including navigational and meteorological warnings.

2:4:4 SEARCH AND RESCUE.

Governments are required to set up search and rescue organisations whose work is to search for and provide aid to persons who are or are feared to be in need of assistance.

It is normally executed by ships at sea, search and rescue organisations which have facilities for air, maritime and coastal search and rescue.

Regional co-ordinating centres are set up and each centre is assigned an area of operation. However co-ordinating centres often co-operate in search and rescue operations. It is a very hard job, very demanding and it can be very costly for the not well to do nations. To reduce the burden on individual countries, mutual agreements between nations are highly encouraged for optimisation of resources and a gain in the increase of the safety level.

The IMO Search and Rescue Manual (S R M) is a necessity for all administrations and individuals who are eager to get the details of the service with regards to setting up search and rescue organisations, and the search and rescue procedures. Similar publications are available from some of the developed maritime nations.
CHAPTER III

MARITIME ACCIDENTS AND CAUSES.

"Many would be considered dead ashore had it not been for the frequent loss of temper of the sea." (Mokiwa G L

The human being is the most advanced living creature on earth. He uses all his brains to make good use of his environmental resources. The land is where we all think we belong but the land is becoming scarce everyday to an extent that in some areas like Japan, land reclamation is public knowledge.

Water occupies about three quarters of the earth's surface and from the sea, human being extracts building materials, mineral resources, food, energy, etc.

But nature has put risks to almost all activities done on land and elsewhere and unfortunately this includes maritime activities as well.

Maritime accidents can be categorised as foundering, stranding, collision, explosion / fire and others. Before the author goes further with accidents analysis, it would be appropriate to let the readers know who are the contributors of a safe passage. The elements that make the domain of a safe passage are the seafarers, ship and cargo, weather, and regulations.

The ship shall be so designed and constructed such that she can carry without constraints, her intended cargo.
The problems of securing of containers are substantial on board a ship designed to carry cargoes other than containers. Likewise a container vessel is most competent and convenient for the carriage of containers and nothing else. The moment diversion of cargo is made from the one originally designed for, the level of compatibility of ship and cargo is reduced and this will be the beginning of problems.

Seafarers should be capable of operating the ship, her equipments and all the machinery. They should be able to navigate the vessel from point A to B within the expected perils of the sea. They should be proper husbands of the ship. Job description should be well defined and accountability enforced to the maximum. Proper match of seafarers and ship type and trade should be aimed for. This casts a lot of doubt to the credibility of dual officers and dual ratings.

Weather: Nothing much can be done about the weather except praying for the weather forecasting stations to send you as near perfect predictions as possible so that appropriate measures can be taken to avoid catastrophic incidencies. It is the author's wish that technology will advance to such a level as to diffuse a depression, tropical revolving storms and other disturbing effects that the seamen dread for.

Regulations: The most effective element of the four if they are enacted by genuine people who understand the problems to be solved, and if they establish workable solutions which are tirelessly implemented, enforced and that those who infringe the regulations are properly
dealt with for the benefit of safety and all.

3.1 TYPES OF SHIPS AND ACCIDENTS

Most accidents are associated with particular activities. Therefore one of the approaches of reducing accidents is by categorizing the activities or accidents and dealing with individual groups. Since the paper is mainly concerned with maritime safety, the author wishes to divide the merchant ships into three main categories.

- Tankers: which include among others, liquid bulk petroleum tankers, chemical tankers, gas tankers etc.

- Dry bulk and combined carriers

- General cargo ships which in this paper includes ROROs, container ships, ferries and passenger ships. Fishing vessels may be included in some paragraphs for the purpose of awareness only, but they are not intended to form part of the main aim of the paper.

3.2 CAUSES OF ACCIDENTS

In section 2.1.3 ship safety was divided into Structural safety and operational safety. One of these has to go wrong for a risk of danger to exist.
The hazards under this heading which had led to accidents in recent years can be grouped as follows:— Authorities, Management and Manning.

Authorities

The authorities are the supreme body of the operational safety in that, they are the ones who set the regulations, rules etc which govern the standards to be achieved and the procedures to be followed to reach such standards of safety.

The authorities in performing their duties and with the awareness of their responsibilities, need the maximum of understanding of how to reach the optimum safety level with the available resources.

It is not uncommon in some areas, to have very good regulations, rules and recommendations yet when one comes to reality, he finds out that with the available resources, these regulations, rules and recommendations are near impossible to implement. The result will be a tendency of different operators operating at different levels of safety which does not serve the purpose. The paper also brings into view, the tendency of some authorities concentrating on commercial shipping and forgetting the safety side of it.

While the author sees no objection to authorities being involved with commercial shipping, due regard shall be given to safe shipping. Safe shipping within their jurisdiction navigable waters and within their ports.
Management and manning.

Generally, an aeroplane or jet owner will fly with two pilots in his own jet. Owners and managers of shipping companies rarely travel on board their ships. As a result they are never present when ships experience problems. They always get an away from the scene information which can never be compared to an own eye observation.

Ship management requires among other conditions, shore based staff with necessary expertise to oversee safe marine operations. In recent years the author is aware of some shipping companies managed by shore based staff who have never worked at sea nor did their former jobs have any connections with the sea. It does not imply that they are or were incompetent, but it pauses serious doubts as to their capability and willingness to discuss seriously with the seafarers on matters of mutual interest.

Communication becomes very complicated because the vertical levels of understanding of the matters of common interest are very far apart. The transitional period from zero shipping knowledge to acceptable level is normally too long since shipping is very complex and highly unpredictable. This period is a very dangerous period.

Shore / Sea staff job understanding gap should be reduced to the minimum so that the benefit of compatibility can be enjoyed by all. Horizontal compatibility should be the level to aim for.

It is also not uncommon to find ships manned by untrained inexperienced officers who have obtained "CERTIFICATES" without examination.
A practice which is very dangerous since these officers are entrusted with peoples lives and property when they are on watch. The author would appreciate the setting up of a global standard for shore based maritime personnel.

The manning of ships is often done by agents who take no responsibilities for the successful outcome of the voyage. The human element of supplying crew which may not be the best one can easily overcome the agent. The agent may also not know how well this crew will manage in the ship, since he may not know the level of automation of the ship. It should also be remembered that taking an incompetent man to sea is exactly the same as giving him an overdose of sleeping tablets. His chances of causing accident to himself, others and/or to the ship and her cargo are just as great as the chances of the overdosed person continuing to sleep forever.

With recent economical unrest to individuals, companies and governments, ships have been hit by the less manning disease. While less manning is not bad in itself, how less and the influence of this how less to safety is the big question. Cases have occurred where evidence existed beyond doubt that a particular accident could have been avoided if the manning was adequate. Adequate is relative and it can be construed differently by two different parties. Consultations with authorities should be sought of before reaching a conclusion on the ship's required crew number.

Unfortunately cases have also existed whereby owner induced loss of ships and cargo eg maritime fraud, deliberate stranding and scuttling, have taken place.
Research by Breslow and Buell (1960) indicated a relationship between working long hours and coronary heart disease mortality. Findings indicated that subjects of less than 45 years working over 48 hours per week have twice the risk of death from coronary heart disease compared with similar sample but working 40 hours or less per week. The minimum number of hours seafarers work per week is 56.

Shift Work

Shift work which involves night shift is also a major contributor to stress. A shift worker has to balance sleep, social and family life and circadian rhythms. These factors are all interrelated and a problem in one may lead to negation of the positive effects of success achieved in the others. (Monk and Folkard (1983)).

Stress and strain to seamen from overstaying on board ships without being replaced is another factor which contributes risk of accidents. This may sound impossible to places where seamen are relieved every fortnight (North Sea) and every four months in foreign going ships of some countries, but places do still exist where seamen go on a stretch of over a year before leave.

Age of seafarers also play a big role to accidents. Stress can be traced to be prominent to a season of a man’s life. (Valerie J. Sutherland)

Modern technology on board ships will hardly replace shift work. Its influence on the reduced manning scale
will in one way or another contribute to longer hours of duty than now. Already fatigue is a main topic to officers of vessels trading in North Western Europe. An average of 20 working hours per day for three days is now normal. It will not be long before the public learns of the negative side of advanced technology in this respect.

Accidents due to fatigue are imminent and if this trend is not checked then safety is very much endangered.

Compatibility between younger officers who are technologically oriented and older traditional officers who do not accept changes easily. Good workmanship relation sometimes lacks due to this difference in levels of technological understanding.

Another part which comes under the operational safety is the cargo. While specialized ships have their dedicated cargoes, the problem of putting the rest of the cargo in general cargo carriers explains the higher accident rate of general cargo ships. Cargoes have been increasing faster in specialization than the ships dedicated for them and a dangerous transitional period surfaces before all settles down safely. Sometimes accidents have been unknowingly self-inflicted by wrongly loading cargo in void spaces. eg carriage of naphthalene in the void spaces of a liquified gas carrier.

3:2:2 STRUCTURAL SAFETY.

In the case of combination carriers, the design system of putting oil and bunker pipelines in a vast "DUCT KEEL" creates an explosion atmosphere situation in case of a
small leak from one of the tanks. Sometimes vessels are not clearly defined with regards to conditions the vessel has been built to encounter. This leads to a vessel entering areas where she is not fit to navigate, e.g., navigating in ice.

Postponement of structural maintenance required under Classification Society rules does not always serve the good purpose they are intended for, and it then serves as an accident assisting agent. Some designs may be good but very vulnerable. This includes the ROROs. There are also some designs which make it very hard for carrying out repairs because there hardly exists enough space to put big repair parts into the engineroom. Some of the SWATH vessels can be cited as examples.

Initial designs of WOWOs (Walk on walk out) vessels which are used for carrying live stocks had some problems. Initial stability calculations overlooked the free surface effect of the refuse from the animals plus the zero means of draining this waste thus allowing accumulation of weight where it is not needed.

Transfer of ownership

Specially designed vessels needing maximum technical knowledge to operate, being sold second hand to owners who do not have the know how to run these vessels. Examples of these are the Ore carriers and tankers designed on an assumption that they will be loaded and discharged with minimum longitudinal stress, being sold to operators who have neither the officers or equipment nor the opportunity to keep stress to the minimum. It may
be undiplomatic to draw an easy conclusion on the reason for such an incidence but ignorance to a certain degree must be among the predominant contributors to this safety hazard. Whether it is the buyer to blame or whether it is the former owner to blame is beyond the scope of this paper but what the author strongly recommends is an in depth study on how best this problem can be solved.

Accidents have existed, are existing and will always do, but their magnitude must be reduced. Reduction of accidents is always possible if there exists inter alia, an effective inquiry system. This system is supposed to investigate the causes of the accidents, how and why they happened and trying to find the remedy so that these accidents do not recur.

Recurrance of accidents will be effectively avoided if the lessons / findings and recommendations from the accidents are passed to all people / parties concerned. Unfortunately this is not satisfactorily so.

Accidents happen to ships, cargo, seamen etc but the last person to receive the information concerning these accidents is the seaman. In fact he will be lucky to get any information apart from instructions /recommendations on what to do and what not to do when carrying out a particular operation.

The flow chart of information on casualties should help to remind those whose influence could help in seeing to it that seafarers get the casualty information, and that by not doing so, they are willingly or intentionally allowing / sentencing 156 ships, their cargoes and sometimes crew to unwarranted death which could be avoided.
Flow chart included in the appendix.
If seamen will continue being denied the findings from casualty investigations BUT same information is passed over to Owners of ships lost, Solicitors of interested parties, Salvage associations, Underwriters, P and I clubs, Arbitrators, Classification societies and to maritime authority of the flag state, then the seriousness that the authorities project with regards to safety leaves a lot to be justified.
The author proposes the solution as being publishing the reports of the inquiries and making them easily available to the public. Means shall be provided of notifying the public that such reports are ready. Of course they should not be offered free, but by the same token, they should not be discouragingly too expensive either.

3.3 REFERENCE DATE FOR INTRODUCTION OF RADAR.

Radar was invented during the world war two and introduced to the merchant shipping in the late 1940s. In the early 1960s, the majority of the west European and American merchant shipping vessels had radar installed on them. IMCO (now IMO) was established much later than the introduction of radar on board. Since from IMOs resolutions one can only go back to a resolution adopted in 19th November 1981, the author finds it wise to take 1960 as the date of introduction of radar on board ships.

The paper would like to draw the attention of the readers that special radar training courses were introduced in the United Kingdom in the 1950's.

The paper takes Collisions and contacts as the radar associated accidents.
3.4 REFERENCE DATE FOR THE INTRODUCTION OF INERT GAS, COW, ETC.

Similar complications existed for fixing a particular date in this section. 1970 has therefore been considered as the date of introduction of inert gas and COW systems. Fire and Explosions are taken by the author as the accidents associated with these systems.

3.5 REFERENCE DATE FOR INTRODUCTION OF MODERN WEATHER FORECASTING INSTRUMENTS AND EQUIPMENTS.

Different dates of introducing weather routeing for ships exist among the pioneers being Netherlands, USA and UK. 1970 will be taken as the reference date because it is only a few years after weather routeing for merchant navy was introduced.

Foundering is associated with this. It is the type of accident which can be avoided if the vessels know of the bad weather and find shelter before being hit by the weather.
CHAPTER IV.

UNSAFETY DOMAIN AND TREND OF ACCIDENTS.

"IF YOU WANT TO GO TO SEA WITHOUT ANY RISK OF CAPSIZING THEN DO NOT BUY A SHIP, RATHER BUY AN ISLAND."
(Marcel Pagnol, from Pannisse's lips.)

4.1 PHILOSOPHY OF UNSAFETY FIRST, SAFETY SECOND.

Corrective measures are always done after an incidence has occurred. So long as a system works properly or satisfactorily, its known faults can be overlooked until a big catastrophe happens. Pressure from the public which eventually ends up to political pressure will result in corrective measures being taken.

Since bad publicity is assumed bad for everyone though to a varying degree, bad incidences are met with different responses from different regions. It is common to hear people wishing a particular accident to happen to say USA. Not that they want the Americans dead, NO. They know for sure that if such an accident happened there, effective corrective measures will be taken worldwide and that the rate of recurrence of that particular accident will be definitely reduced.

The development of SOLAS came from the Titanic accident and the Torrey Canyon, Amoco Cadiz accidents had big influences in the passing of two IMO conventions. While this paper is being written, the shipping industry is anxiously waiting for the changes that will come in the structural safety and operational safety of ROROs, from the Herald of Free Enterprise ferry accident whereby 188 lives were lost.
4.2 THE UNSAFETY SET

The road to complete safety is too long and it does not seem to be properly charted either. This means that the road is unsafe. The approach taken by this paper is to try to balance the forces that contribute to SAFETY.

\[
\text{UNSAFETY} \pm \text{MAN AND TECHNOLOGY} \rightarrow \text{SAFETY}
\]

The domain of the unsafety set is unlimited in resources but man and technology have very limited resources. While man and technology are supposed to work together to fight unsafety, it is usual to hear of occasions where these two have worked against each other and thus helping unsafety.

The positive sign in the above expression indicates positive contribution from man and technology, which means maximum tendency towards safety. The negative sign means the contrary.

The unsafety set can be said to contain all elements that contribute (in one way or another) to unsafety for example weather, man, cargo, design, regulations, ship, environment, technology, etc.

It is an established fact that human error contributes about 80% of accidents to marine activities. This leaves the rest 20% to other causes.

Human errors may be categorised in two main groups.

Those caused by inability (errors due to incompetence)

Those caused despite ability (Errors despite Competency)
The most effective corrective measure to errors caused by inability is to provide proper education and training to the crew and all those concerned.

Corrective measures to Competent errors would include training all concerned in compulsory procedures to be followed while performing their duties and setting up efficient watch organisations. Competent errors are easy to trace when they are genuinely committed, but they can be very hard to trace if they are intentionally done. The use of modern equipments in simulating accidents help in indicating the possible causes of the accidents and corrective measures can be applied accordingly.

4.3 TRENDS OF ACCIDENTS FROM COLLISION AND CONTACT AFTER THE INTRODUCTION OF RADAR.

Problems existed in acquiring consistent data. Table 1 contains total losses casualty returns from 1949 to 1975. From this table the accidents from collision can be put in two different groups. A consistent group of an yearly average of about 15.4 ships lost from collisions with a marked low of 7 in 1954. This is from 1949 to 1962.

From 1963 to 1973 the yearly average rose to 29. The author takes the view that the increase in number of small ships and improper use of the radar can be regarded as the main reasons for the upward trend of accidents. Another reason which should not be overlooked is the people's knowledge of the importance of reporting of accidents.

From table 4 which covers the period between 1974 and 1985, and also dealing with vessels of 100 gross tons and
over, there is no marked difference in yearly figures except in 1978 and 1979 when losses from collisions were 56 and 47 respectively, but the average during the rest of the period has been around 35.

Table 3 is of much interest to the paper because it has relevant figures. Relevant in the sense that they are of vessels of 500 gross tons and over, which are the ones covered by IMO regulations. If a three year running average is done, the following figures are obtained, for collisions and contact respectively. The figures are correct to one decimal point. Period 1974 to 1986.

19, 19, 24, 26, 24, 24, 20, 20, 14, 12, 11.

6, 4, 6, 5, 7, 7, 8, 8, 7, 5, 4.

From these figures it can be noticed that the trend is definitely on the reduction side. From 1980, ships involved in collisions have been below 13 except in 1982 when there were 20 ships involved. In 1986 there were only 7 ships lost from collisions. The author takes the view that if the figures for the whole period from 1949 were consistent, that is for vessels of 500 gross registered tons and over, then the trend would have been the same. That is, general decline of accidents from collisions and contact, with few occasions when the accidents go up. This view is taken because the ratio of accidents of vessels of 500 gross tons and above to those of over 100 gross tons is about 0.6 :1 and if this factor is considered from 1949 with acceptable adjustments, the declining trend would be noticed clearly.
The STCW 1978 convention which requires watchkeeping officers to have undergone radar training could also be viewed as being one of the main contributors of this decline. Improvements in radars eg magnified screens, plotting screens, better performances and back-up radars for bigger ships decreased the mean time between failures of radars since a redundance system was now installed.

Improvement to the collision regulations especially to the section dealing with conduct of vessels not in sight of one another. The provision of proceeding at safe speed has reduced the concentration of vessels at an area which had very poor visibility. The old rules required that vessels be stopped which meant increase of vessels in this area where visibility was poor and thus increase in encounter rate.

Investigations and research on collision-prone encounter angles have enlightened the seafarers of the most dangerous angles of approach and managed to make them more cautious. All this could not be achieved without the facilities made available by modern technology.

The paper suggests that a minimum distance be spelled out below which vessels shall be considered to be in close quarters situation for crossing vessels. This can be based on distance below which collision can not be avoided plus a constant. This constant is the safe margin. This is well within reach of the equipment that is on board today.
4.4 TRENDS OF ACCIDENTS FROM FIRE AND EXPLOSION AFTER INTRODUCTION OF INERT GAS SYSTEMS, COW, ETC.

If we take 1970 as the base mark for inert gas, COW systems, and installations of modern fire detecting and sensors on board big ships, then the trend is as follows:

From table 1.

There is no significant change in the number of fire/explosion accidents from 1949 to 1964 being mostly below 10 accidents annually.

However the figure increased to an average of 18 accidents annually from 1965 to 1970, the lowest being 13 and the highest being 25. Between 1971 and 1973 the figure increased to an average of 30 lowest being 27 and the highest being 32.

From figure 3 it can be seen that fire/explosion accidents seem to be following a cycle which has upward movement for say 4 to 5 years and then downward trend for another 4 to 5 years. However the ships lost from this cause are too many. This is the leading cause in the total losses at sea.

Early detection of fire coupled with compulsory fire fighting course for officers and improvement on qualities of fire extinguishers will continue to help to reduce these accidents.

As seen from the tables, these accidents are very few in tankers. This can be attributed to specialization in the tankers themselves, improvement in cargo handling equipments and procedures, and training offered to crew.
This specialization which is afforded by the available technology, makes it safer for particular commodities to be shipped in these vessels.

General cargo ships carry all that is left from the specialized side and part of the accidents are contributed by incompatibility of cargoes.

The author is very much worried with the term general as applied to the ships and wonders whether it is safely used. The paper would appreciate if more investigations are done as to what can be considered safe enough to go in a general cargo ship.

4.5 TREND OF ACCIDENTS FROM WEATHER AND FOUNDERING.

Accidents in this area have been increasing steadily from 35 in 1949 to 94 in 1970. From 1971 to 1985 the annual number is above 100 with peak being 169 in 1978. Small vessels contribute quite a lot to the picture that is being projected by these figures. But if we look at table 3, the figures from weather and foundering are almost steady at around 70.

This is an area where improvement is going to be very slow because the contribution from technology towards reduction of accidents resulting from weather is very limited, as it is over run by the economic situation. Once at sea, the best that one can do is to avoid maximum effect from the weather but dogging it completely may be very hard to achieve due to economic constraints, ship’s position at time of bad weather and from some other reasons. Short term forecasting can be relied upon but caution is definitely needed for long term forecasting.
4.6 TREND OF ACCIDENTS FROM STRANDING.

For vessels of 100 gross tons and above, two groups can be made from the accidents record. Those ones with an annual rate of below 70 which is from 1949 to 1961 with an exception of 1951 which had 82 accidents. The rest is of above 70 with majority being over 100 mark. Again most of these accidents are from small crafts which come under the 500 gross tons. While they may have the equipments, a lot of doubt is expressed on how good the equipment is in position fixing, and how qualified the user is, in using the equipment and in normal safe watchkeeping.

The figures in table 3 indicate the trend for vessels of 500 gross tons and above. The trend can be taken to be decreasing very slowly. Passage planning is expected to decrease these accidents even further so long as all Colleges teach effective passage planning. Availability of two modern radar sets on the bridge gives the navigator the option of using one set for safe navigation and the other set for passage planning.

4.7 TREND OF ACCIDENTS FROM SHIPS AGE.

Table 2 is dedicated to this.

As days go by, man improves on technology and corrective measures to past mistakes make newer ships better than the older ones. It is the aim of the author to assume that modern technology will be found on newer ships.

Table 2 is divided into 5 year age categories of ships. Each category has three types of ships being Tankers, Bulk and Containers, and the last one being Others.
It can easily be noticed that the lesser accidents happen to younger ships. The trend reverses in the last two columns for Tankers, and Bulk and Containers. The main reason is that not many ships from these types live to see those years. Many would have already been taken for scrap. The ones that still operate are normally in very good order and that is the reason for having less accidents. Of course modern technology on the ships becomes more effective if it is assisted by modern ship operation. In most companies, it is normally the best crew that is posted to the newer ships. The crew is generally safety conscious and very responsible. This is another factor which help in having less accidents from younger ships.

4.8 MAN - TECHNOLOGY RELATIONSHIP TOWARDS SAFETY.

In dealing with man - technology relationship, the question of safety is usually overlooked or taken for granted because most of the attention is given to economic and social factors. During the old time, mechanization aimed at removing people from accident-prone duties was met by fierce strife from the people who were taken out of work. The situation is still the same though to a lesser degree. In this modern time, a lot of explanation is done so that both parties understand the objectives of the mechanization. Mechanization and automation has taken over all industrial processes where high risks accidents to health and safety exist. This has reduced the number of accidents and injuries to people because the number of workers is low. In areas where unemployment is high, or where capital is short, health and safety is thought of more in percentage rather than in terms of total number of injuries.
This has one advantage of hiding the total number of accidents and since labour in such areas is cheap, ratio of injuries to total labour force is very minimal and false impression of safe picture is portrayed.

Before embarking in a mechanized and automation exercise a thorough survey is needed to compare the advantages and disadvantages of putting either man or machine to do the particular job.

The human being is preferred in jobs which need the following properties.

- Less capital and high availability
- Overload tolerance
- Self protection
- Flexibility in performance
- Decision making needs reasoning
- Interpretation of unclear signals
- Adaptability to new programmes
- Ability to cope with unexpected events
- Learning from experience
- Human beings for some reasons are needed.

Machines are preferred in jobs which need the following properties.

- Taking orders of varying degrees
- Resistance to radiation, temperature, toxic hazards
- Mechanical power
- Routine work is carried out
- Quick acquisition of information
- Disposibility
Human being can not work due to lack of space etc.
Safer for machine but not so for human beings.
For example shift work that can be done by machines need not be left for human beings.
Morally degrading
Stress and strain causing jobs.

Source: Industrial hazard and safety handbook by King Magid + Own addition.

Decision on what to choose with respect to the above may be easy but sometimes a good study is necessary especially when liability to errors is involved. Man makes errors but due to the fear of responsibility, once he detects an error, he corrects it promptly while the machine rarely goes wrong but should it do so, correction is not easy. Sensing of errors is easier by modern machines. The human being has also a variety of senses but it sometimes becomes very hard to detect some important signals.

Another area which needs a lot of consideration is the man - machine interface. Accidents are often caused by misjudgements and hazards arising from the machine themselves. This is mostly due to inadequate information and sometimes the information from the machines renders itself ambiguous to interpret and this leads to the misjudgement from the human operator. Where man - machine interface can not be avoided, due regard shall be taken to make the interface a perfect marriage. All applicable favourable conditions of modern ergonomics should be applied to make the man - machine interface a successful one. That is, aimed at increasing safety and not too much overrun by economic and social factors.
Safety is associated with risks or accidents. What is not safe is either dangerous or risky. One of the main aims of technology is to make it convenient for the worker to perform his duties and at the same time increase performance output and safety.

This chapter is divided into two parts. The first part covers general knowledge on reliability of equipments and matters associated with it, and briefly touches on the existence of risk and encounter rates.

The second part relates the equipment cost to safety. This has been done through brief explanation and worked examples.

5.1 SUCCESS ANALYSIS OF EQUIPMENTS

Quantitative success analysis of equipments depend on two factors:

Reliability \((R)\) which is the probability that an equipment will perform successively within the intended period of time in a stipulated environment.

If \(Q\) is taken as the probability of failure of same equipment, then \(P(R) + P(Q) = 1\)

meaning that \(P(R) = 1 - P(Q)\).
Equipment failures can occur in three life stages of an equipment.

Early failures which occur in the "running in" period. These are mostly due to substandard components or poor workmanship during assembly of components.

Random failures which occur at any time of the equipments life period.

Wear out failures which occur after useful time of components. Mainly due to fatigue, age, etc.

Another factor which needs serious consideration is the $t/T$ ratio, where $t$ is the required operating time and $T$ is the mean time between failures.

When $t/T$ is 1 reliability is 0.368

$$P(Q) = \left(1 - e^{-t/T}\right) \text{ and since}$$

$$P(R) = 1 - P(Q) \text{ then}$$

$$P(R) = 1 - \left(1 - e^{-t/T}\right) = e^{-t/T}.$$ 

To increase reliability the $t/T$ ratio shall be as small as possible.

Mode of operation of the system plays a big part as well in system reliability. If two equipments are operating in series and each with a reliability of say $r$, then the system's reliability obeys the Product Law of reliability

$$R_s = r \times r = r^2 \text{ ( } r = \text{ individual reliability } )$$
If say \( r = 0.9 \) then system reliability = \( 0.9 \times 0.9 = 0.81 \)

Should the same equipments be operating in parallel,
then failure probability of each = \( 1-r \)

Probability that both will fail = \((1 - r)^2\)

Should \( r \) remain as 0.9 then \( 1 - 0.9 = 0.1 \)

Probability of both failing = \((0.1)^2 = 0.01\)

Giving system reliability as 0.99

In order to keep the reliability as high as possible the following should be considered as important.

- If funds are there then buy equipments of very high reliability according to available funds
- Encourage the use of parallel redundant systems
- Installation of standby equipments
- Equipments to be used under prescribed optimum environmental conditions
- Equipments to be handled by people who are duly qualified to use them
- Manufacturers manuals of instructions to be followed closely
Redundant systems are costly, they increase complexity and maintenance load. Sometimes they may stay for a very long time without being used but the weight of their function when their services are called for, can never be parallel with anything else within the given conditions.

Means shall be provided for early detection of malfunction of system and the faulty components should be identified by the detection system.

Improvement of environmental conditions by controlling temperature, humidity, shock, vibration, corrosion, erosion, radiation, friction etc can not be strongly stressed because the paper takes the view that in this computerized phase, the sensitivity of the equipments is common knowledge at least to the people addressed by the paper. Most of the conditions asked for, for high reliability are well taken care of at sea except redundancy system which is not done in most of the ships.

The high accuracy of radar and ARPA, coupled with their high reliability satisfy by far the required IMO standards of performance as stipulated in Resolution A 477.

Some ARPAs have extra facilities like the Possible Points of Collision which help in indicating possible points of collision with other ships. The main problem with modern equipments is proper compatibility with the operators. Many accidents are caused by this problem.

The man-machine interface is the area which needs more attention for optimum use of equipments and the human resources. It is from the solution of this problem that the contribution of modern technology can be appreciated.
5.2 EXISTENCE OF RISK

Different methods of establishing the existence of risk in a particular situation do exist. While statistics can be fully exploited in this situation, the problem with it is that it depends on past history of particular occurrences in a given area. Accidents do not happen in the same area all the time, mostly because never does the same situation occur in the same area. Time factor will also add to the problem because an area may undergo many changes in traffic density and traffic regulations. This leads to data being collected from different points of references. This may also lead to irregularities in magnitude of accidents during same intervals of time. Thus you may find unproportional number of accidents happening during corresponding intervals. Sizes of ships involved in the accidents and nature of the accidents influence a lot on the recurrence of accidents. All these are conditions which need consideration for risk measurement.

In determining existence of risk, boundaries need to be defined beyond which the risk becomes less significant for immediate response.

Distance from the ship to the boundary will be called ship domain which was defined by E.M. Goodwin as the effective area around a ship which a navigator would like to keep free with respect to other ships and stationary objects. The domain would vary in size and shape according to manoeuvring characteristics of a ship, traffic density in the area, speed of vessel, visibility, water available, how well the ship is equipped both equipmentwise and manwise.

Since this paper is mainly involved with the technical
aspect of the subject, consideration will be given to the ability of the vessel to detect its presence in the domain and the possibility of averting danger. This means that within the domain there must be a smaller domain below which no action can succeed in averting danger. This domain was called the "HARDCORE DOMAIN" by Fujii.

The word encounter has been used by most authors to mean the penetration of a vessel in another one's domain. Just like domain, encounters do vary in degrees of risks they carry. An encounter with a slower vessel from the stern when overtaking is generally less serious to an encounter with a crossing vessel, or a head on vessel. An encounter with a stationary object should pose minimum risk if proper consideration was given before the encounter. Encounters with bad weather vary in degree of danger as well.

Modern position fixing equipments, not only do they offer reliability and accuracy but also availability within the IMO requirements (being able to get the ship's position at all times). Therefore with the technology currently present, measurement of existence of risk is possible.

5.3 ENCOUNTERS

An encounter is said to have occurred if a vessel enters the domain of another vessel, or generally the area of danger. The higher the number of encounters the higher is the existence of danger in that particular area. Encounter rate is the number of encounters per unit time. Number of encounters with danger depend on many factors, among them being season, time of day, vessels speed, area in consideration, etc.
The probability of encountering bad weather in the North Atlantic in winter is higher than in summer. This leads to the understanding that the probability of sustaining damage from weather in winter is higher than in summer in this area. The lesser the speed the longer the vessel will be exposed to this type of danger. The contribution by technology to this factor is the availability of vessels capable of trading in these waters during such season, modern weather forecasting methods giving reliable predictions, and the seasonal load line rules to be observed.

When it comes to ships, the encounter rate between ships indicates the probability of collisions. But this is only true to a certain degree. When navigators become aware of a risky area, a lot of preparations are done to see that a safe passage is executed throughout this area.

At the back of this document, an annex on encounter rates is included for detailed information.

5.4 RELATIONSHIP BETWEEN EQUIPMENT COST AND SAFETY FACTOR LEVEL.

THE BITTERNESS OF LOW QUALITY REMAINS LONG AFTER THE SWEETNESS OF LOW PRICE IS FORGOTTEN. (Port of Gothenburg

Modern technology as applied to ships, it means, inter alia, ship automation.
Ship automation system consists of:

- Bridge automation
-Engine room automation

-Cargo handling, cargo plans, stability, stress, etc

-Administration management- use of computers

-Ship safety control

-Telecommunication etc

Ship automation system is expensive and very taxing to the ship owner. Cost verses benefit analysis is necessary to convince the ship owner of its justification in being applied to the ships. The ship owner is already overburdened by the existing expenses of ship operations. We should refrain from the common notion of branding ship owners who resist investing on non fully explained technological adventures as putting commercial considerations before the lives of his crew. What we should try to do is to convince the shipowners that installation of technologically advanced devices does not only increase safety or helps in maintaining the existing level of safety, but could be commercially attractive.

The author would like to point out that Decca navigator is not a mandatory equipment on board the ship yet it is fitted on in majority of ships, plying in Decca covered areas.
Navigation as it is today, is collection of data, filtering the data, selecting the filtered data and optimally manipulating this data to provide a highly efficient control of the ship's movement along a designated path. Generally, the more sophisticated a navaid is, the more precise navigation is expected from its proper application. As indicated above, more sophisticated equipments mean more expenditure to governments / shipowners and thus the understanding to their resentment to efforts by IMO and other international bodies of trying to increase number of mandatory equipments for installation on board ships.

Three main factors may be benefited from the above subtopic.

-Savings in the running time of ships

-Savings in fuel consumption

-Reduction of marine accidents.

Savings in the running time of ships can be performed by reducing error in position fixing and reducing error in dead reckoning between fixes. These errors can be eliminated by using sophisticated nav aids whose accuracy is precise thus eliminating position errors due to equipments, and if the availability of the equipment is continuous, then there will be no need for dead reckoning. Global Positioning Satellite receivers meet the continuous availability requirement if and only if the controller allows it to do so. (Controller is the owner of the system.)
Another contributor to savings in running time is reduction in propulsive losses owing to the optimal steering control. The influence of control performance upon propulsion of the ship is long known. The losses are caused by additional resistance to ships movement due to rudder action and inertial drag arising when yaw and lateral drift occur simultaneously. Propulsive losses are especially pronounced during sharp turns where the ship velocity may be reduced by 25-30 per cent. It can be shown that the relative increment of ship's velocity relates to ship's movement parameters as follows:

\[ \frac{dv}{V} = K_1 \delta^2 + K_2 \omega^2 \]

Where \( dv \) = relative increment in ship's velocity

\( V \) = Ship's velocity

\( K_1 \) and \( K_2 \) are constants

\( \delta^2 \) and \( \omega^2 \) are variances in rudder angles and ship's rate of turn respectively.

An example may serve as illustration.

Imagine two similar ships with different navaids in them. Let ship 1 have conventional navaids and ship 2 have modern sophisticated navaids equipments.

Let \( t \) be running time per voyage in days

\( R \) be running time at sea in days

\( B \) be berthing time ie time in port in days
be running time coefficient \( \frac{t_R}{t} \)

\[ t = t_R + t_B \]

\[ t_R = t \]

\[ t_R = t_1 R - t_2 R = 1 - \frac{t_2 R}{t_1 R} \] \( \text{(Savings in running time)} \)

\[ \frac{t_2}{t_1} = 1 - t_R \]

Let \( n = \text{number of voyages per year} \)

\( T = \text{Operational time per year in days} \)

\[ n_1 = \frac{T}{t_1} \]

\[ n_2 = \frac{T}{t_2} \]

\[ \frac{n_2}{n_1} = \frac{t_1}{t_2} = \frac{1}{1 - t_R} \]

Let \( Qv \) be quantity of cargo transferred during one voyage.

\[ Q_1 = n_1 Qv \]

\[ Q_2 = n_2 Qv \]

\[ \frac{Q_2}{Q_1} = \frac{n_2}{n_1} = \frac{1}{1 - \xi t_R} \]

Maintenance expenditure can be obtained as follows:

\[ e_1 = t_1 m \text{ Where } m = \text{daily expenditure} \]

\[ e = \text{maintenance expenditure per voyage} \]

\[ e_2 = t_2 m \]

Saving of voyage maintenance expenditure

\[ \Delta e = e_1 - e_2 = (t_1 - t_2)m \]

\[ = (t_1 R - t_2 R)m = \zeta_0 t_R t_1 m \]
Maintenance expenditure annually

\[ \Delta E_m = \Delta e_1 n_1 = mT \dot{\xi}_d t_R \]

Since \( n_1 = T \)

Savings in investment returns

\[ \Delta E_1 = \left[ \left( \frac{C}{Q_1} - \frac{C}{Q_2} \right) Q_2 \right] \]

Where \( C \) = Building cost of the ship

\( d \) = Depreciation coefficient (Initial investment)

If the life cycle of the ship is 15 years then \( d = 0.15 \)

\[ \Delta E_1 = dC(Q_2 - 1) = dC Q_2 - Q_1 \]

\[ \Delta E_1 = dC \left( \frac{1}{(1 - t_R)} - 1 \right) \]

\[ = \frac{dC \dot{\xi}_d t_R}{1 - t_R} = dC \dot{\xi}_d t_R \]

Example.

Consider a container ship with the following:

\[ \text{DW} = 14720 \text{ tonnes} \]
\[ V = 15 \text{ knots} \]
\[ T = 336 \text{ days} \]
\[ = 0.7 \]
\[ m = 6540 \text{ dollars per day} \]
\[ mf = 3000 \text{ dollars per day (fuel consumption)} \]
\[ C = 13380 \text{ thousand dollars} \]
\[ u = 1100 \text{ dollars per one thousand deadweight} \]
\[ d = 0.15 \]
OMEGA RECEIVER (1)  
\( \Delta = 3.0 \text{ nm} \)
\( \tau = 0.0 \)
\( \delta = \tau \times \sigma = 3.0 \)
\( \delta_{dr} = K_{dr} \times \tau = 0.8 \times 1.0 = 0.8 \)
\( \delta = (0.5^2 + 0.8^2)^{1/2} = 0.9 \text{ nm} \)
\( \delta_{tr} = K \sigma (2 - 2) \)
\( K \sigma = 0.0044 \)
\( \delta_{tr} = 0.0044 (3^2 - 0.9^2) = 0.036 = 3.6\% \)

Yearly Economy in fuel consumption:
\( \Delta E_F = 0.7 \times 0.036 \times 3000 \times 336 = 25400 \text{ dollars} \)

TOTAL COST EFFICIENCY
omitted

\( \Delta \text{Eff} = d_{tr}(mT + dC) + \Delta P u_0 - (\Delta m + dA) \)
no records considered
for open sea negligible

\( = 0.7 \times 0.036 (6.54 \times 336 + 0.15 \times 13380) - 0.15 \times 5.0 \)
\( = 105 \text{ thousand dollars.} \)
The total cost efficiency is constituted by:

- Maintenance expenditure saving
- Investment return saving
- Reduction of losses due to navigational accidents

Example 2.

TRANSIT RECEIVER       GPS RECEIVER
\[ \tau = 1.0 \text{ Hour} \quad \tau = 0.0 \text{ Hour} \]

\[ \delta = (\delta^2_{PF} + \delta^2_{DR})^{1/2} \]

\[ \delta_{DR} = 0.8 \]

\[ \delta_{PF} = 50 \text{ Metres} \]

\[ \delta = (\delta^2_{PF} + \delta^2_{DR})^{1/2} = 50 \text{ Metres} \]

\[ \delta = 0.027 \text{ nm} \]

\[ \delta_{TR} = \kappa v (\delta^2_1 - \delta^2_2) \]

\[ \delta_{TR} = 0.0044(0.9^2 - 0.027^2) = 0.0036 = 0.36\% \]

Transferring to fuel economy:

\[ \Delta E_F = * t_R * mf * \tau \]

\[ = 0.7 * 0.0036 * 3.0 * 336 = 2.54 \text{ thousand dollars per year.} \]
ACCIDENT REDUCTION RATE

Accuracy consideration.

\[ p = e^{-R^2/2\sigma_1^2} - e^{-R^2/2\sigma_2^2} \]

R normally between 0.5 and 2 nm \( R = 0.5 \) nm, \( P = 0.86 \)
Percentage of navigational casualties =0.8 covered by GPS

\[ P = 0.86 \times 0.8 = 0.688 \]
Total cost efficiency:

\[ \text{Eff} = 0.7 \times 0.0036 \times (6.54 \times 336 + 0.15 \times 13380) + \]
\[ 0.688 \times 1.1 \times 14.72 - 0.15 \times 5 = 19560 \text{ dollars}. \]

MORE CONSIDERATION ON FUEL CONSUMPTION

Let \( f \) be specific fuel consumption per 1 unit of Engine horse power.
Let \( P \) be Engine horse power.
Total fuel consumption per voyage \( F = fP t \)
(only running time is considered).

\[ F + \Delta F = f(P + \Delta P)(t + \Delta t) \]

\[ F + \Delta F = fPt + f\Delta Pt + fP\Delta t + f\Delta P\Delta t \]
this is a small part

dividing by \( F = fPt \)

\[ \frac{\Delta F}{F} = \frac{\Delta P}{P} + \frac{\Delta t}{t} \]
it can also be shown that \( \Delta t = \frac{\Delta s}{s} - \frac{\Delta v}{v} \).

Small deviations on engine power are directly proportional to deviations in speed.

\[ \frac{\Delta P}{P} = k \frac{\Delta v}{v} \] where \( k \) is the constant of proportionality

\[ \frac{\Delta F}{F} = (k - 1) \frac{\Delta v}{v} + \frac{\Delta s}{s} \]

Considering two ships of same dimensions we can obtain difference in fuel consumption as follows:

\[ \delta F = \left( \frac{\Delta F}{F} \right)_1 - \left( \frac{\Delta F}{F} \right)_2 \]

\[ = \left[ \frac{\Delta v}{v} \left( k^{-1} \right)_1 - \left( \frac{\Delta v}{v} \right)_2 \right] + \left( \frac{\Delta s}{s} \right)_1 - \left( \frac{\Delta s}{s} \right)_2 \]

\[ \delta F = (1-k) \left[ \left( \frac{\Delta v}{v} \right)_2 - \left( \frac{\Delta v}{v} \right)_1 \right] + \left[ \left( \frac{\Delta s}{s} \right)_1 - \left( \frac{\Delta s}{s} \right)_2 \right] \]
CHAPTER VI

MANNING OF SHIPS

6.1 FORCES INFLUENCING MANNING.

Manning of ships is influenced by many factors among them being Regulatory bodies, owners, unions, shiptype, trade, economic situation, past experience, etc.

6.2 REGULATORY BODIES.

Manning of ships is regulated by the National Maritime Administrations. Each ship should have its own manning scale depending on a number of independent factors. Labour situation, safety consideration, ship size and its equipments, crew qualifications, national and international instruments are among the guidelines that govern manning of ships, not forgetting article 94 of the United Nations Convention on Law of the sea. Crew number should not be reduced solely because the ship is highly automated. Relationship between independent automated functions and their combined performance towards safety should be thought of before decisions are made. A one-man bridge watch system in a highly automated ship would raise many questions if such a ship has no toilet on the bridge. The watchkeeping officer may need the toilet during his hours of watch. Working condition of the few people must also be taken into consideration. Many more factors are there which differ both in strength and magnitude.
6.3 OWNERS.
Owners would generally like their ships to carry the minimum number of crew required for safe and economical passage. Advancement in ship automation will continue until no more benefit comes from crew reduction. There is strong belief that owners are in the process of grading the existing crew to safety, economical and social, with the aim of having full control over possibly the economical and social crew. The author does understand the already heavy burden that the shipowners have especially with high manning expenses, made worse by the soaring educational and training expenses. The author does not sympathise though, with shipowners who intentionally underman their ships and end up with accidents that could be avoided. With the recent experience of the RORO ship Herald of Free Enterprise, owners need to show more initiative in seeing to it that manning is not reduced to an unsafe scale.

6.4 UNIONS.
The unions are generally interested in getting as many people on board as possible. They also do understand that too many people in a work area increase the probability of failure and thus add to the possibilities of the risks of accidents. Since unions are supposed to control their members, a strong union is necessary to ensure that only capable people are sent to sea. They should be capable to such a level that unnecessary supervision shall not be called for when one is assigned to a job. Incompetent people who might have been sent to sea because of the notion, "It is who you know and not what you know" should be discharged from the ship as soon as possible or hold a rank which fits them.
6.5 SHIPTYPE.
The type of ship should be considered when manning is done.

Some of the factors that need serious considerations are:

Cargo carried --> Where the cargo carried is too dangerous such that no much repair or maintenance work can be done on board when the vessel is at sea, the vessel should carry just enough people for the duties intended to be done on board with due consideration for emergencies. It is easier to deal with just the right number of people during an emergency than having to deal with more than needed to operate the ship. It is also easier to rescue and put to safety, fewer people than many. Sophisticated ships which have many automated facilities, need to carry enough crew for the ships safe operation. A lot of study in ergonomics is needed to come up with a safe manning scale especially in very new sophisticated vessels. One man bridge watch system will soon be applied everywhere but nobody knows how many ships are worth applying the one man bridge manning scale. Again, how many bridges have toilets? Is the duty officer going to call the master every time he wants to go to the toilet? Will the master be there at all the time when he is needed? Do the bridge wings have means of knowing what is going on in the bridge or are the regulations going to tie the watchkeeping officers only in the bridge? A few designs of the bridge of the future ship have come up with completely enclosed bridges and wings. While low bearings may be ably taken from the bridge and wings, high doubts exist as to whether sights can be observed conveniently. It is the view of many that the time of the sextant are long time gone but should we not take it out of the requirements first before we start contravening with the legally existing rules and regulations?
6.6 TRADE.

By trade, the paper is more concerned with type of cargo, duration of voyage and frequency of trips. While small ships which ply in coastal waters are normally allowed to sail with few crew, the author feels that these are the vessels which require relatively many people when compared to the foreign going ships. These ship do not normally wait at the roads for pilots thus having no running time - berthing time delay. Being small ships, duration of stay in port is very short and since duration of voyage is also very short, people working in such ships hardly have time to rest before going on duty. The tendency is a long stretch of duty, followed by a very short rest and then back to duty. Again the recent example of the member of crew of the Herald of Free Enterprise who was overworked to an extent that when he was eventually relieved, he went to deep sleep which unfortunately could not see him wake up to perform one of the most important tasks before the ship leaves port. Consequently the vessel ended up capsizing with a loss of 188 lives. Extra cost is what everyone of us is trying to avoid but where it is inevitable, it should be met with open hands and especially where safety to life is endangered.

6.7 ECONOMIC SITUATION.

Nothing much can be said in this topic except the fact that when the economic situation is good then the negotiations with regards to size of manning do not meet with big resistances as compared to when the economic situation is in the doldrums.
6.8 PAST EXPERIENCE.

*Experience is the best teacher.*

There are no perfect answers to questions regarding manning. Anything that has no perfect answer would have many alternative ways of solving. Decisions made on scanty information are dangerous and should be avoided. Where people have not got the required experience on the matter, they should seriously seek for advice. This will save them from the pitfalls of TRIAL and ERROR methods, and also from management in crisis which normally accompanies such practices. Decisions should be based on results from research supported by past experience where applicable. Modern equipments (computers, simulators, etc.) combined with modern ways of exchange of information/data coupled with modern thinking, ergonomics included, should be able to aid past experience in coming up with something better for the future.
CHAPTER VII

CONCLUSION AND RECOMMENDATIONS.

The paper covers many topics and it is hoped that it will be of interest and everyone concerned with the topic would study it. In reaching the major recommendations which follow, the authors consideration was given to these issues:-

- The adverse impact international competition is having on shipping between the developed maritime nations and its spill over influence to the less developed maritime nations

- The growing extent to which technology is being incorporated in ships and applied to shipping operations

- The growing extent to which shipping companies want flexibility and freedom from constraints in their operations

- Lack of infrastructure, resources and the drive to work efficiently in some of the countries

- Unawareness of current developments in the shipping industry and the difficulties involved in keeping pace with what is currently going on (applies to some countries only)

- The fact that the author constantly remembered that he comes from a less developed maritime nation
1. CONCLUSION

Sea transportation is still the cheapest transportation mode with the smallest fatal rate.

RECOMMENDATION

In countries where shipping is not developed may be due to it not being one of the nation's priorities, serious consideration shall be given to exploit the above mentioned advantages.

2. CONCLUSION

Delegation of some of Government's responsibilities to non-government institutions as experienced between the government authorities and the Classification societies has so far worked excellently and there is no doubt that it will continue to do so.

RECOMMENDATION

Delegation of some of Government's responsibilities to non-government institutions needs to be extended to other possible fields.

3. CONCLUSION

Technology-based training is initially more expensive than instructor-based training but it becomes cheaper than instructor-based training for recurring courses which are conducted for a long time. Shipping technology is complex and changes faster than accepted by many people in the shipping industry.
Where a choice exists, one should go for technology-based training. This is a technology-based world and everyone should try to adjust himself to it. Refresher courses should be given frequently/regularly to keep the people up to date with the developments in the industry.

4. CONCLUSION
Transfer of ownership/technology will continue as uneconomical highly automated ships change hands to mostly foreign owners. The guarantee of having the right crew for a particular ship will not be there for every ship. Manning agents will exist for much longer than anticipated. The stress, strain and fatigue from long working hours, shift work, less manning, commercial pressures for expeditious passage making and from the challenges of advanced technology will continue until a good solution is worked out.

RECOMMENDATION
When buying a highly sophisticated second hand ship, the following shall be considered:

- Whether the right people to operate the vessel are available

- Whether the influence of modern technology towards safety is known eg Capable people in the country to conduct quick and effective investigations.
These investigations will be conducted under pressure because the ship has to sail and also developed maritime nations investigation costs are unapproachably high. This is why the paper recommends capable local investigators for less developed maritime nations. Where there are no capable local accident investigators, foreign help should be considered.

Where evidence exists beyond doubt that a crew agent supplied unfit crew for a ship with knowledge, steps to stop this bad practice should be taken against such agents.

The questions of fatigue, stress, strain from the effects of advanced technology require the utmost attention.

5. CONCLUSION

Advanced technology has had a marked achievement in the reduction of accidents at sea especially in collision and groundings, and the same trend is noticed in the specialized carriers with regards to losses from fire/explosion. Not much impact is noticed in the weather associated accidents. With regards to age, the younger ships enjoy the least number of losses.

RECOMMENDATION

The question of reliability of equipments must be constantly stressed. The mean time between failure that is indicated for a particular equipment shall be the least one of the different components making up the equipment. Technology should be allowed to advance.

MAY BE NOT AT ITS OWN PACE, BUT IT SHOULD NOT BE CONTROLLED TO SUCH AN EXTENT AS TO HINDER ITS PROGRESS.
6. CONCLUSION

Government maritime authorities are the government bodies overseeing maritime affairs. Credibility for efficient and effective maritime rules and regulations, plus enforcement of these rules and regulations is owed to them. The rules, regulations and enforcement have in most cases been adequate, yet nobody is wholly satisfied with the current magnitude of the number of losses of ships due to maritime accidents. A deep desire to prevent accidents seem to be lacking.

RECOMMENDATION

ALL MEANS AND RESOURCES SHALL BE USED TO CULTIVATE THIS DEEP DESIRE TO PREVENT ACCIDENTS TO ALL PARTIES CONCERNED.
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For vessels of 500 gross registered tonnage and above.

**Source:** Paper 2 by J.P. Cashman to Second West European Conference on Marine Technology "Safety at Sea" held in London May 1977.
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APPLIES TO VESSELS OF 500 GROSS REGISTERED TONS AND ABOVE.

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**TOTAL** | 195 193 208 203 261 278 228 248 236 209 214 189 156
---|---
**Merchant Fleets** | 61194 63724 65887 67945 69020 71129 73832 73864 75151 76106 76432 75421
**World Tonnage Loss ratio** | 0.34 0.35 0.33 0.31 0.35 0.56 0.43 0.39 0.35 0.33 0.31 0.32 0.31

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<td>38</td>
<td>7</td>
<td>2</td>
<td>23</td>
<td>12</td>
<td>156</td>
</tr>
</tbody>
</table>

**SOURCE:** LLOYD'S REGISTER CASUALTY RETURNS.
5.3 ENCOUNTER RATES

The Encounter rate is given by \( C = 2 R p (V_r) \)

where \( R \) = encounter radius
\( p \) = density of stream
\( V_r \) = mean speed of main stream relative to that of the vessel.

If all the vessels are restricted to one speed, then the relative velocity can be given by

\[ V_r = (U^2 + V_m^2 - 2UV_m \cos \theta)^{1/2} \]

Where \( U \) = speed of vessel in consideration (own)
\( V_m \) = speed of main stream
\( \theta \) = angle between direction of own vessel and main stream.

If we consider a vessel with speed \( U \) crossing a route at an angle \( \theta \), such that the main route has a traffic flow of \( N_m \) ships in time \( T \) given by the function \( f(v) \)

The mean number of ships of speed \( V \) in the main route passing a particular point is given by

\( N_m f(v) \, dv/T \) per unit time.

On average these ships will be a distance

\( Tv / (N_m f(v) \, dv) \), apart.

If the route is of width \( W \), there will be one such ship.
in an area $T Wv / (Nmf(v)dv)$ thus giving an average area density of $Nmf(v)dv / T Wv$.

Since the domain radius of the crossing ship is $R$ and the relative velocity with respect to the ships in the main route is $(U^2 + Vm^2 - 2UVm \cos D)^{1/2}$, then the area in which encounters occur covered by the crossing vessel in unit time is given by:

$$2R (U^2 + Vm^2 - 2UVm \cos D)^{1/2}$$

Average number of encounters per unit time

$$= 2R (U^2 + Vm^2 - 2UVm \cos D)^{1/2} Nm f(v)dv$$

$$\frac{\text{Time taken to cross the main route is } W \div (U \sin D)}{TWv}$$

Therefore total number of encounters made in a completed crossing is

$$2R Nm f(v) * (U^2 + Vm^2 - 2UVm \cos D)^{1/2} dv$$

$$\frac{\text{Time taken to cross the main route is } W \div (U \sin D)}{TUVm \sin D}$$

The total number of encounters for all "$V"$ ships =

$$2RNm \int_{U V}^{V = \max} f(v) (U^2 + Vm^2 - 2UVm \cos D)^{1/2} dv$$

$$\frac{T \sin D}{V = 0}$$

The encounter rate in such a crossing area for two crossing routes is

$$E_x = 2RNmNU \frac{u=\max}{T^2 \sin D} \frac{v=\max}{v=0} \int_{u=0}^{u=\max} f(u) f(v) (u^2 + Vm^2 2UVm \cos D)^{1/2} du dv$$

$$U V$$

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The encounter rate for a given area gives the navigating officer an indication of the level of probable risk to his own ship while navigating in such an area. Not all accidents happen in an area with heavy traffic, and sometimes areas with dense traffic register less number of accidents. Some of the reasons to this fact are awareness of the high probability of risk in such areas, proper voyage planning, execution and monitoring of the progress at different stages while in the area, not forgetting proper performance of navigational aids, backed up by well trained crew.

From the above formulae, to reduce the number of encounters, the variation in speeds of the vessels in the main route should be as small as possible. This suggests a given speed by all vessels within a lane of a main route. Theoretically easy to fulfil but practically close to impossible due to the fact that current vessels differ very much in their safe operational speeds. While this may technologically be possible, it definately is not economically viable and as such, it stands zero chance of success.

The other possibility is by all vessels to cross each other with same speed which is also not possible using the same reasoning above.

Thirdly, encounters can be minimised by using an optimum crossing angle. According to the formulae above, this angle should be 90 degrees, but work by W.G.P.Lamb on "Calculation of collision risk" indicate minimum risk rate occurring at about 60 degrees, when crossing vessel gives way and at about 95 degrees when it stands on. Corresponding minimum risks per encounter occur at 60 degrees and 135 degrees respectively. The above figures refer to clear visibility condition.

In conditions of restricted visibility the angles for
minimum risk rate occur at about 15 degrees and a minor minimum at about 80 degrees when main traffic gives way. His work also came up with a conclusion that the risk per encounter rises in both cases as the course difference angle is increased except when the give way vessels are the ones in the main route. In this situation the maximum is at 55 degrees and the minimum is at 110 degrees. Difference in result to angles come due to the fact that Mr W.G.P.Lamb got his results using the weighting method whereby different weights were applied depending on whether the vessels were at the boundary of the domain or close to own ship. Approaching vessels to the domain and the ones which were on the leaving phase were also given different weights.

With modern technology, equipments capable of handling programs that can give to the navigator, the optimum crossing angle for less or minimum encounters are available. This, coupled with the existing ARPA facility of trial manoeuvre, should be able to reduce the stress and strain that the navigators bear in congested waters. The other feature of the ARPA which gives the Probable points of collisions between two ships, does also help to indicate the risks involved between two ships on crossing courses. The main problem to the capability of the present technology is that it is not yet properly married to the collision regulations which are legally binding. If people will just follow a course because it gives them the least number of encounters or the least risk per encounter then strict observance to the traffic separation scheme regulations will be smeared, which may result in an increase in the number of accidents especially in the areas with dense traffic. Therefore for these findings to be of any value, they should be supported by the law ie they should be
incorporated in the COLREGs. Once incorporated, the remaining can be easily handled by radar, ARPA and the man. Another problem may be to justify its need in a time when the shipping industry is experiencing a very hard economical phase to remain in the game, as once incorporated then it would involve acquiring the necessary equipments for its implementation.
## BASIC SHIP CARRIAGE REQUIREMENTS FOR THE SYSTEM

<table>
<thead>
<tr>
<th>Area/Equipment</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Area A1</strong></td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td><strong>Area A2</strong></td>
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<td>x</td>
<td></td>
<td>x</td>
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<td></td>
</tr>
<tr>
<td><strong>Area A3</strong></td>
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<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
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<td>x</td>
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<tr>
<td><strong>Area A4</strong></td>
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<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

- **VHF radio-station capable of voice and DSC communications**
- **MF radio-station capable of voice and DSC communications**
- **MF/HF radio-station capable of voice, DSC and direct printing communications**
- **NAVTEX receiver in areas covered by NAVTEX transmissions**
- **INMARSAT ship earth station (Standard-A or Standard-C)**
- **Satellite EPIRB operating on the 406 MHz frequency through the COSPAS-SARSAT**
- **VHF EPIRB**
- **Survival craft**
- **9 GHz radar transponders**
- **VHF portable radio station**

* See note on page 7.
### PROVISIONAL COST ESTIMATES FOR GMDSS EQUIPMENT

<table>
<thead>
<tr>
<th>No.</th>
<th>Equipment</th>
<th>Estimated cost (US$)</th>
<th>Equipment</th>
<th>Estimated cost (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>VHF radiostation capable of voice and digital selective calling (DSC) communications</td>
<td>5500</td>
<td>VHF DSC</td>
<td>25000</td>
</tr>
<tr>
<td>2</td>
<td>MF radiostation capable of voice and DSC communications</td>
<td>7400</td>
<td>MF DSC</td>
<td>47500</td>
</tr>
<tr>
<td>3</td>
<td>MF/HF radiostation capable of voice, DSC and direct printing communications</td>
<td>11100</td>
<td>HF DSC + radiotelex³</td>
<td>150000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>NBDP</td>
<td>90000</td>
</tr>
<tr>
<td>4</td>
<td>NAVTEX receiver</td>
<td>1000</td>
<td>NAVTEX</td>
<td>90000</td>
</tr>
<tr>
<td>5</td>
<td>INMARSAT ship earth station (SES)</td>
<td>30000</td>
<td>INMARSAT coast earth station³</td>
<td>7-10 million</td>
</tr>
<tr>
<td></td>
<td>Standard-A</td>
<td>30000</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Standard-C</td>
<td>5000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Satellite EPIRB (406 MHz)</td>
<td>500-1000</td>
<td>COSPAS-SARSAT local user terminal³</td>
<td>800,000</td>
</tr>
<tr>
<td>7</td>
<td>VHF EPIRB</td>
<td>2000</td>
<td>INMARSAT satellite CES</td>
<td>1,000,000</td>
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<td></td>
<td></td>
<td></td>
<td>EPIRB processing equipment</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>SAR transponder</td>
<td>500-1000</td>
<td>Ship earth station</td>
<td>30000</td>
</tr>
<tr>
<td></td>
<td>survival craft equipment</td>
<td></td>
<td>for use at RCC</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Portable VHF equipment (two sets)</td>
<td>1100</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

1 Cost estimates are considered accurate within ± 30% and include 15% installation costs.

2 The estimated total cost of equipment for ships depends on carriage requirements which are defined in accordance with each ship's area of operation. The estimated total cost of equipment for ships sailing in GMDSS areas will be:

   - area A1: $9,100 - 10,100
   - area A1 + A2: $16,500 - 17,600
   - area A1 + A2 + A3 without SES: $27,600 - 28,600
   - area A1 + A2 + A3 with SES Standard-A: $46,500 - 47,500
   - area A1 + A2 + A3 with SES Standard-C: $21,500 - 22,500
   - area A1 + A2 + A3 + A4 without SES: $27,800 - 28,600
   - area A1 + A2 + A3 + A4 with SES Standard-A: $57,600 - 58,600
   - area A1 + A2 + A3 + A4 with SES Standard-C: $32,600 - 33,600

   For comparison, the cost of providing a radiotelegraph station meeting the minimum requirements of the 1974 SOLAS Convention, as amended, is in the order of $25,000 for the equipment. However, in most cases extra equipment is also provided and the average cost of equipment fitted is $35,000. The cost of providing equipment for ships obliged to carry only a radiotelephone installation to the minimum requirements of the SOLAS 1974 Convention, as amended, are in the order of $8,000 for the equipment and, if HF RT is included, $13,000.

3 It has yet to be decided whether these costs should be included in estimates since "regional use" can be made of existing coast earth stations which also provide non-distress communications and COSPAS-SARSAT local user terminals will be used on shared basis with other services. The same could apply to HF DSC.

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250 ships lost in 1 year

SPECIFIC CASUALTY INFORMATION

→ Owners of ships lost
→ Solicitors of interested parties.
→ The Salvage Association
→ Underwriters - Hull and Cargo
→ Protection and Indemnity Clubs
→ Arbitrators
→ Classification Societies

CASUALTY INFORMATION HELD IN CONFIDENCE - NOT PASSED TO SHIPS IN SERVICE.

Maritime Authority of the Flag State

Formal Inquiry (not always held)

Report of Inquiry (not always published)

System for circulation of Inquiry findings to all ships - non-existent

Ships in service not informed of cause of loss of 250 ships in the year.

250 more ships sailing to disaster next year.

SEA TRANSPORT - The Flow of Information on Casualties.
TOWNSEND SAID NO TO SAFETY CALLS

The evidence

STATEMENT FROM WORKING PARTY - 15 FEBRUARY 1982

Progress has been made towards concluding agreements but “Spirit” class meaning is still in contention particularly when one of these vessels is scheduled as seaborne relief. Management feel we are gaining agreement and custom and practice in the case of the seaborne relief. We define this as an agreement specifically to “Spirit” class ships by name but we do agree that these vessels have operated to seaborne with “Free Enterprise” meaning...
OPINIONS AND COMMENTS ON SOME MAJOR DISASTERS

To give some examples of the opinions of others, the comments about some typical cases are quoted:

TITANIC

"Although this inquiry was held with top level legal aid it would seem that after all these years the validity of some of its judgments leave room for doubt".

DERBYSHIRE

"Major safety probe after 'Derbyshire'. The Government launched a major safety probe into ship stability after the loss of the 'Derbyshire' but refused to conduct an official inquiry into the loss of the vessel itself."

Lloyds List 14 May 1981 page 1

ALEXANDER KIELLAND

"Inquiry convened under Norwegian Maritime Law. The Commission of Inquiry was appointed by the Ministry of Justice and consisted of 5 men chaired by a District Judge."

Lloyds List 5 May 1981 page 14

Det Norske Veritas said that the Commission of Inquiry "over-dimensioned and idealised its function and place in the structure of inspection and control which is based on supervision of control and repair procedures by the builder and operator rather than detailed direct involvement".

Lloyds List 4 April 1981 page 1
KURDISTAN

"Wreck Commission stated proceedings were taking too long with too much
detail being given in primary and expert evidence."

Lloyds List 7 July 1981 page 1

(in all the Inquiry lasted 10 weeks and cost over one million pounds).

Dr Ewan Corlett giving evidence at the Inquiry said the "maritime world
should take a leaf from the aeronautical industry's book in the way
casualties are investigated.

More casualty information should be made available to owners and the
procedures for investigating a crack in the hold of a ship or an
aeroplane should be the same.

As soon as an accident occurs, the authorities in the region should carry
out their own investigation as quickly as possible and send the
preliminary information by telex to the appropriate administrations around
the world. Then information would be given to classification societies
for further investigation and information passed to interested parties and
owners."

Lloyds List 15 July 1981

BETELGUESE

In a speech in October 1980 Dr Black said of the Inquiry "it seemed too
much to have the character of a civil action rather than an Inquiry into
causes. The fundamental nature of the Inquiry seemed to be lost sight
of."

CUTTLEFISH

Whilst noting the delays in most marine inquiries it must be admitted that
the judgment delivered on the skipper's certificate was delivered only
about 10 months after the stranding.

It is understood that the Department of Trade have a formulae for deciding
whether a casualty is of a serious nature or otherwise and thus merits
the cost, time and trouble of an inquiry. It would be of interest if
someone from the Department would outline their basis of decision making.
In the event that every accident were investigated besides adding consider­
ably to the cost it would mean that the operating personnel's certificates
and livelihood would be at stake and where the loss was purely commercial
this may be too severe a penalty.
Enforcement traffic management functions

It has been seen that rules form the main method whereby the organisation for traffic management influences traffic. Since such rules are designed to improve safety and efficiency, it follows that they should be observed and complied with.

There are a number of mechanisms for ensuring a high state of observance of rules. The major one is that all the relevant decision makers see clear benefits in obeying the rules. However, there will be those who either are unaware of the rules, or who choose to break the rules for whatever reason.

Hence the need arises to encourage compliance with rules. This has been termed enforcement, although Cost 301 recognises that such an expression can represent one extreme of a series of measures designed to achieve the objective of full observance by all concerned of all the relevant rules. VTS, by virtue of the information it can acquire, can have a role in the enforcement of rules.

The general scheme for studies of the enforcement functions of traffic management is shown in Fig. 3.4. Enforcement is concerned with rules (Box 1) which must therefore be identified. The extent to which each rule is complied with can be measured in terms of its state of observance, the parameters of which must be defined (Box 2). For any authority—in e.g., a VTS—to be able to enforce rules, it must first detect any non-compliance, and the parameters which can be used must be identified (Box 3). VTS as part of the organisation for traffic management can take a number of actions in an enforcement role (Box 4). A number of factors (Box 5), some of which will be influenced by VTS, can affect the actual state of observance of rules (Box 6).

Studies on enforcement functions

Within the general scheme shown in Fig. 3.4, outline studies were carried on within Cost 301 on the following topics:

(a) Rules: the typology of rules, jurisdiction and summary of rules to be considered (Box 1).
(b) The existing situation regarding the state of observance of rules and enforcement measures, leading to rules which should be better enforced (Boxes 6 and 7).
(c) The parameters which can be used to detect non-compliance (Box 3).
(d) The factors which affect the state of observance of rules (Box 5).
(e) VTS enforcement functions and information (Box 6).

Figure 3.5: Collisions in the Dover Strait, 1960–79. This actual state of observance will have an effect on the safety and efficiency of traffic in the area and on pollution (Box 7).

Figure 3.4: Parameters relevant to enforcement functions.
The long-term trend of improvement in the passenger safety record for the scheduled air services of the world (international and domestic) was reversed in 1966 for the first time since 1960, the fatality rate per 100 million passenger-kilometres rising from 0.35 in 1965 to 0.40 in 1966, and the number of passengers killed increasing from 684 to 908. (The figures are still preliminary but are unlikely to be altered by more than 1 or 2 per cent.) It seems clear, however, that this deterioration in the accident rates can be regarded as a temporary phenomenon due to the chance occurrence of a number of serious accidents to relatively large aircraft with unusually high load factors.

This conclusion is reinforced by the fact that these accidents all occurred in the first quarter of the year when there were some 400 fatalities more than would be expected according to previous first quarters. Such occurrences may be expected to take place from time to time according to the rules of statistical probability. The following quarter, with only 31 fatalities as compared with previous second quarters at about 150, was as exceptionally good as the first quarter was exceptionally bad, and the remainder of the year showed a satisfactory improvement when compared with the second half of 1965. The statistics suggest that during the present decade the total number of passenger fatalities due to flying accidents on the scheduled air services of the world is likely to average about 750 per year, and to vary any individual year within 200 of that figure. Since the average in the previous decade from 1950 to 1959 was about 450 per year, the long-period trend of this total would seem to be upwards, although in 1964 and 1965 it seemed to have flattened off.

The last column in Table 6 shows, for the first time in these Reports, figures of fatal accidents per 100 thousand aircraft landings, which are now available from the year 1960 (although the figures for the first three years had to be estimated from other data and are therefore somewhat tentative). The exposure to risk of accident is generally recognized to be related to the number of landings made on stages flown since the majority of accidents happen during the approach, landing, or subsequent take-off and climb-out. Even some of the en route risks are more related to the number of stages flown than to the distance covered (e.g., breaking cloud, passing through storms). It will be observed, however, that the figures of fatal accidents per 100 thousand aircraft landings vary in a closely similar way to those of fatal accidents per 100 million kilometres flown, although falling somewhat more slowly. This is because the average stage length flown on scheduled air services and hence the number of stages flown for any given distance is nearly constant from year to year with a slight tendency to increase in the long period.
### Table 6
**Accidents with Passenger Fatalities**

**Scheduled Air Services**

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of accidents to passengers killed</th>
<th>Number of passengers killed</th>
<th>Total accidents</th>
<th>Total accidents per 100 million Pass.</th>
<th>Fatal accidents</th>
<th>Fatal accidents per 100 million Pass.</th>
<th>Fatality rate per 100 million Pass.</th>
<th>Fatal accidents per 100 000 aircraft hours</th>
<th>Fatal accidents per 100 000 aircraft landings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1950</td>
<td>27</td>
<td>551</td>
<td>1.97</td>
<td>1.15</td>
<td>1.88</td>
<td>3.02</td>
<td>0.34</td>
<td>0.36</td>
<td>0.33</td>
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<tr>
<td>1951</td>
<td>20</td>
<td>443</td>
<td>0.77</td>
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<td>1.44</td>
<td>2.32</td>
<td>0.44</td>
<td>0.43</td>
<td>0.41</td>
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<td>1952</td>
<td>21</td>
<td>386</td>
<td>0.97</td>
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<td>556</td>
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<td>0.43</td>
<td>0.41</td>
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<tr>
<td>1958</td>
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<td>615</td>
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<td>1.02</td>
<td>1.65</td>
<td>0.34</td>
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<td>0.63</td>
<td>1.02</td>
<td>0.91</td>
<td>1.46</td>
<td>0.31</td>
<td>0.31</td>
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<td>1960</td>
<td>32/1</td>
<td>847</td>
<td>0.78</td>
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<td>1.03</td>
<td>1.66</td>
<td>0.37</td>
<td>0.37</td>
<td>0.37</td>
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<tr>
<td>1961</td>
<td>28</td>
<td>805</td>
<td>0.69</td>
<td>1.11</td>
<td>0.80</td>
<td>1.29</td>
<td>0.32</td>
<td>0.32</td>
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<tr>
<td>1962</td>
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<td>765</td>
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<td>0.86</td>
<td>1.39</td>
<td>0.36</td>
<td>0.36</td>
<td>0.36</td>
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<td>1963</td>
<td>30</td>
<td>717</td>
<td>0.49</td>
<td>0.78</td>
<td>0.88</td>
<td>1.41</td>
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<td>0.38</td>
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<td>1964</td>
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<td>0.38</td>
<td>0.62</td>
<td>0.65</td>
<td>1.05</td>
<td>0.29</td>
<td>0.29</td>
<td>0.29</td>
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<td>1965</td>
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<td>0.35</td>
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<td>0.94</td>
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<td>1966</td>
<td>24/1</td>
<td>908</td>
<td>0.40</td>
<td>0.64</td>
<td>0.54</td>
<td>1.08</td>
<td>0.26</td>
<td>0.26</td>
<td>0.26</td>
</tr>
</tbody>
</table>

**Notes:**
- Includes a mid-air collision counted as one accident.
- Preliminary figures.

**Exclusions:**
- The People's Republic of China, the USSR and other States which were not members of ICAO as at 31 December 1966.
### Table 7
Number of Fatal Accidents, Passenger Fatalities and Survivors

**Turbo-jet, Turbo-propeller and Piston-engined Aircraft**

**Scheduled Air Services**
(Total, International and Domestic)

<table>
<thead>
<tr>
<th>Classification</th>
<th>Fatal Passenger Accidents</th>
<th>Passengers Killed</th>
<th>Passengers Surviving</th>
</tr>
</thead>
<tbody>
<tr>
<td>-------------------</td>
<td>------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td><strong>Turbo-jet</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td><strong>Turbo-propeller</strong></td>
<td>75g</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td><strong>Piston-engined</strong></td>
<td>25g/</td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>33</td>
<td>25</td>
<td>23</td>
</tr>
</tbody>
</table>

**Notes:**
- Preliminary figures.
- Includes one mid-air collision between a turbo-jet and a propeller-driven (piston) aircraft (counted as two accidents in the total).
- Includes 1 helicopter with 20 passenger fatalities.
- Includes 1 helicopter with 3 passenger fatalities.
- Includes one mid-air collision between two piston-engined aircraft (counted as two accidents in the total).

**Exclusions:**
- The People's Republic of China, the USSR and other States which were not members of ICAO at 31 December 1966.
### Table 1-18. Aircraft accidents involving passenger fatalities on scheduled air services, 1966-1985

<table>
<thead>
<tr>
<th>Year</th>
<th>Aircraft accidents</th>
<th>Passengers killed</th>
<th>Passenger fatalities per 100 million Pass.- km</th>
<th>Passenger fatalities per 100 million Pass.- mile</th>
<th>Fatal accidents per 100 million Km flown</th>
<th>Fatal accidents per 100 million Miles flown</th>
<th>Fatal accidents per 100 000 Aircraft hours flown</th>
<th>Fatal accidents per 100 000 Aircraft landings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1966</td>
<td>31</td>
<td>1 001</td>
<td>0.44</td>
<td>0.70</td>
<td>0.69</td>
<td>1.11</td>
<td>0.33</td>
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</tr>
<tr>
<td>1967</td>
<td>30</td>
<td>678</td>
<td>0.25</td>
<td>0.40</td>
<td>0.57</td>
<td>0.91</td>
<td>0.29</td>
<td>0.35</td>
</tr>
<tr>
<td>1968</td>
<td>35</td>
<td>912</td>
<td>0.29</td>
<td>0.46</td>
<td>0.57</td>
<td>0.92</td>
<td>0.31</td>
<td>0.38</td>
</tr>
<tr>
<td>1969</td>
<td>32</td>
<td>946</td>
<td>0.27</td>
<td>0.43</td>
<td>0.48</td>
<td>0.77</td>
<td>0.27</td>
<td>0.34</td>
</tr>
<tr>
<td>1970</td>
<td>28</td>
<td>687</td>
<td>0.18</td>
<td>0.29</td>
<td>0.40</td>
<td>0.64</td>
<td>0.23</td>
<td>0.30</td>
</tr>
<tr>
<td>1971</td>
<td>31</td>
<td>867</td>
<td>0.21</td>
<td>0.34</td>
<td>0.44</td>
<td>0.71</td>
<td>0.26</td>
<td>0.32</td>
</tr>
<tr>
<td>1972</td>
<td>42</td>
<td>1 210</td>
<td>0.26</td>
<td>0.42</td>
<td>0.58</td>
<td>0.94</td>
<td>0.34</td>
<td>0.44</td>
</tr>
<tr>
<td>1973</td>
<td>36</td>
<td>862</td>
<td>0.17</td>
<td>0.27</td>
<td>0.48</td>
<td>0.77</td>
<td>0.28</td>
<td>0.36</td>
</tr>
<tr>
<td>1974</td>
<td>29</td>
<td>1 299</td>
<td>0.24</td>
<td>0.38</td>
<td>0.39</td>
<td>0.63</td>
<td>0.23</td>
<td>0.30</td>
</tr>
<tr>
<td>1975</td>
<td>20</td>
<td>443</td>
<td>0.08</td>
<td>0.12</td>
<td>0.27</td>
<td>0.43</td>
<td>0.16</td>
<td>0.21</td>
</tr>
<tr>
<td>1976</td>
<td>20</td>
<td>734</td>
<td>0.12</td>
<td>0.19</td>
<td>0.26</td>
<td>0.41</td>
<td>0.15</td>
<td>0.20</td>
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<tr>
<td>1977</td>
<td>24</td>
<td>516</td>
<td>0.07</td>
<td>0.12</td>
<td>0.30</td>
<td>0.48</td>
<td>0.18</td>
<td>0.24</td>
</tr>
<tr>
<td>1978</td>
<td>25</td>
<td>755</td>
<td>0.09</td>
<td>0.15</td>
<td>0.29</td>
<td>0.47</td>
<td>0.18</td>
<td>0.24</td>
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<tr>
<td>1979</td>
<td>31</td>
<td>878</td>
<td>0.10</td>
<td>0.16</td>
<td>0.34</td>
<td>0.54</td>
<td>0.21</td>
<td>0.29</td>
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<tr>
<td>1980</td>
<td>21</td>
<td>812</td>
<td>0.09</td>
<td>0.14</td>
<td>0.22</td>
<td>0.36</td>
<td>0.14</td>
<td>0.20</td>
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<tr>
<td>1981</td>
<td>21</td>
<td>362</td>
<td>0.04</td>
<td>0.06</td>
<td>0.23</td>
<td>0.37</td>
<td>0.14</td>
<td>0.21</td>
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<tr>
<td>1982</td>
<td>26</td>
<td>764</td>
<td>0.08</td>
<td>0.13</td>
<td>0.29</td>
<td>0.46</td>
<td>0.18</td>
<td>0.25</td>
</tr>
<tr>
<td>1983</td>
<td>20</td>
<td>809</td>
<td>0.08</td>
<td>0.13</td>
<td>0.21</td>
<td>0.34</td>
<td>0.13</td>
<td>0.19</td>
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<tr>
<td>1984</td>
<td>16</td>
<td>228</td>
<td>0.02</td>
<td>0.03</td>
<td>0.16</td>
<td>0.26</td>
<td>0.10</td>
<td>0.14</td>
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<tr>
<td>1985*</td>
<td>22</td>
<td>1 067</td>
<td>0.09</td>
<td>0.15</td>
<td>0.20</td>
<td>0.33</td>
<td>0.13</td>
<td>0.19</td>
</tr>
</tbody>
</table>

1. Owing to incomplete data, the USSR is not included.
2. Includes one mid-air collision shown here as one accident.
3. Includes two mid-air collisions shown here as two accidents.
4. Includes one collision on the ground shown here as one accident.
5. Preliminary figures.

Compiling accident statistics. According to this preliminary information there were 22 fatal aircraft accidents in 1985 involving 1 067 passenger fatalities in scheduled services. These numbers do not take into account the crash of a Boeing 747 aircraft in the Atlantic, which resulted in 307 passenger fatalities, since the cause of this crash is still under investigation. In 1984, there were 16 fatal accidents and 228 passenger fatalities (see Table 1-18, Table 1-19 and Diagram 5). Relating passenger fatalities to the volume of traffic, the number of passenger fatalities per 100 million passenger-kilometres increased from 0.02 in 1984 to 0.09 in 1985. The number of fatal aircraft accidents per 100 000 aircraft hours flown increased from 0.13 in 1985 from 0.10 in 1984 and the number of fatal aircraft accidents per 100 000 landings also increased to 0.19 in 1985 from the previous rate of 0.14 in 1984.

The safety levels are significantly different for the various types of aircraft operated on scheduled passenger services. For instance, in turbo-jet aircraft operations, which account for about 95 per cent of the total volume of scheduled traffic (i.e. passenger-kilometres performed), there were 7 accidents in 1985 with 861 passenger fatalities (see Table 1-19); in turbopropeller and piston-engined aircraft operations, which account for about 5 per cent of the scheduled traffic volume, there were 15 accidents with 206 passenger fatalities. The fatality rate for turbo-jet aircraft operations was, therefore, far lower than for propeller-driven aircraft. This difference may, to some extent, be explained by the route patterns and the general operating environments of the two categories of aircraft, as well as by the superior reliability of the turbo-jet engine.

4. It may be noted that for 1985, as for earlier years, the ICAO record of accidents and fatalities is probably incomplete in reference to smaller aircraft in commuter or air-taxi types of operations, both scheduled and non-scheduled. This shortcoming is believed to be insignificant in the over-all safety picture of commercial air transport.
Non-Scheduled Commercial Operations

Non-scheduled commercial operations include both the non-scheduled flights of scheduled airlines and all air transport flights of non-scheduled commercial operators. Data available to ICAO on the safety of non-scheduled passenger operations show that in 1985 there were 28 fatal accidents with 506 passenger fatalities compared to 37 fatal accidents with 146 passenger fatalities in 1984.

In non-scheduled operations performed with aircraft of more than 9000 kg take-off mass, whether by scheduled airlines or non-scheduled operators, no fatal accidents were recorded in 1984, whereas in 1985 there were 5 fatal accidents with 443 passenger fatalities.

General Aviation

Complete statistical information is not available on safety in general aviation operations, that is, other than scheduled and non-scheduled air transport operations. In 1984, it is estimated that general aviation aircraft were involved in some 1000 fatal accidents and the number of fatalities in these accidents was about 2050. The number of fatal accidents per 100,000 aircraft hours flown was about 2.2 in 1984. In the United States, which accounts for about 70 per cent of all general aviation activities in the world, excluding China and the USSR, there were 490 fatal accidents in 1985 resulting in 937 fatalities according to preliminary information. The corresponding numbers for 1984 were 545 fatal accidents and 1114 fatalities. For the United States, the rate of fatal general aviation accidents per 100,000 aircraft hours flown was about 1.5 in 1985, a decrease from 1.7 a year ago.

Table 1-19. Number of fatal accidents, passenger fatalities and survivors

<table>
<thead>
<tr>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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<td></td>
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<tr>
<td>Turbo-jet</td>
<td>11</td>
<td>8</td>
<td>10</td>
<td>6</td>
<td>11</td>
<td>13</td>
<td>12</td>
<td>7</td>
<td>68</td>
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<tr>
<td>Turbo-propeller</td>
<td>9</td>
<td>10</td>
<td>4</td>
<td>9</td>
<td>10</td>
<td>7</td>
<td>10</td>
<td>10</td>
<td>69</td>
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<td>13</td>
<td>7</td>
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<td>5</td>
<td>4</td>
<td>5</td>
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<tr>
<td>Total</td>
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<td>21</td>
<td>26</td>
<td>20</td>
<td>16</td>
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<tr>
<td>Turbo-jet</td>
<td>553</td>
<td>682</td>
<td>698</td>
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<td>507</td>
<td>762</td>
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<td>861</td>
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<td>Turbo-propeller</td>
<td>154</td>
<td>174</td>
<td>86</td>
<td>143</td>
<td>192</td>
<td>47</td>
<td>165</td>
<td>179</td>
<td>1140</td>
</tr>
<tr>
<td>Piston-engined</td>
<td>48</td>
<td>62</td>
<td>28</td>
<td>25</td>
<td>65</td>
<td>-</td>
<td>16</td>
<td>27</td>
<td>271</td>
</tr>
<tr>
<td>Total</td>
<td>755</td>
<td>878</td>
<td>812</td>
<td>362</td>
<td>764</td>
<td>809</td>
<td>228</td>
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<td>5675</td>
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<td>Passengers surviving</td>
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<tr>
<td>Turbo-jet</td>
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<td>153</td>
<td>595</td>
<td>30</td>
<td>1094</td>
<td>346</td>
<td>109</td>
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<td>3078</td>
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<tr>
<td>Turbo-propeller</td>
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<td>11</td>
<td>71</td>
<td>66</td>
<td>44</td>
<td>39</td>
<td>25</td>
<td>371</td>
</tr>
<tr>
<td>Piston-engined</td>
<td>8</td>
<td>36</td>
<td>3</td>
<td>13</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>5</td>
<td>65</td>
</tr>
<tr>
<td>Total</td>
<td>731</td>
<td>239</td>
<td>609</td>
<td>114</td>
<td>1160</td>
<td>390</td>
<td>148</td>
<td>123</td>
<td>3514</td>
</tr>
</tbody>
</table>

1. Owing to incomplete data, the USSR is not included.
2. Includes one mid-air collision between a turbo-jet aircraft and a small piston-engined aircraft on a training flight (counted as one accident).
3. Includes one collision on the ground between two turbo-jet aircraft (counted as one accident).
4. Includes one mid-air collision between two turbotop prop aircraft (counted as one accident).
5. Preliminary figures.
Diagram 5
FATAL ACCIDENT RATES FOR PASSENGERS ON WORLD SCHEDULED SERVICES
1966-1985

Number of Passengers killed on scheduled services

Passenger Fatalities per 100 million pass.-km.

Fatal Accidents per 100 million aircraft-km.

Fatal Accidents per 100,000 landings

Accident rate per passenger-mile of ICAO States covered

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